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Associations of Historical Redlining With BMI and Waist Circumference in Coronary Artery Risk Development in Young Adults

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Introduction: Historical maps of racialized evaluation of mortgage lending risk (i.e., redlined neighborhoods) have been linked to adverse health outcomes. Little research has examined whether living in historically redlined neighborhoods is associated with obesity, differentially by race or gender.

Methods: This is a cross-sectional study to examine whether living in historically redlined neighborhoods is associated with BMI and waist circumference among Black and White adults in 1985−1986. Participants' addresses were linked to the 1930s Home Owners' Loan Corporation maps that evaluated mortgage lending risk across neighborhoods. The authors used multilevel linear regression models clustered on Census tract, adjusted for confounders to estimate main effects, and stratified, and interaction models by (1) race, (2) gender, and (3) race by gender with redlining differentially for Black versus White adults and men versus women. To better understand strata differences, they compared Census tract−level median household income across race and gender groups within Home Owners' Loan Corporation grade.

Results: Black adults (n=2,103) were more likely than White adults (n=1,767) to live in historically rated hazardous areas and to have higher BMI and waist circumference. Redlining and race and redlining and gender interactions for BMI and waist circumference were statistically significant (p<0.10). However, in stratified analyses, the only statistically significant associations were among White participants. White participants living in historically rated hazardous areas had lower BMI ($\beta = -0.63$ [95% CI= −1.11, −0.15]) and lower waist circumference ($\beta = -1.50$ [95% CI= −2.62, −0.38]) than those living in declining areas. Within each Home Owners' Loan Corporation grade, residents in White participants' neighborhoods had higher incomes than those living in Black participants' neighborhoods (p<0.0001). The difference was largest within historically redlined areas. Covariate associations differed for men, women, Black, and White adults, explaining the difference between the interaction and the stratified models. Race by redlining interaction did not vary by gender.

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Conclusions: White adults may have benefitted from historical redlining, which may have reinforced neighborhood processes that generated racial inequality in BMI and waist circumference 50 years later.

INTRODUCTION

Despite significant policy efforts to improve obesity-related environments, the prepandemic U.S. National Health and Nutrition Examination Survey 2017 to March 2020 estimated that obesity prevalence reached 42% among adults.[1] Obesity increases many diseases, including cardiometabolic disorders, Type 2 diabetes, cancer, mental illness, and shorter lifespan.[2,3] Central adiposity is the accumulation of fat in the lower torso around the abdominal area and is a greater risk factor than overall body fat for cardiovascular disease, Type 2 diabetes, liver disease, and cancers.[4–7] Racial and ethnic obesity disparities are profound: obesity prevalence was estimated at 50% for non-Hispanic Black adults and 46% for Hispanic adults, compared with 41% in non-Hispanic White adults and 16% in non-Hispanic Asian adults from 2017 to March 2020.[1] Among Black men and women, estimated obesity prevalence was 40% and 58%, respectively, whereas obesity prevalence was 43% and 40% among White men and women, respectively.

Neighborhood environments are well-recognized determinants of health, where unequal allocation of resources has been and continues to be shaped by historical and present-day policies and processes exploiting people of color to benefit White communities. One example of these racist processes is historical mortgage discrimination. The 1934 National Housing Act introduced federally backed mortgages, and the federal government, including the Home Owners' Loan Corporation (HOLC), institutionalized the appraisal industry practice of using a racialized evaluation method. HOLC drew maps for more than 200 U.S. cities to document and rate supposed investment worthiness across neighborhoods.[8] Ratings were determined by neighborhood racial and ethnic makeup, housing conditions, and access to public facilities. Hazardous neighborhoods were drawn in red (hence redlining). Although discriminatory mortgage lending and segregation patterns existed before HOLC,[9] the maps became a tool to promote racial segregation through discriminatory practices (e.g., restrictive covenants). At the time, the maps were not distributed publicly, but the survey process methodology and techniques that heavily considered neighborhood racial composition and trends were discussed widely in the real estate trade.[10] Desiring to highlight the detrimental effects of this practice, a sociologist, John McKnight, coined the term redlining to describe how denial of mortgages to entire communities solely based on their racial and socioeconomic demographics institutionalized neighborhood inequalities.[11]

The maps were part of long-standing efforts involving public–private decision making that leveraged people of color as collateral to benefit wealth creation for White people.[12] Over time, efforts to exclude people of color from wealth evolved to appear race neutral.[13] For example, zoning laws changed from excluding undesirables to excluding building developments such as apartment buildings and public transit that would make suburban communities more affordable and accessible to people of color. The laws' premise was to "preserve community character."[13] Such laws and practices continue to be detrimental to people perceived as non-White. Although historical policies and practices of structural racism and racial dispossession predated the redlining maps and continue today, redlining codified racism into the real estate industry and underlies today's neighborhood social determinants of health. Research using data from 1980 to 2016 has linked historically redlined neighborhoods to low home values,[14] foreclosure vulnerabilities,[15] high-interest rates,[16] high intraurban heat,[17] heightened air pollution,[18] and low income.[19] Although racial discrimination in housing, including redlining, became illegal in the U.S. with the Fair Housing Act of 1968, this historical practice lingers. Research has explored the legacy of redlining on health[20] and has identified associations between hazardous and declining HOLC map ratings and lower preterm birth,[21,22] severe maternal morbidity,[23] increased overall mortality,[24] self-rated poor health,[15] poor cardiovascular health,[25,26] and higher risk of certain cancers.[27–29] Few studies have examined the historical redlining maps in relation to obesity outcomes.[25] Mujahid et al.[25] found that Black adults who lived in historically redlined areas had lower cardiovascular health scores than those residing in areas rated as best, with variation by neighborhood social environment.

The authors of the present study conceptualize the impacts of redlining as the diversion of wealth and resources from communities of color to White communities, which underlies racial segregation today.[19] Black Americans are consequently more likely than White Americans to reside in socioeconomically disadvantaged neighborhoods with high crime rates.[30] Furthermore, impacts of redlining could have translated into neighborhood conditions that increase the risk of obesity, such as greater availability of fast food and lack of opportunities for physical activity. Across 102 urban cities, historically redlined neighborhoods had a higher likelihood of unhealthy retail food environments (e.g., fast food), even for Census tracts with present-day economic and racial privilege.[31] In addition to providing energy-dense nutrient-poor foods and beverages that contribute to obesity,[32] convenience foods and beverages may also increase vulnerability to obesity through the consumption of endocrine disruptors from the packaging.[33] However, it is unclear whether endocrine disruptors increase obesity risk differentially by race and sex.[34] Neighborhoods assigned worse HOLC grades were also associated with reduced present-day greenspace,[35] which could limit opportunities for physical activity, especially for women who are less physically active than men.[36] Although neighborhood-built environment characteristics (e.g., parks) have been differentially associated with obesity by gender,[37–40] responses to neighborhood social environments may also affect people's risk of obesity differentially by race and gender.[41,42] For example, women feel less safe than men in neighborhoods where threats of sexual harassment, exploitation, and violence are frequent and pervasive.[41,43]

Black women in particular may face compounded barriers to healthy behaviors owing to the intersection of their race and gender that creates multiple levels of overlapping and interdependent systems of discrimination and/or disadvantage that perpetuate inequities.[44] For example, Rayshawn Ray discussed middle-class Black women's lack of physical activity with an intersectionality lens: "The intersectionality framework suggests that raced and gendered experiences structure how time allocation, the racial composition of neighborhoods, and body size perceptions function as mechanisms that are uniquely related to the physical activity of Black women compared to other groups."[45]

The authors of the present study recognize that the U.S. has an anti-Black fear of fat that is rooted in racism. In *Fearing the Black Body*, Sabrina Strings shows how fatphobia related to Black women did not originate with medical findings but with the Enlightenment era belief that fatness was evidence of savagery and racial inferiority.[46] Fatness was used to justify the lack of civilization, and this idea was maintained throughout the U.S. in the 19th and 20th centuries as a way to justify slavery, racism, and classism, and control women through temperance.[47] Weight stigma impacts healthcare clinical and behavioral management of obesity. In Lee and Pause's autoethnographic account, they describe how provider antifat attitudes and confirmation bias can lead to a failure to provide evidenced-based health care to patients who are fat.[48]

Obesity emerged in the U.S. between 1976 and 1980[49] when the prevalence was relatively low among young adults (5.5%). Despite low disease burden in young adulthood, this is a critical period when significant changes in lifestyle and health behaviors occur. Although cardiovascular disease typically develops in mid-to-late adulthood, in 1979–1985, young Black adults were at higher risk than young White adults for obesity and all causes of cardiovascular-related death.[50] Thus, young Black adults who should have been healthy were facing risks strong enough to create disease and cause death. Since when it was relatively rare in the 1970s, obesity and its racial disparities increased,[51] and diet and physical activity may not be the only contributors, suggesting potential environmental factors.[52] In 1985, the early roots of the now widely prevalent factors influencing overeating and sedentary behavior—such as the surge in portion sizes and ultraprocessed foods—were just beginning to grow.[53] Coronary Artery Risk Development in Young Adults (CARDIA) baseline offers a unique opportunity to examine young Black adults' environmental exposures that could have increased their early adulthood obesity risk prior to the environment becoming saturated with factors that promote obesity. How living in a neighborhood with a history of redlining may differentially underlie obesity prevalence by race and gender is unknown.

The authors of this study examined whether living in a historically redlined neighborhood is associated with BMI and waist circumference (WC) and whether some groups may be more vulnerable to obesity-related neighborhood features among Black and White young adult men and women during a critical period of their adulthood and the burgeoning obesity epidemic. Authors linked participants' residences in 1985–1986 to the 1930's HOLC maps that guided mortgage lending practice with grades A (best), B (still desirable), C (definitely declining), and D (hazardous) at baseline.

METHODS

Study Sample

The authors used data from the CARDIA study, a longitudinal cohort study of cardiovascular disease development.[54–56] In 1983, the National Heart, Lung, and Blood

Institute initiated a study designed to help fill gaps in knowledge about the development of cardiovascular disease among young adults, including women and Black individuals. Four field centers were selected: Birmingham, Alabama (University of Alabama at Birmingham); Chicago, Illinois (Northwestern University); Minneapolis, Minnesota (University of Minnesota); and Oakland, California (Kaiser Permanente). Participants were enrolled in 1985−1986, with approximately equal numbers by self-reported race, gender, education (high school or less versus more than high school), and age (18−24 years vs 25−30 years) within each field center, and they have been followed for more than 35 years. Although gender was rarely discussed in the 1980s, participants self-reported their sex as either male or female, so the authors consider this their gender rather than their sex. CARDIA includes detailed data collected for 5,115 White and Black U.S. adults aged 18−30 years at baseline from 4 cities with a history of redlining: Birmingham, Alabama; Chicago, Illinois; Minneapolis, Minnesota; and Oakland, California.[8]

This study examined a subsample of CARDIA participants whose residence was in a neighborhood that was rated by HOLC. Appraisers decided which neighborhoods to include in their ratings; these areas generally covered the city limits and, in some cases, also included surrounding suburban areas. On the basis of the 1980 Census place boundaries, the percentage of the area within CARDIA city boundaries that were appraised were 47%, 59%, 73%, and 59% for Birmingham, Chicago, Minneapolis, and Oakland, respectively. Among the mapped areas, the percentage of the area within city boundaries rated as hazardous was 64% in Birmingham, 29% in Chicago, 17% in Minneapolis, and 27% in Oakland.[8]

The analysis used data from the baseline examination (1985−1986) when the U.S. obesity epidemic was just beginning and at an earlier age than participants in other established cohorts.[57] The deidentified cohort data are publicly available. The authors conducted this cross-sectional study, restricted to examination years 1985−1986 for a subset of participants whose residential Census tract centroid was located within an appraised area. Several approaches exist (e.g., proportion land area) for assigning exposure.[21,25] Ideally, authors would have used a population-weighted center instead of an area-weighted approach because this study examined health outcomes and because land area does not always correlate with population density. However, in 1980, no block or block group boundary was available for calculating population-weighted centers. The authors used the centroid approach because they wanted a single grade for each person rather than a blend. Using these data, they sought to understand the association between living in a historically redlined neighborhood and BMI in young adulthood and whether this association differed by race and gender.

Of 5,115 adults, the authors excluded participants if they asked to be removed from the study (1 [0.02%]), were pregnant (7 [0.1%]), lived outside HOLC-mapped areas (1,143 [22.4%]), and were missing BMI or WC (17 [0.3%]) or covariate (77 [1.5%]) data at baseline. Compared with the analytic sample, the excluded participants were older, were more likely to be White, were currently or formerly married, attained higher levels of education, lived in Birmingham and Oakland, and lived in Census tracts with higher median income (Appendix, available online). This study followed STROBE reporting guidelines for cohort studies. All study protocols were approved by each participating institution's IRB, and participants signed an informed consent document.

Measures

BMI was one study outcome. Weight was measured while the participant was wearing light clothing (e.g., short-sleeved shirt) and recorded to the nearest 0.2 pounds. Height was measured while the participant stood erect on the floor with no shoes and with their back against the vertically mounted metal centimeter ruler. The carpenter square was brought snugly to the top of their head, and their height was recorded to the nearest 0.5 cm. BMI was calculated as weight (kg) divided by height squared (m^2).

Waist circumference was another study outcome. WC was measured laterally at the point midway between the iliac crest and the lowest lateral portion of the rib cage and anteriorly at the point midway between the xiphoid process of the sternum and the umbilicus and recorded to the nearest 0.5 cm.

Participants' sociodemographics were collected at each examination year from standard questionnaires that were either self-administered or interviewer administered. Self-reported race (White/Black), which is a social construct "shaped by geographic, cultural, and sociopolitical forces,"[58,59] and gender (men/women) were independent variables of interest.

Redlining maps were used to determine the exposure of interest. The authors linked digitized historical HOLC grading maps[8] to CARDIA participants' residential locations using the centroid of the individual's Census tract of residence in examination years 1985−1986. They categorized participants according to the historical HOLC area grade (A, B, C, or D) given at their residential location.

The authors included the following as covariates: age (mean centered), field center, marital status (never married, married or living as married, formerly married), children or stepchildren aged ≤18 years living in the household (any, none), and attained educational status (less than high school, high school or associate degree,

bachelor's degree, and master's degree or higher) at baseline. CARDIA did not collect participants' income in 1985−1986, given that many were still in school. To partially address SES, the authors used Census tract−level median household income (mean centered) from the 1980 Census. They controlled for these covariates because they have been associated with BMI and where people live.[60,61]

Statistical Analysis

The authors constructed a cross-sectional, multilevel linear regression model between exposure to living in a historically redlined area during young adulthood and both BMI and WC. Multilevel models accounted for individuals living in the same Census tract. When assumptions of multilevel linear regression models were not met, the authors used Huber and White sandwich estimators for fixed effects.[62] For each outcome, authors estimated a main effect model. Because obesity prevalence is often higher among women than among men and among Black than among White Americans, authors examined whether relationships between HOLC grade and obesity outcomes were modified by individual-level factors. They first tested a 3-way interaction of redlining by race and gender to identify whether race and gender subgroups may have been susceptible to obesogenic influences of living in a historically redlined area. With absence of the 3-way interaction, they tested 2-way interactions between redlining and race and between redlining and gender. Descriptive statistics and regression analyses were performed using the statistical software SAS, Version 9.4 (SAS Institute, Cary, NC). Statistical significance of interaction terms was assessed with Wald F-tests at $p<0.10$ because effect modification tests are often underpowered.[63] The authors estimated stratified models by race and gender; provided the HOLC estimates for every possible grade comparison; and plotted estimated mean BMI and WC by race, gender, and redlining. Statistical significance in main effect and stratified models was assessed with Wald F-tests at $p<0.05$. To gain a deeper insight into neighborhood socioeconomic variation, when stratified estimates differed between Black and White adults or between men and women, the authors calculated unadjusted mean Census tract median household income for each HOLC grade. Then, they used F-tests to compare means by either race or gender. Analyses for this manuscript were performed between December 1, 2022 and November 10, 2023.

RESULTS

A total of 3,870 participants (1,182 Black women [30.5%]; 921 Black men [23.8%]; 909 White women [23.5%]; and 858 White men [22.2%]) were included (Table 1). Participants had mean (SD) age at baseline of 24.2 (3.8), 24.1 (3.8), 25.4 (3.4), and 25.3 (3.3) years, respectively. At baseline, most Black and White participants had never been married. Almost half of Black women lived with at least 1 child, whereas the prevalence of living with children was 23% among Black men, 20% among White women, and 11% among White men. About 10% of Black adults and about 40% of White adults had attained a bachelor's degree or higher. Approximately 80% of Black men and women lived in areas with a history of being graded as either hazardous or declining, whereas the proportion was about 60% among White men and women. Median household income was about $16,000 (1985 dollars, or not accounting for inflation) among the Census tracts where White participants lived compared with $12,000 among the Census tracts of the Black participants. Mean BMI among these race−gender groups ranged from 23 kg/m^2 to about 26 kg/m^2, and WC ranged from 72 cm to 83 cm.

Redlining was associated with neither BMI ($p=0.69$) nor WC ($p=0.50$) (Table 2).

The 3-way interaction among redlining, race, and gender was not significant for BMI ($p=0.83$) or for WC ($p=0.36$).

The association between HOLC grades and outcomes significantly differed by race for BMI ($p=0.09$) or WC ($p=0.03$). The authors identified an interaction between living in a historically hazardous-rated area and race for BMI ($\beta = 0.80$ [90% CI=0.10, 1.51]) and WC ($\beta = 2.23$ [90% CI=0.67, 3.80]). Betas indicate whether associations were stronger among Black adults living in historically hazardous areas than among White and Black adults living in best or desirable areas.

In stratified analyses, HOLC grades were not associated with BMI for Black adults ($p=0.88$) (Table 3). In contrast, living in historically rated declining and hazardous areas was associated with BMI for White adults ($p=0.03$). White participants living in hazardous areas had a lower BMI than those living in declining areas ($\beta = -0.63$ [95% CI= −1.11, −0.15]). Figure 1 shows how the BMI trends differed by race and HOLC.

In stratified analyses, HOLC grades were not associated with WC for Black adults ($p=0.42$), but HOLC was associated with WC for White adults ($p=0.03$) (Table 4). White participants living in hazardous areas had a lower WC than those living in declining areas ($\beta = -1.50$ [95% CI= −2.62, −0.38]). Figure 1 illustrates how the trends observed in WC are comparable with those in BMI.

Mean Census tract median household income was higher for White than for Black participants within each HOLC grade ($p<0.0001$) (Table 5). In historically redlined areas, Black participants' tract-level median household income was about $9,500 compared with $14,000

Table 1. Baseline Characteristics of CARDIA Participants by Race and Gender, 1985–1986

Characteristics	Black adults		White adults	
	Women, *n*=1,182	Men, *n*=921	Women, *n*=909	Men, *n*=858
Age, mean (SD), years	24.2 (3.8)	24.1 (3.8)	25.4 (3.4)	25.3 (3.3)
Marital status, *n* (%)				
Never married	826 (69.9)	674 (73.2)	579 (63.7)	637 (74.2)
Married	230 (19.5)	171 (18.6)	244 (26.8)	183 (21.3)
Formerly married	126 (10.7)	76 (8.3)	86 (9.5)	38 (4.4)
Any children in household, *n* (%)	585 (49.5)	212 (23.0)	181 (19.9)	91 (10.6)
Highest attained education, *n* (%)				
Less than HS	122 (10.3)	137 (14.9)	37 (4.1)	48 (5.6)
HS or associate degree	944 (79.9)	689 (74.8)	480 (52.8)	465 (54.2)
Bachelor's degree	107 (9.1)	81 (8.8)	322 (35.4)	256 (29.8)
Master's degree or above	9 (0.8)	14 (1.5)	70 (7.7)	89 (10.4)
Study center, *n* (%)				
Birmingham	254 (21.5)	199 (21.6)	133 (14.6)	167 (19.5)
Chicago	280 (23.7)	212 (23.0)	233 (25.6)	221 (25.8)
Minneapolis	274 (23.2)	253 (27.5)	318 (35.0)	296 (34.5)
Oakland	374 (31.6)	257 (27.9)	225 (24.8)	174 (20.3)
Median household income of census tract in $1,000s, mean (SD)	12.7 (4.1)	12.5 (4.2)	16.3 (6.6)	15.9 (6.3)
HOLC grade, *n* (%)				
A=Best	15 (1.3)	11 (1.2)	86 (9.5)	77 (9.0)
B=Still desirable	227 (19.2)	185 (20.1)	254 (27.9)	259 (30.2)
C=Definitely declining	520 (44.0)	409 (44.4)	337 (37.1)	303 (35.3)
D=Hazardous	420 (35.5)	316 (34.3)	232 (25.5)	219 (25.5)
BMI, mean (SD)	25.8 (6.6)	24.5 (4.4)	23.1 (4.4)	24.2 (3.6)
WC, mean (SD)	76.6 (13.4)	80.6 (10.0)	72.0 (9.3)	82.8 (8.8)

HS, high school; WC, waist circumference.

in their White counterparts, constituting the largest racial neighborhood income disparity of $4,000.

The association between HOLC grades and outcomes significantly differed by gender for WC (p=0.05) but not BMI (p=0.18). The authors identified interactions between living in a historically hazardous–rated area and gender for WC ($\beta = 1.95$ [90% CI=0.25, 3.65]) and between a historically declining–rated area and gender for WC ($\beta = 2.18$ [90% CI=0.64, 3.73]). Betas indicate whether associations were stronger among women living in historically hazardous areas than among women living in best or desirable areas and men.

Redlining was associated with BMI for neither men (p=0.61) nor women (p=0.76) (Table 3). Similarly, the associations between redlining and WC were null for men (p=0.90) and women (p=0.27). These gender-stratified null associations are illustrated for BMI and WC in Figure 2.

DISCUSSION

Redlining is one among many racist policies and practices that purposefully directed wealth to White populations and curtailed the socioeconomic well-being of people perceived as non-White. Even before redlining maps were created, Black people were systematically excluded from accessing wealth and power,[64] but the maps provided an institutional justification of racism by conflating race with financial risk.[12] The maps also lent credence to local and national racist values and ideologies that persist and may be even worse today.[65,66]

Nationally, historically redlined areas have the highest proportion of low- to middle-income households.[19,67] Black Americans disproportionately live in neighborhoods with stressors, including crime, reduced access to healthy foods, and reduced safe places to engage in physical activity. Such neighborhood disadvantage is partly due to historic racist practices of residential segregation,[42] including racial and ethnic[68] and housing discrimination.[19]

In this study, Black participants had higher BMI and WC than White participants, regardless of where they lived. Although estimated mean BMI and WC from the interaction models suggested that living in historically redlined neighborhoods was linked to higher BMI and WC among Black adults, the stratified models told a

Table 2. Adjusted Associations Between HOLC Grade and BMI and WC (1985–1986)

Outcome	BMI β (95% CI)	Waist circumference β (95% CI)
Intercept	**23.52 (22.66, 24.39)*** **	**81.01 (79.27, 82.75)*** **
Race		
Black	**1.27 (0.91, 1.63)*** **	0.72 (−0.09, 1.53)
White	ref	ref
HOLC grade		
Declining minus best/desirable	0.18 (−0.24, 0.60)	0.50 (−0.35, 1.36)
Hazardous minus best/desirable	0.08 (−0.42, 0.59)	0.43 (−0.64, 1.51)
Hazardous minus declining	−0.10 (−0.55, 0.35)	−0.07 (−1.01, 0.87)
Age, mean centered	**0.18 (0.12, 0.23)*** **	**0.51 (0.40, 0.62)*** **
Gender		
Women	0.11 (−0.27, 0.50)	**−7.50 (−8.33, −6.67)*** **
Men	ref	ref
Marital status		
Married	**0.55 (0.13, 0.98)** **	**1.00 (0.14, 1.86)***
Formerly married	−0.19 (−0.83, 0.46)	0.03 (−1.32, 1.38)
Never married/living with a partner	ref	ref
Children in household	0.26 (−0.21, 0.73)	**1.65 (0.65, 2.65)** **
Highest attained education		
High school or some college	0.23 (−0.38, 0.83)	0.54 (−0.67, 1.76)
College graduate	−0.58 (−1.28, 0.13)	**−1.46 (−2.85, −0.08)***
Graduate degree	−0.21 (−1.03, 0.61)	−0.82 (−2.62, 0.98)
Less than high school	ref	ref
Study center		
Chicago	0.03 (−0.55, 0.61)	0.11 (−1.08, 1.30)
Minneapolis	−0.25 (−0.83, 0.33)	**−1.34 (−2.56, −0.12)***
Oakland	−0.02 (−0.59, 0.55)	−0.63 (−1.81, 0.55)
Birmingham	ref	ref
Median household income of the 1980 Census tract in $1,000s, mean centered	**−0.05 (−0.08, −0.01)** **	−0.06 (−0.13, 0.01)

Note: Boldface indicates statistical significance (*$p<0.05$, **$p<0.01$, ***$p<0.001$).
Shown is a cross-sectional, multilevel linear regression model between exposure to living in a historically redlined area (i.e., HOLC grade) during young adulthood and both BMI and WC, clustered on Census tract, and controlling for mean-centered age, field center, marital status (never married, married or living as married, formerly married), children or stepchildren aged ≤18 years living in the household (any, none), attained educational status (less than high school, high school or associate degree, bachelor's degree, and master's degree or higher), and mean-centered Census tract median household income. Every possible HOLC grade comparison combination is presented.
HOLC, Home Owners' Loan Corporation; WC, waist circumference.

different story. The only significant associations with redlining, BMI, and WC were among White participants, where those living in historically redlined neighborhoods had a lower BMI and WC than those living in neighborhoods rated as declining. Although potential neighborhood decline may have exposed White participants to neighborhood conditions that promoted obesity, it appears that those living in the areas with the worst historical rating had healthy BMI and WC profiles. The presence of White participants with low BMI and WC in historically redlined areas could be attributed to gentrification. Neighborhoods gentrify when socioeconomically disadvantaged neighborhoods experience increases in the proportion of White residents, housing costs, educational attainment, and household income.[69] Although gentrification has been related to racial integration, it is also linked with increased economic inequality.[19] Gentrification is another example of where White people gain an advantage over Black communities' disadvantage.[69]

Similar to the results in the race-stratified models, the authors did not see any significant associations between redlining, BMI, and WC in the gender-stratified models. To understand why the race and gender interaction models differed from the stratified models, one looks to the covariates. Interaction models force associations between covariates and outcomes to be the same for all race and gender groups, whereas associations can differ in stratified models. The authors found several demographic associations that differed by race and gender.

Table 3. Adjusted Associations Between HOLC Grade and BMI, Stratified by Race and Gender (1985–1986)

Outcome	BMI: White β (95% CI)	BMI: Black β (95% CI)	BMI: Men β (95% CI)	BMI: Women β (95% CI)
Intercept	**24.16 (23.18, 25.14)*** **	**24.44 (23.26, 25.63)*** **	**23.81 (22.82, 24.80)*** **	**23.50 (22.14, 24.86)*** **
Race				
Black	—	—	**0.46 (0.01, 0.91)***	**2.07 (1.52, 2.62)*** **
White	—	—	ref	ref
HOLC grade				
Declining minus best/desirable	0.37 (−0.01, 0.76)	−0.00 (−0.68, 0.67)	0.15 (−0.30, 0.60)	0.28 (−0.45, 1.01)
Hazardous minus best/desirable	−0.25 (−0.72, 0.22)	0.17 (−0.67, 1.00)	−0.05 (−0.65, 0.54)	0.19 (−0.64, 1.02)
Hazardous minus declining	**−0.63 (−1.11, −0.15)***	0.17 (−0.51, 0.85)	−0.20 (−0.67, 0.26)	−0.09 (−0.75, 0.58)
Age, mean centered	**0.12 (0.05, 0.19)*** **	**0.21 (0.14, 0.28)*** **	**0.11 (0.05, 0.17)*** **	**0.24 (0.15, 0.32)*** **
Gender				
Women	**−1.16 (−1.57, −0.75)*** **	**1.31 (0.79, 1.83)*** **	—	—
Men	ref	ref	—	—
Marital status				
Married	0.16 (−0.36, 0.68)	**1.09 (0.37, 1.82)** **	**1.15 (0.56, 1.74)*** **	0.44 (−0.19, 1.08)
Formerly married	−0.06 (−0.90, 0.78)	−0.03 (−0.94, 0.89)	0.55 (−0.26, 1.35)	−0.52 (−1.44, 0.40)
Never married/living with a partner	ref	ref	ref	ref
Children in household	**0.96 (0.31, 1.61)** **	−0.42 (−1.05, 0.22)	−0.04 (−0.61, 0.54)	−0.03 (−0.69, 0.63)
Highest attained education				
High school or some college	−0.07 (−0.91, 0.76)	0.08 (−0.66, 0.82)	0.18 (−0.47, 0.82)	0.04 (−0.90, 0.99)
College graduate	−0.80 (−1.70, 0.10)	−0.45 (−1.60, 0.70)	0.16 (−0.69, 1.02)	**−1.43 (−2.53, −0.32)***
Graduate degree	−0.33 (−1.35, 0.69)	−0.13 (−2.09, 1.83)	0.41 (−0.54, 1.36)	**−1.50 (−2.77, −0.23)***
Less than high school	ref	ref	ref	ref
Study center				
Chicago	0.22 (−0.46, 0.90)	0.14 (−0.69, 0.97)	−0.00 (−0.62, 0.61)	0.02 (−0.87, 0.91)
Minneapolis	0.29 (−0.28, 0.86)	−0.50 (−1.38, 0.37)	−0.24 (−0.89, 0.41)	−0.01 (−0.91, 0.88)
Oakland	−0.20 (−0.84, 0.45)	0.16 (−0.59, 0.92)	−0.34 (−0.98, 0.31)	0.26 (−0.59, 1.12)
Birmingham	ref	ref	ref	ref
Median household income of 1980 Census tract in $1,000s, mean centered	−0.03 (−0.06, 0.00)	−0.03 (−0.10, 0.04)	−0.01 (−0.05, 0.02)	**−0.06 (−0.11, −0.01)***

Note: Boldface indicates statistical significance (*$p<0.05$, **$p<0.01$, ***$p<0.001$).
Shown is a cross-sectional, multilevel linear regression model stratified by race between exposure to living in a historically redlined area (i.e., HOLC grade) during young adulthood and both BMI and WC, clustered on Census tract, and controlling for mean-centered age, field center, marital status (never married, married or living as married, formerly married), children or stepchildren aged ≤18 years living in the household (any, none), attained educational status (less than high school, high school or associate degree, bachelor's degree, and master's degree or higher), and mean-centered Census tract median household income. Every possible HOLC grade comparison combination is presented.
HOLC, Home Owners' Loan Corporation; WC, waist circumference.

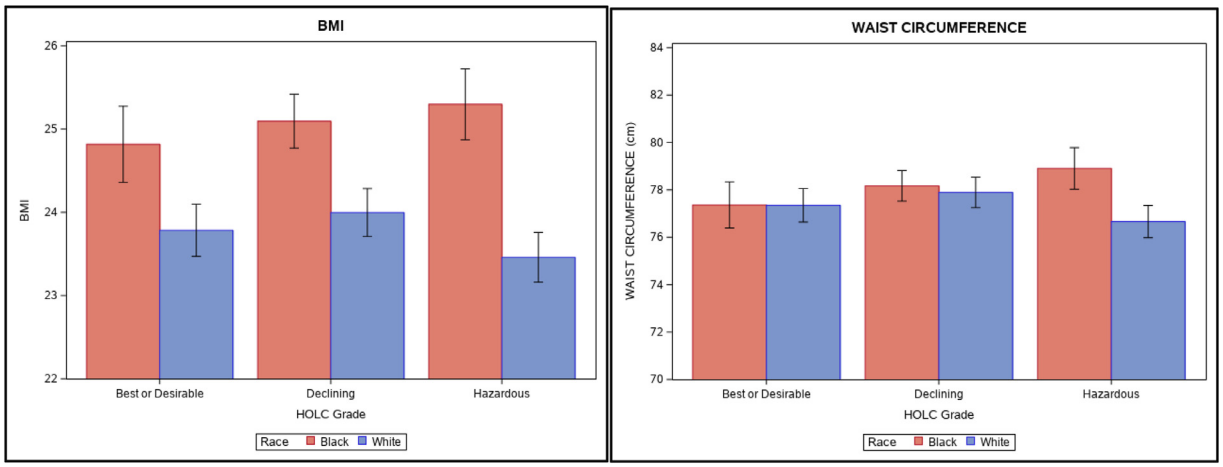

Figure 1. Predicted mean BMI and WC by race and HOLC grade.
Shown is a cross-sectional, multilevel linear regression model between exposure to living in a historically redlined area (i.e., HOLC grade) during young adulthood and both BMI and WC, clustered on Census tract, with interactions between race and HOLC grade, and controlling for age, field center, marital status (never married, married or living as married, formerly married), children or stepchildren aged ≤18 years living in the household (any, none), attained educational status (less than high school, high school or associate degree, bachelor's degree, and master's degree or higher), and Census tract median household income. Error bars indicate 90% CI.
HOLC, Home Owners' Loan Corporation; WC, waist circumference.

Among White participants, women's BMI was 1.2 Kg/m^2 lower than men's BMI, but among Black participants, the relationship was reversed, where women's BMI was 1.3 Kg/m^2 higher than men's. Being married versus never married was associated with higher BMI and WC only among Black participants and men, whereas living with any children in the household was associated with high BMI only among White participants. Having more education was associated with low BMI and WC for White participants and women but not for other participants. Tract-level median household income was only negatively associated with BMI among women. Greater educational attainment was only associated with low BMI and WC for women. Different patterns of covariate associations suggest that where adults live at specific stages during distinct life milestones (e.g., marriage, children, and educational attainment) has varying impacts on BMI and WC for women, men, Black, and White adults.

This study found that 80% of Black participants compared with 60% of White participants lived in historically redlined neighborhoods. Living in disadvantaged neighborhoods can be detrimental for Black people.[70] Chronic exposure to such conditions can increase stress and obesity risk through stress-related physiologic pathways, including cortisol dysregulation.[71] Navigating economic and health challenges while coping with impoverished conditions may limit a person's capacity for healthy behaviors. Managing stressors with limited resources while bearing cognitive load[72] can diminish self-control.[73] Women, especially Black women in severely disadvantaged segregated neighborhoods, are also challenged more than men by environments where threats of sexual harassment, exploitation, and violence are frequent and pervasive.[43] Consequently, women feel less safe in their neighborhoods than men.[41] In addition, acceptance of larger body sizes among Black communities may be influenced by a rejection of fat phobia and by a stance that obesity is a White norm that is a racially oppressive measure of health.[74,75] This study's findings do not align with increasing research that identified associations between redlining and adverse health outcomes.[15,20–29] Instead, this study found that White adults may have better health in historically redlined areas. Black adults face structural and interpersonal racist barriers that are not present for White adults.[76] Residing in a previously redlined neighborhood might have limited impact on Black adults compared with that on White adults because the influence of such residency is overshadowed by the pervasive effects of racism experienced by Black individuals across various facets of life, including economic mobility.

On the other hand, Black communities may also have high levels of social cohesion owing to communal care and mutual aids as well as vibrant social and cultural amenities.[77] Black communities may engage in social activism to achieve racial equity, which mobilizes social capital and resilience.[78] With respect to obesity, in Ashanté M. Reese's *Black Food Geographies: Race, Self-Reliance, and Food Access in Washington, D.C.*, her

Table 4. Adjusted Associations Between HOLC Grade and Waist Circumference, Stratified by Race and Gender (1985–1986)

Outcome	Waist: White β (95% CI)	Waist: Black β (95% CI)	Waist: Men β (95% CI)	Waist: Women β (95% CI)
Intercept	**83.17 (80.77, 85.56)*** **	**80.35 (78.04, 82.66)*** **	**81.89 (79.77, 84.01)*** **	**73.03 (70.44, 75.62)*** **
Race				
Black	—	—	**−1.70 (−2.73, −0.67)** **	**3.10 (1.95, 4.26)*** **
White	—	—	ref	ref
HOLC grade				
Declining minus best/desirable	0.68 (−0.22, 1.59)	0.45 (−0.88, 1.77)	−0.01 (−1.01, 1.00)	1.14 (−0.27, 2.54)
Hazardous minus best/desirable	−0.82 (−1.93, 0.30)	1.09 (−0.55, 2.74)	−0.25 (−1.52, 1.03)	1.06 (−0.59, 2.72)
Hazardous minus declining	**−1.50 (−2.62, −0.38)** **	0.65 (−0.71, 2.01)	−0.24 (−1.32, 0.84)	−0.07 (−1.40, 1.26)
Age, mean centered	**0.36 (0.21, 0.52)*** **	**0.61 (0.45, 0.76)*** **	**0.49 (0.35, 0.63)*** **	**0.55 (0.38, 0.71)*** **
Gender				
Women	**−10.99 (−11.86, −10.12)*** **	**−4.21 (−5.27, −3.15)*** **	—	—
Men	ref	ref	—	—
Marital status				
Married	0.38 (−0.76, 1.51)	**2.16 (0.69, 3.62)** **	**2.21 (0.87, 3.55)** **	1.05 (−0.21, 2.32)
Formerly married	0.23 (−1.71, 2.18)	0.57 (−1.28, 2.42)	1.58 (−0.38, 3.54)	−0.49 (−2.30, 1.32)
Never married/living with a partner	ref	ref	ref	ref
Children in household	**3.05 (1.64, 4.45)*** **	−0.01 (−1.28, 1.27)	0.45 (−0.98, 1.89)	1.03 (−0.34, 2.40)
Highest attained education				
High school or some college	−0.58 (−2.60, 1.44)	0.31 (−1.07, 1.70)	0.74 (−0.66, 2.15)	−0.34 (−2.15, 1.47)
College graduate	**−2.27 (−4.40, −0.14)***	−1.22 (−3.30, 0.87)	0.68 (−1.18, 2.55)	**−3.96 (−5.97, −1.95)*** **
Graduate degree	−1.42 (−4.00, 1.16)	−0.93 (−4.76, 2.91)	0.63 (−1.68, 2.93)	**−4.04 (−6.61, −1.46)** **
Less than high school	ref	ref	ref	ref
Study center				
Chicago	1.29 (−0.24, 2.82)	−0.04 (−1.73, 1.65)	0.67 (−0.77, 2.11)	−0.28 (−2.06, 1.49)
Minneapolis	−0.01 (−1.32, 1.29)	−1.70 (−3.46, 0.06)	**−1.49 (−2.87, −0.11)***	−0.59 (−2.41, 1.22)
Oakland	−0.73 (−2.15, 0.69)	−0.29 (−1.85, 1.27)	−0.95 (−2.41, 0.51)	−0.24 (−1.96, 1.49)
Birmingham	ref	ref	ref	ref
Median household income of 1980 Census tract in $1,000s, mean centered	−0.06 (−0.13, 0.01)	−0.01 (−0.14, 0.13)	−0.04 (−0.13, 0.04)	−0.06 (−0.16, 0.04)

Note: Boldface indicates statistical significance (*$p<0.05$, **$p<0.01$, ***$p<0.001$).
Shown is a cross-sectional, multilevel linear regression model stratified by race between exposure to living in a historically redlined area (i.e., HOLC grade) during young adulthood with both BMI and WC, clustered on Census tract, and controlling for mean-centered age, field center, marital status (never married, married or living as married, formerly married), children or stepchildren ≤18 years living in the household (any, none), attained educational status (less than high school, high school or associate degree, bachelor's degree, and master's degree or above), and mean-centered Census tract median household income. Every possible HOLC grade comparison combination is presented.
HOLC, Home Owners' Loan Corporation; WC, waist circumference.

Table 5. Census Tract Median Household Income Means (SE) and Differences for Black and White Participants by HOLC Grade (1985–1986)

HOLC grade	Census tract median household income in $1000s, mean (SE)		Difference Black–White (SE)	*p*-value
	Black	White		
Best or desirable	15.29 (0.24)	18.18 (0.19)	−2.88 (0.30)	<0.0001
Declining	13.78 (0.16)	15.64 (0.19)	−1.86 (0.25)	<0.0001
Hazardous	9.53 (0.18)	13.62 (0.23)	−4.09 (0.29)	<0.0001

HOLC, Home Owners' Loan Corporation.

ethnographic fieldwork demonstrates how Black residents navigate unequal food access with resilient and self-reliant strategies.[79] Thus, the impacts of living in a historically redlined neighborhood may be more nuanced than detrimental influences.

This study did not identify significant race-by-gender interactions; however, this may be due to limited statistical power. The intersection of race and gender is still relevant to this study because it may amplify structural oppressions and neighborhood stressors. For example, Black women face discrimination that is more than the sum of sexism and racism; instead, it is a unique experience for this group of women. Black women also have greater prevalence of obesity possibly due to discrimination, time allocation, the racial composition of neighborhoods, and body size perceptions.[1,45]

Limitations

This study has limitations. It is cross-sectional, and findings can only be interpreted as associations. In addition, the authors do not know participants' prebaseline residential histories. However, they identified differential associations that suggest that historical lending risk ratings may have perpetuated obesity inequities by race and gender among young adults.

Future work should consider whether meditation of proximal neighborhood changes (e.g., segregation and property value inequities) contributes more to health disparities than historical redlining.[12] Furthermore, historical redlining is only 1 example of racist policies and practices that existed decades before and after the maps (e.g., restrictive covenants).[64] HOLC created the maps after it had completed most of its lending and may have had limited influence on the Federal Housing Administration's design and implementation of its discriminatory federally insured mortgage credit program.[9] Moreover, discriminatory mortgage lending and real estate practices continue.[66,80–85] This study did not examine dietary behaviors and physical activity. Future work should examine longitudinal and dynamic

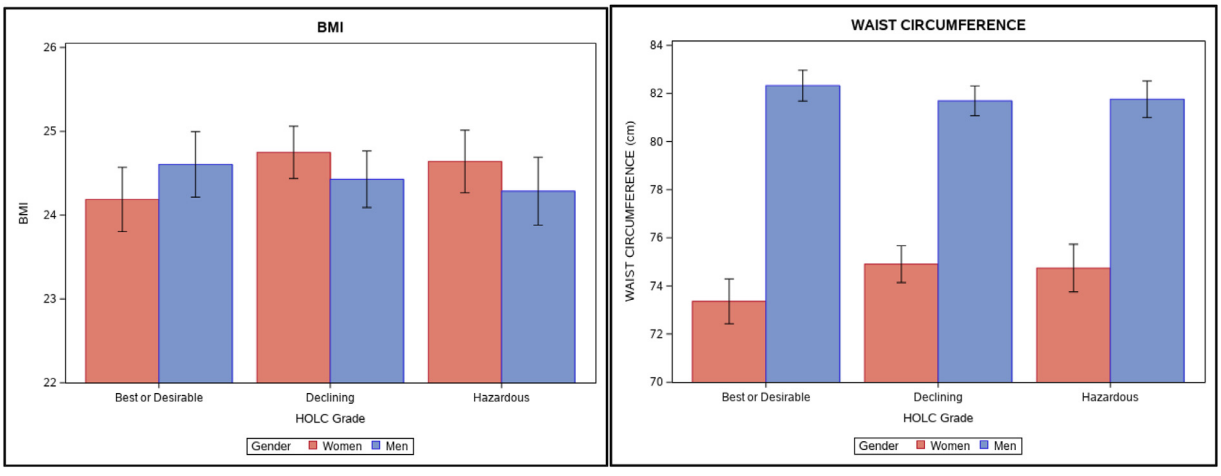

Figure 2. Predicted mean BMI and WC by gender and HOLC grade.

Cross-sectional, multilevel linear regression model between exposure to living in a historically redlined area (i.e., HOLC grade) during young adulthood with both BMI and WC, clustered on Census tract, with interactions between gender and HOLC grade, and controlling for age, field center, marital status (never married, married or living as married, formerly married), children or stepchildren aged ≤18 years living in the household (any, none), attained educational status (less than high school, high school or associate degree, bachelor's degree, and master's degree or higher), and Census tract median household income. Error bars indicate 90% CI.

HOLC, Home Owners' Loan Corporation; WC, waist circumference.

relationships between historical and contemporaneous redlining and downstream health through modifiable and measurable features of neighborhood disinvestment and health behaviors. Despite the study limitations, this study leveraged WC, considered to be a better reflection of disease risk[4–7] than BMI, and examined associations in relation to living in neighborhoods with histories of redlining. To the authors' knowledge, this is the first study to investigate historical redlining association with BMI and WC differentially by race and gender among a large geographically diverse cohort of Black and White young adults.

These results underscore the disproportionate concentration of Black individuals in historically redlined neighborhoods. However, regardless of their residential location, Black individuals consistently had higher BMI and WC than their White counterparts. Blaming historic appraisers and public and private agents that used the maps to choose where to and where not to invest ignores the many other people and processes that did and continue to divert wealth and power away from people of color to White communities.[13] Understanding that past racist processes have not disappeared and continue while appearing race neutral (e.g., urban renewal) is critical to addressing racial oppression. The authors join others who call for urgent eradication of systems that punish Black and Brown people and tacit racism that is entrenched in everyday interactions.[86–90] As Peniel E. Joseph wrote in *The Third Reconstruction: America's Struggle for Racial Justice in the Twenty-First Century*, "Commit to the hard work of confronting and atoning for the racial horrors embedded in the U.S.'s past and present, or return to a mythology of the country's history that has excused white violence and terrorism to reinforce white supremacy."[86] With respect to housing discrimination, future studies should investigate efforts that unjustly diverted and continue to divert wealth and investments from neighborhoods and residents, exacerbating social and health disparities.

CONCLUSIONS

This cross-sectional study using a cohort of Black and White adults found that living in a historically redlined neighborhood in young adulthood was not associated with BMI and WC in Black adults, but for White adults, living in historically redlined neighborhood may have conferred health benefits. These findings illustrate how historical practices may continue to benefit White people half a century later. It behooves on us to ensure that current policies and practices ameliorate rather than perpetuate or aggravate these long-term effects.

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SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.focus.2024.100209.

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