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Seeing Red: Associations between Historical Redlining and Present-Day Visual Impairment and Blindness

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Abstract

Purpose: Redlining was a discriminatory housing policy in the United States that began in 1933 and denoted neighborhoods with high proportions of Black individuals as “undesirable” and a high risk for lending, which therefore excluded people from obtaining traditional insured mortgages to purchase a home. Simultaneously, realtors discouraged Black individuals from purchasing homes in predominantly non-Black neighborhoods. This resulted in decreased home ownership and wealth accumulation among Black individuals and neighborhoods with high proportions of Black individuals. This study investigated rates of visual impairment and blindness (VIB) in neighborhoods that at one time were graded for redlining.

Design: Secondary data analysis of American Community Survey data and historical grades for redlining.

Participants: United States census tracts (CTs) from 2010 with historical grades for redlining.

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HUMAN SUBJECTS: No human subjects were included in this study. The Michigan Institutional Review Board deemed that approval is not needed for secondary data that are public use files. The requirement for informed consent was waived because of the retrospective nature of the study. All research adhered to the tenets of the Declaration of Helsinki
No animal subjects were included in this study.

Methods: One-way analysis of variance, Kruskal–Wallis test, chi-square test, and logistic regression modeling.

Main Outcome Measures: The main outcome was CT percentage of residents reporting VIB and the association with historical grades for redlining. Grades were converted to numeric values (1 to 4, with higher values indicating worse grade) and aggregated over a CT based on the distribution of grades within to obtain a redlining score. Logistic regression was used to model the effect of redlining on the probability of having VIB.

Results: Eleven thousand six hundred sixty-eight CTs were analyzed. Logistic regression found that a 1-unit increase in average redlining score was associated with a 13.4% increased odds of VIB after controlling for CT measures of age, sex, people of color (any non-White race), state, and population size (odds ratio [OR], 1.134; 95% confidence interval [CI], 1.131–1.138; $P < 0.001$). Similar results were observed for an additional model that adjusted for the estimated percentage of Black residents within a CT (OR, 1.180; 95% CI, 1.177–1.183; $P < 0.001$).

Conclusions: Historical government-sanctioned residential segregation through redlining was found to be associated with higher proportions of people living with VIB in these neighborhoods today. Understanding how neighborhood segregation impacts eye health is important for planning improved mechanisms of eye care delivery to mitigate health disparities.

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Keywords

Redlining; Health equity; Visual impairment; Social determinants of health; Neighborhood health

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In 1933, the Home Owners' Loan Act was enacted, and the Home Owners' Loan Corporation (HOLC) was established to combat the negative effects of the Great Depression by refinancing mortgages at low rates. Home Owners' Loan Corporation maps used a system to grade neighborhoods according to their mortgage investment risk.[1] These HOLC maps used the following system to delineate which neighborhoods had the lowest and highest mortgage investment risk: letter A (green) indicated "best," letter B (blue) indicated "still desirable," letter C (yellow) indicated "definitely declining," and letter grade D (red) indicated "hazardous."[2] Neighborhoods with high proportions of Black individuals were outlined in red and labelled "hazardous."[3] This act of drawing a red line around these majority Black neighborhoods begat the term *redlining*. The system sustained itself; realtors encouraged Black individuals to purchase homes in these redlined neighborhoods and discouraged or disallowed them from purchasing homes in neighborhoods with better grades, thus continuing residential segregation and low grades for predominantly Black neighborhoods.[4] Furthermore, those Black individuals purchasing a home in a redlined area then were ineligible for government-insured mortgages because of the hazardous grade and therefore had to use nontraditional financing methods, such as land contracts, that had less protections for the borrower. No land contract standardization was required, and interest rates and fees were not regulated. A real estate owner could set any interest rate rules, such as immediate repossession of property by the lender for a single missed payment.[5] During this same time, the Federal Housing Authority was subsidizing builders who mass-produced suburban subdivisions that excluded Black families.[6] These policies led to residential segregation, low home ownership, and low wealth accumulation within the Black community.[5]

Historic discriminatory housing policies and persistent residential segregation in the United States have caused injustices in education, wealth, and health outcomes for those excluded.[7–9] Residential redlining became illegal in 1968, but the impacts of these policies are being felt to this day. People living in previously redlined neighborhoods are more likely to live in areas with high crime, poor environmental quality, low educational attainment, poor economic opportunities, and poor health outcomes.[7] Research shows an association between redlining and chronic disease outcomes, including a higher prevalence of diabetes, hypertension, stroke, obesity, cancer, and asthma.[8,10–12] In addition to chronic disease, other health inequities such as increased risk of COVID-19 infection have been reported.[13] Although people rank losing vision as bad as or worse than losing hearing, memory, speech, or a limb, the relationship between living in a previously redlined neighborhood and vision impairment or blindness (VIB) has yet to be elucidated.[14] In this work, we assessed the hypothesis that census tracts (CTs) with worse redlining scores have a greater estimated percent of people with VIB compared with CTs with better redlining scores. By understanding the association between redlining and VIB, targeted interventions can be developed to address disparities in eye health and vision care in redlined neighborhoods and in areas with fewer resources. Furthermore, after exposures that lead to VIB are identified, it is essential also to address the exposures through policy and intervention to prevent high concentrations of VIB in historically redlined neighborhoods.

Methods

Home Owners' Loan Corporation grades were obtained from the Open Inter-university Consortium for Political and Social Research (OpenICPSR 10/15/2021 version 2)[15] for 2010 United States CTs. Meier and Mitchell[15] found that CTs were not always composed of areas with only 1 HOLC grade, so the grades were converted to numeric values and were aggregated over a CT based on the distribution of grades within.[16] Redlining scores were calculated by using the summed proportion of HOLC grades and were multiplied by a weighting factor that was based on the area within each individual CT.[15,16] Census tracts with less than 20% of the area graded were excluded.[15,16] These redlining scores range from 1 to 4, with higher scores indicating that larger proportions of the territory has worse grades. The Michigan Institutional Review Board deemed that approval is not needed for secondary data that are public use files. The requirement for informed consent was waived because of the retrospective nature of the study. All research adhered to the tenets of the Declaration of Helsinki.

Census tract estimates for demographic and health data were obtained using PolicyMap, a United States–based geographic information system mapping service[17] that mapped American Community Survey (ACS) 5-year data from 2011 through 2015 to CTs from 2010. The civilian noninstitutionalized population self-reported VIB prevalence was estimated from responses to the ACS question, "Is this person blind or does he/she have serious difficulty seeing even when wearing glasses?" Other estimates obtained at the CT level included median age, percentage of residents that were female, percentage of residents that were people of color (POC; anyone who identified as Hispanic or Latino, multiracial, or any race other than White). An additional estimate included the percent of residents that were Black or African American (not including multiracial Black or multiracial African American).[17] Census tract population size and state where CT was located also were obtained.

Statistical Methods

Census tracts that had missing data or unstable estimates for any of the variables of interest obtained from PolicyMap were excluded. Census tracts with estimates having large margins of error were considered unreliable and were dropped from our sample. A large margin of error in our study was defined as an estimate with a margin of error of > 15% of the estimated value.[18] Demographic and health estimates were summarized with descriptive statistics over CTs and were investigated for distributional properties and outliers with histograms. The distribution of redlining scores across CTs were categorized into quartiles. The 1-way analysis of variance and Kruskal–Wallis tests were performed to test for difference between redlining quartiles with respect to age, population size, and continuous measures of sex, race, and VIB (average percentage across CTs within each redlining quartile). Significant results for Kruskal–Wallis testing were followed by post hoc pairwise comparisons using a Holm-adjusted Dunn's test. Although sex, race, and VIB are measured as a percentage within each CT, the frequency of each subcategory (e.g., male vs. female sex) can be obtained by multiplying the CT population by the percentage. These frequencies (events) and population sizes (trials) then can be aggregated to obtain an overall frequency and percentage within redlining quartile categories. Thus, chi-square tests also were performed to test the difference between redlining quartiles and categorical measures of sex, race, and VIB (overall frequency and percentage of each category across CTs within each redlining quartile). ArcGIS Pro software version 2.5 (Esri, Inc.) was used to map redlining scores and VIB by CTs in an example area of Detroit, Michigan (Fig 1).

Logistic regression models were used to estimate the effect of redlining score on the probability of VIB. Although aggregate data at the CT level were used, the probability of VIB can be estimated using the frequency of VIB by population size (events/trials).[19] Model results are reported with odds ratios (ORs), 95% confidence intervals (CI), and P values. Logistic regression models were adjusted for age, sex, race, population per 1000, and state where the CT was located (to account for any health insurance differences by state). Separate models were run to adjust for estimates of POC and Black or African American residents. Poverty, education, and income were not included in the model because we hypothesize that these variables mediate the relationship between the independent variable (redlining) and the dependent variable (VIB). Age and sex were included in the model as adjustment covariates because they affect the outcome, or dependent variable, VIB. Race was included in the model as a confounding variable because it affects both redlining and VIB (Fig S2, available at www.aaojournal.org). Correlations among poverty, income, and education were calculated. Analyses were performed using R statistical software (R Foundation for Statistical Computing).

Results

In 2010, the United States had 74 134 CTs, of which 12 888 (17.38%) were in areas where redlining occurred. Of the CTs with redlining scores, 11 668 (91%) had complete data and stable estimates for inclusion. The lowest redlining quartile (quartile 1) had scores ranging from 1 to 2.446 (mean, 1.87; n = 3071 CTs), quartile 2 ranged from 2.447 to 3.0 (mean, 2.90; n = 4181 CTs), quartile 3 ranged from 3.001 to 3.585 (mean, 3.25; n = 1704 CTs), and quartile 4 ranged from 3.586 to 4.0 (mean, 3.94; n = 2712 CTs).

Significant differences between CTs in different redlining quartiles were observed (Table 1). Specifically, median age decreased across quartiles. Census tracts in the worst redlining quartile included significantly younger residents than each of the other quartiles (quartile 4 mean, 33.8 years of age vs. quartile 1 mean, 38.6 years of age; $P < 0.001$). The percentage of POC and the percentage of Black or African American residents increased across quartiles. Census tracts in redlining quartile 4 showed significantly higher percentages of POC and Black or African American residents than each of the other quartiles (quartile 4 mean, 70.6% and 34.4% vs. quartile 1 mean, 57.3% and 26.0%, respectively; $P < 0.001$). The percentage of female residents decreased with higher redlining scores (quartile 4 mean, 51.9% vs. quartile 1, 52.2%; $P < 0.001$). Visual impairment and blindness significantly increased with higher redlining scores, such that quartile 4 showed the highest percentage of residents with VIB (quartile 4 mean, 2.92% vs. quartile 1, 2.04%; $P < 0.001$). Finally, population size in thousands (10^3) decreased with higher redlining scores (quartile 4 mean, 3.65×10^3 vs quartile 1: 3.85 10^3; $P < 0.001$). Similar results were observed when analyzing demographic variables as categorical (Table S2, available at www.aaojournal.org).

Logistic regression models assessing the association between redlining score and VIB are presented in Table 3. In the univariate model, a 1-unit increase (worsening) in redlining score was associated with an 18% increased odds of VIB (OR, 1.181; 95% CI, 1.178–1.84; $P < 0.001$). After adjustment for CT estimates of POC, age, sex, population size, and state, worse redlining scores remained associated with significantly increased odds of VIB, such that a 1-unit increase in redlining score was associated with a 13% increased odds of VIB (OR, 1.134; 95% CI, 1.131–1.138; $P < 0.001$). Similar results were observed in the logistic regression model adjusting for the estimated percentage of Black or African American residents, such that a 1-unit increase in redlining score was associated with an 18% increased odds of VIB (OR, 1.180; 95% CI, 1.177–1.183; $P < 0.001$).

Discussion

Among historically redlined CTs, those with worse scores showed an increased odds of VIB. This association persisted even after adjusting for state, population size, and demographic makeup. Poverty, income, and education are correlated significantly with redlining (Table S4, available at www.aaojournal.org). We did not adjust for poverty, education, or income in the model because we hypothesized that they are part of the causal pathway between the independent variable (redlining) and the dependent variable (VIB; Fig S2). We also added a supplemental figure showing the variables on the causal pathway as mediators, rather than confounders (i.e., redlining impacting poverty, income, and education, which then impacts VIB, not poverty, income, and education impacting both redlining and VIB). Regardless of the current age, sex, or racial makeup, CTs that had worse redlining scores had a higher prevalence of VIB than CTs with better scores. This study provides insight into how historic redlining, as one of the many factors and systems that produced “racialized spatial disadvantage,” has impacted current-day vision health outcomes.[20] Although this observational study cannot prove causation, it adds important evidence to support the causative effect between government policies and health outcomes. Furthermore, the way that we assessed CT level redlining score ensured that we could account for the fact that a CT is not always composed of areas with only 1 HOLC grade. This more nuanced way of assigning redlining scores to a geographic area may help to quantify the redlining exposure more accurately to estimate better the policy’s impact on health outcomes.

Research in other fields has examined associations between redlining and poor health outcomes. A recent study found that in CTs with worse historical redlining scores, risk factors for increased morbidity and mortality resulting from COVID-19 were more prevalent, including diabetes, hypertension, kidney disease, stroke, asthma, and chronic obstructive pulmonary disease.[8] Additional studies focused on the associations between historical redlining score and current day preterm birth and asthma-related emergency room visits.[21,22] Kreiger et al[21] found that women in redlined (grade D) neighborhoods had a 20% higher odds of preterm birth compared with women in blue-lined (grade A) neighborhoods, after adjusting for maternal sociodemographic characteristics and current CT poverty. Nardone et al[22] found that prevsiously redlined neighborhood residents who had asthma had a 40% increased risk of visiting the emergency room for uncontrolled disease compared with previously blue-lined neighborhood residents with asthma. Redlining also has been associated with reduced life expectancy. Huang and Sehgal[23] found that after controlling for household income and the proportion of the population who identified as Black, residing in a historically redlined (grade D) and yellow-lined (grade C) neighborhood was associated with a 5.23-year and 4.93-year life expectancy reduction, respectively, compared with living in a historically blue-lined neighborhood.

In our study, CTs with worse historic redlining scores were associated with an increased odds of residents self-reporting VIB today. High prevalence of visual impairment increases the risk of multitudes of clinically important sequelae, such as poor mental health, increased social isolation, risk of falls, injuries, and serious fractures.[24–26] In addition, individuals with vision impairment are more likely to have restricted mobility and restricted independence requiring additional accommodations. However, CTs with worse redlining scores may not have these additional accommodations. For example, if an individual is unable to drive, they may not have the option to walk or use public transportation in previously redlined neighborhoods. This is because of decades of divestment from historically redlined areas, leaving sidewalks in disrepair with poor lighting, curbs without curb cuts, and a lack of voice-enabled crosswalks and ramps for wheelchairs or walkers.[27,28] Additionally, public transportation, which provides an important source of mobility and independence for many visually impaired people,[29] is poorly funded and poorly available in locations across the United States, including previously redlined neighborhoods.[8] That is, areas with the highest VIB prevalence paradoxically may have fewer resources.

Residents of historically redlined neighborhoods are at increased risk of serious eye disease developing. Richardson et al[8] found a higher prevalence of diabetes and hypertension in historically redlined neighborhoods, both risk factors for eye disease.[30,31] Most people (71%) living in historically redlined neighborhoods belonged to minority groups, and a higher prevalence of eye disease exists among racial and ethnic minorities.[32–36] Although older individuals are at increased risk of eye diseases developing and the residents of neighborhoods with worse historic redlining scores were younger, Hispanic and Black individuals are more likely to demonstrate eye conditions at an earlier age compared with White individuals.[37,38]

Redlining is an example of historical structural and systemic racism that continues to impact health outcomes today.[39] Black individuals were denied the ability to purchase homes with government-backed mortgages in more “desirable” neighborhoods because of restrictive covenants and were allowed to purchase homes only in redlined neighborhoods. Although this policy was made illegal in 1968, a Brookings analysis and the University of Richmond Mapping Inequality project found that a greater percentage of minority populations still live in previously redlined neighborhoods than in so-called more desirable neighborhoods.[40] In contrast, a lower percentage of the White population lives in previously redlined neighborhoods than in other so-called more desirable neighborhoods. Currently, 74% of previously redlined neighborhoods comprise low-to-moderate income areas, and 64% comprise areas with majority racial and ethnic minority populations.[41] However, the demographics of some previously redlined areas have been changed by gentrification, so these neighborhoods may have an increase in White individuals with higher education and income. This could be one potential reason why some areas lacked concordance between the map in which we plotted VIB and the map in which we plotted redlining in Detroit, Michigan (Fig 1).[42] We estimated the association between VIB and redlining score adjusting for the proportion of the population comprising POC and ran an additional model adjusting for the proportion of the population comprising Black or African American people to ensure that we adjusted for the demographic attributes that the racist policies have targeted both historically and in the present.

Past residential segregation policies, including redlining, affect the resources that neighborhoods have access to, which then influence health outcomes.[21] Krieger et al[21] provide a conceptual model for understanding how historic redlining led to neighborhood disinvestment and ultimately to poor health. Access to reliable transportation, healthy foods, green spaces, employment, education, preventative health care, and clean air and water can influence a person’s lifestyle, overall health, and eye health.[21] For example, if an individual has diabetes, but because they live in a historically redlined neighborhood, the neighborhood has fewer resources such as less access to healthy foods and safe green spaces for exercise, it is easier for diabetes to become uncontrolled, which can lead to diabetic retinopathy and vision loss.[43,44] Another example is environmental exposures. A higher proportion of toxic waste is dumped in previously redlined neighborhoods, including particulate matter 2.5 and 10, which are mixtures of liquid droplets and solid particles that are small enough to be inhaled and cross into the bloodstream from the lungs. Particulate matter comes from many sources, including emissions from automobiles, power plants, unpaved roads, and smokestacks.[45] Research suggests that particulate matter 2.5 and 10 may be associated with the development of glaucoma, which, if untreated, leads to VIB.[46,47] Where an individual lives determines both their ease of access to resources to maintain health and their environmental exposures, which in turn can impact eye health. Future research and policy should acknowledge and address the lasting public health impact of historical segregation. Case-control studies assessing environmental exposures by historic redlining grades could help to provide additional information on exposures within specific redlining grades for specific eye diseases and conditions.

Successful local attempts have been made to combat persistent racial segregation. In 1995, Black families who lived in federal housing projects in Baltimore, Maryland, sued the United States Department of Housing and Urban Development for violating the Fair Housing Act of 1968. In 2005, after 10 years of litigation, Judge Marvin J. Garbis ruled that the city violated the Act by unfairly concentrating Black individuals in the most impoverished, segregated areas of Baltimore. The judge ruled that the Department of Housing and Urban Development must create strategies and programs that give Black families who were public housing project residents access to fair housing opportunities. This ruling produced the Baltimore Housing Mobility Project, which gave low-income families rent vouchers and assistance in finding housing in higher income Baltimore neighborhoods. A 2009 survey of program participants reported that 80% felt safer, more peaceful, and less stressed in their new neighborhoods. In these new neighborhoods, 21% of people identified as Black compared with the old neighborhoods, where 80% identified as Black. Furthermore, 33% of students were eligible for free lunch and 7.5% of people lived below the poverty limit in the new neighborhoods compared with 83% of students and 33% of people in the old neighborhoods.[48] Although this initiative has been successful, it has not been scaled widely, and residential segregation remains a systematic barrier to health and wellness in the United States.[49]

This research has limitations. First, the ACS 5-year data for 2014 are an average of the data from 2010 through 2014; thus, the study findings are valid only for this time frame.[50] Second, the ACS ascertained self-reported VIB, so potential exists for both social desirability bias and reporting bias. Third, not all CTs with redlining scores were included because of missing data. Fourth, the outcome variable does not assess individual eye diseases or conditions because the ACS ascertained only blindness or difficulty seeing with glasses. Fifth, redlining does not represent all forms of racial residential segregation that have occurred through policies throughout United States history. Not all cities with segregation historically were redlined.[40]

In the United States, CTs with worse historic redlining scores showed a greater prevalence of VIB. These findings are consistent with previous studies demonstrating the associations between historical residential segregation and current neighborhood health outcomes. Future work should identify if these associations exist within individual eye conditions and if certain racial and ethnic minority groups have disproportionately higher prevalence of VIB to inform interventions better. In addition, our study observed historic redlining at a CT level. Additional research at the patient level could map individual addresses to HOLC maps to provide a HOLC grade of A, B, C, or D to provide more granular redlining data.

Additional work to understand individual- and community-level barriers to eye care would inform potential interventions better.

Conclusions

Redlining became illegal in 1968, but previously redlined communities reflect the health implications of this racist policy to this day. We provided insight into the association of previous redlining with VIB as an indicator of one example of specialized structural racism, such that people living in areas with worse historical redlining scores experience worse eye health outcomes today. Policy change is essential to ensuring that CTs with worse spatialized residential segregation and neighborhoods with higher proportions of VIB have the necessary resources to carry out interventions to mitigate preventable VIB. These policies could include addressing such issues that disproportionately affect redlined neighborhoods including elevated levels of environmental pollutants, lack of green spaces, limited access to transportation for eye appointments, and access to quality preventative eye care services.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations and Acronyms:

ACS	American Community Survey
CI	confidence interval
CT	census tract
OR	odds ratio
POC	people of color
VIB	visual impairment and blindness

References

1. Lynch EE, Malcoe LH, Laurent SE, et al. The legacy of structural racism: associations between historic redlining, current mortgage lending, and health. SSM Popul Health. 2021;14:100793.
2. Hillier AE. Redlining and the Home Owners' Loan Corporation. J Urban Hist. 2003;29(4):394–420.

3. Schinasi LH, Kanungo C, Christman Z, et al. Associations between historical redlining and present-day heat vulnerability housing and land cover characteristics in Philadelphia, PA. J Urban Health. 2022;99(1):134–145. [PubMed: 35076872]
4. Szto M, Real estate agents as agents of social change: redlining, reverse redlining, and greenlining, Seattle Journal for Social Justice, 12 (2), 2013. Available at: https://digitalcommons.law.seattleu.edu/sjsj/vol12/iss1/2
5. Abramovitz M, Smith RJ. The persistence of residential segregation by race, 1940 to 2010: the role of federal housing policy. Fam Soc. 2020;102(1):5–32.
6. McGhee H.The Sum of Us : What Racism Costs Everyone and How We Can Prosper Together. New York: Random House Publishing Group; 2021.
7. Townsley J, Andres UM, Nowlin M. The lasting impacts of segregation and redlining. Available at: https://www.savi.org/2021/06/24/lasting-impacts-of-segregation/; 2021. Accessed 29.04.22.
8. Richardson J, Mitchell BC, Meier HCS, et al. Redlining and neighborhood health. Available at: https://ncrc.org/holc-health/. 2020. updated 109.20. Accessed 29.04.22.
9. Burke L, Schwalbach J. Housing redlining and its lingering effects on education opportunity. Available at: https://www.heritage.org/education/report/housing-redlining-and-its-lingeringeffects-education-opportunity; March 11, 2021. Accessed March 11, 2021.
10. Nardone A, Chiang J, Corburn J. Historic redlining and urban health today in U.S. cities. Environmental Justice. 2020;13(4): 109–119.
11. Lee EK, Donley G, Ciesielski TH, et al. Health outcomes in redlined versus non-redlined neighborhoods: a systematic review and meta-analysis. Soc Sci Med. 2022;294:114696.
12. Collin LJ, Gaglioti AH, Beyer KM, et al. Neighborhood-level redlining and lending bias are associated with breast cancer mortality in a large and diverse metropolitan area. Cancer Epidemiol Biomarkers Prev. 2021;30(1):53–60. [PubMed: 33008873]
13. Li M.and Yuan F, Historical redlining and resident exposure to COVID-19: a study of New York City, Race Soc Probl, 14 (2), 2022, 85–100. [PubMed: 34178163]
14. Scott AW, Bressler NM, Ffolkes S, et al. Public attitudes about eye andvisionhealth.JAMAOphthalmol.2016;134(10):1111–1118.
15. Meier HCS, Mitchell BC. Historic redlining scores for 2010 and 2020 US census tracts. Available at: 10.3886/E141121V2; May 25, 2021. Accessed June 6, 2022.
16. National Community Reinvestment Coalition. Tracing the legacy of redlining: a new method for tracking the origins of housing segregation. Available at: https://www.ncrc.org/redlining-score/; February 2022. Accessed June 6, 2022.
17. PolicyMap. About us. Available at: https://www.policymap.com/about; March 18, 2022. Accessed May 31, 2022.
18. Data Planet LibGuides. American Community Survey, 5-year estimates: ACS and margin of error values. Available at: https://data-planet.libguides.com/c.php?g=398862&p=758 2625; June 2022.
19. Chen K, Cheng Y, Berkout O, Lindhiem O. Analyzing proportion scores as outcomes for prevention trials: a statistical primer. Prev Sci. 2017;18(3):312–321. [PubMed: 26960687]
20. Swope CB, Hernández D, Cushing LJ. The relationship of historical redlining with present-day neighborhood environmental and health outcomes: a scoping review and conceptual model. J Urban Health. 99 (6), 2022:959–983. [PubMed: 35915192]
21. Krieger N, Van Wye G, Huynh M, et al. Structural racism, historical redlining, and risk of preterm birth in New York City, 2013e2017. Am J Public Health. 2020;110(7): 1046–1053. [PubMed: 32437270]
22. Nardone A, Casey JA, Morello-Frosch R, et al. Associations between historical residential redlining and current age-adjusted rates of emergency department visits due to asthma across eight cities in California: an ecological study. Lancet Planet Health. 2020;4(1):e24–e31. [PubMed: 31999951]
23. Huang SJ, Sehgal NJ. Association of historic redlining and present-day health in Baltimore. PLoS One. 2022;17(1): e0261028.
24. Demmin DL, Silverstein SM. Visual impairment and mental health: unmet needs and treatment options. Clin Ophthalmol. 2020;14:4229–4251. [PubMed: 33299297]

25. Tetteh J, Fordjour G, Ekem-Ferguson G, et al. Visual impairment and social isolation, depression and life satisfaction among older adults in Ghana: analysis of the WHO's Study on global AGEing and adult health (SAGE) Wave 2. BMJ Open Ophthalmol. 2020;5(1):e000492.
26. Patino CM, McKean-Cowdin R, Azen SP, et al. Central and peripheral visual impairment and the risk of falls and falls with injury. Ophthalmology. 2010;117(2):199–206.e191. [PubMed: 20031225]
27. Walkability Melillo G. and redlining: how built environments impact health and perpetuate disparities. American Journal of Managed Care; 2022. Available at: https://www.ajmc.com/view/walkability-redlining-how-built-environments-impacthealth-and-perpetuate-disparities. Accessed April 29, 2022.
28. Creatore MI, Glazier RH, Moineddin R, et al. Association of neighborhood walkability with change in overweight, obesity, and diabetes. JAMA. 2016;315(20):2211–2220. [PubMed: 27218630]
29. Bezyak JL, Sabella S, Hammel J, et al. Community participation and public transportation barriers experienced by people with disabilities. Disabil Rehabil. 2020;42(23): 3275–3283. [PubMed: 30991852]
30. Grosso A, Veglio F, Porta M, et al. Hypertensive retinopathy revisited: some answers, more questions. Br J Ophthalmol. 2005;89(12):1646–1654. [PubMed: 16299149]
31. Lima VC, Cavalieri GC, Lima MC, et al. Risk factors for diabetic retinopathy: a case-control study. Int J Retina Vitreous. 2016;2:21. [PubMed: 27847639]
32. Muñoz B, West SK, Rubin GS, et al. Causes of blindness and visual impairment in a population of older Americans: the Salisbury Eye Evaluation Study. Arch Ophthalmol. 2000;118(6):819–825. [PubMed: 10865321]
33. Woodward MA, Hughes K, Ballouz D, et al. Assessing eye health and eye care needs among North American Native individuals. JAMA Ophthalmol. 2022;140(2): 134–142. [PubMed: 34940785]
34. National Eye Institute. U.S, Ethnicity and Eye Disease: A Risk Reminder for Asian-, African- and Latino-Americans. Latinos have high rates of eye disease and visual impairment, Available at: https://www.ncbi.nlm.nih.gov/pubmed/; 2022. Accessed 29 April 2022.
35. Apeles L, Shin H; American Academy of Ophthalmology. https://www.aao.org/eye-health/news/ethnicity-eye-disease-riskreminder-asian-african-; 2022. Updated 26.04.16. Accessed 01. 05.22.
36. National Eye Institute. Eye health among African Americans. Available at: https://www.ncbi.nlm.nih.gov/pubmed/; 2022. Accessed January 5, 2022.
37. Gohdes DM, Balamurugan A, Larsen BA, Maylahn C. Age-related eye diseases: an emerging challenge for public health professionals. Prev Chronic Dis. 2005;2(3):A17.
38. Katz J, Friedman DS. African Americans and glaucoma. Available at: https://glaucoma.org/african-americans-andglaucoma/; 2018. Accessed February 28, 2022.
39. Mujahid Mahasin S, Gao X, Tabb Loni P, et al. Historical redlining and cardiovascular health: the Multi-Ethnic Study of Atherosclerosis. Proc Natl Acad Sci U S A. 2021;118(51): e2110986118.
40. Perry AM, Harshbarger D. America's formerly redlined neighborhoods have changed, and so must solutions to rectify them. Available at: https://www.brookings.edu/research/americas-formerly-redlines-areas-changed-so-must-solutions; 2019. Updated 14.10.19. Accessed May 1, 2022.
41. Mitchell B, Franco J. HOLC "Redlining" Maps: The Persistent Structure of Segregation and Economic Inequality. National Community Reinvestment Coalition; 2018.
42. De los Santos H, Jiang K, Bernardi J, Okechukwu C. From redlining to gentrification: the policy of the past that affects health outcomes today. Harvard Medical School Primary Care Review. Available at: https://info.primarycare.hms.harvard.edu/review/redlining-gentrification-health-outcomes; May 26, 2021. Accessed 17.01.22.
43. National Institute of Diabetes and Digestive and Kidney Diseases, Diabetes diet, eating, & physical activity, Available at: Updated December 2016. Accessed 02.05.22 2022. Available at: https://www.niddk.nih.gov/health-information/diabetes/overview/diet-eating-physical-activity
44. American Optometric Association. Diabetic retinopathy. Available at: https://www.aoa.org/healthy-eyes/eye-and-vision-conditions/diabetic-retinopathy?sso=y; 2022. Accessed May 2, 2022.

45. United States Environmental Protection Agency. Particulate matter (PM) basics. Available at: https://www.epa.gov/pmpollution/particulate-matter-pm-basics; 2022. Updated 25.07. 22. Accessed May 2, 2022.
46. Chua SYL, Khawaja AP, Morgan J, et al. The RElationship between ambient atmospheric fine particulate matter (PM2.5) and glaucoma in a large community cohort. Invest Ophthalmol Vis Sci. 2019;60(14):4915–4923. [PubMed: 31764948]
47. Chiang YW, Wu SW, Luo CW, et al. Air pollutant particles, PM(2.5), exposure and glaucoma in patients with diabetes: a national population-based nested case-control study. Int J Environ Res Public Health. 2021, 9939;18(18). [PubMed: 34574858]
48. Engadahl L, New homes, new neighborhoods, new schools: a progress report on the Baltimore housing mobility program, In: Campaign BRH, Poverty and Race Research, 2009, Action Council. 2021;18:9939. Available at: https://files.eric.ed.gov/fulltext/ED535457.pdf
49. Ray R, Perry AM, Harshbarger D, et al. Homeownership, racial segregation, and policy solutions to racial wealth equity. Available at: https://www.brookings.edu/essay/homeownership-racial-segregation-and-policies-for-racial-wealth-equity/; 2021. Updated 01.09.21. Accessed May 2.
50. Research and Training Center on Disability in Rural Communities. (2017). Data limitations in the American Community Survey (ACS): The impact on rural disability research. Missoula, MT: The University of Montana Rural Institute for Inclusive Communities. Available at: https://scholarworks.umt.edu/cgi/viewcontent.cgi?article=1045&context=ruralinst_independent_living_community_participation.

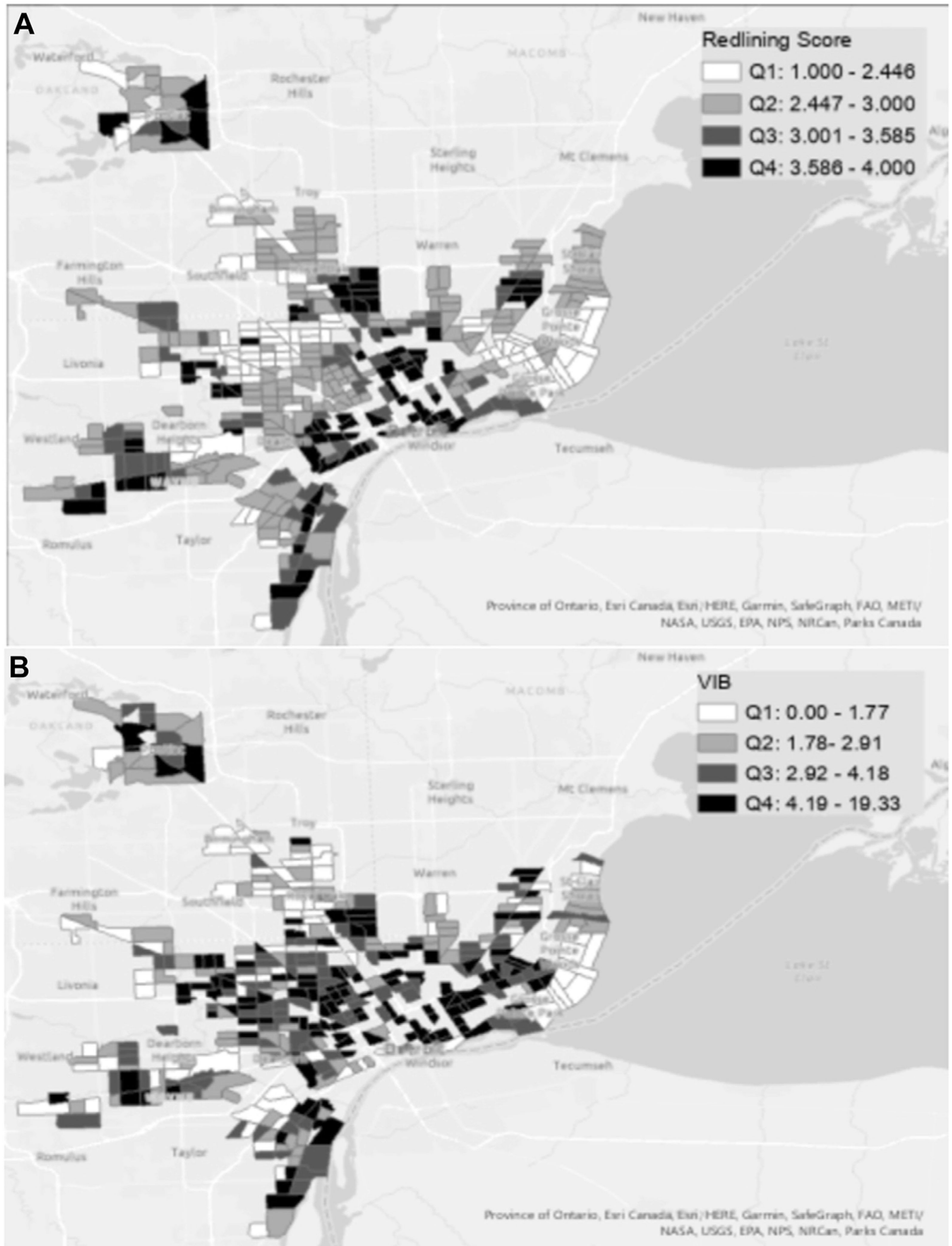

Figure 1.

Geographic Maps of (**A**) redlining scores and (**B**) vision impairment and blindness (VIB) in an example area of Detroit, Michigan by 2010 Census Tracts using Arc GIS Pro software (version 2.5). Q = quartile.

Table 1.

Descriptive Statistics of Neighborhood-Level Variables, Overall and by Quartiles of Redlining Scores

Continuous Variable	Overall, 1.000–4.000 (n = 11 668 Census Tracts)	Redline Quartile 1, 1.00–2.446 (n = 3071 Census Tracts)	Redline Quartile 2, 2.447–3.000 (n = 4181 Census Tracts)	Redline Quartile 3, 3.001–3.585 (n = 1704 Census Tracts)	Redline Quartile 4, 3.586–4.000 (n = 2712 Census Tracts)	*P* Value
Median age (yrs)						< 0.001[*,†,‡,§,‖,¶,#]
Mean ± SD	36.0 ± 6.3	38.6 ± 6.5	36.0 ± 5.8	34.7 ± 6.0	33.8 ± 6.0	
Median (IQR)	36.0 (32.0–40.0)	39.0 (34.0–43.0)	36 (32.0–40.0)	34.0 (31.0–38.0)	33.0 (30.0–37.0)	
Population (per 1000)						< 0.001[**,†,‡,§,‖]
Mean ± SD	3.79 ± 1.63	3.85 ± 1.53	3.88 ± 1.61	3.68 ± 1.65	3.65 ± 1.73	
Median (IQR)	3.59 (2.60–4.72)	3.65 (2.76–4.73)	3.71 (2.70–4.79)	3.46 (2.49–4.62)	3.34 (2.36–4.60)	
POC (%)						< 0.001[**,†,‡,§,‖,¶,#]
Mean ± SD	57.3 ± 32.3	41.6 ± 30.6	58.38 ± 31.7	61.5 ± 30.6	70.6 ± 28.9	
Median (IQR)	57.8 (26.3–91.0)	31.1 (16.2–66.3)	59.17 (28.6–91.0)	65.8 (33.2–92.2)	82.5 (45.7–96.1)	< 0.001[**,†,‡,§,‖,¶]
Black (%)						< 0.001[**,†,‡,§,‖,¶]
Mean ± SD	26.0 ± 31.0	19.56 ± 28.1	23.2 ± 29.2	31.2 ± 31.6	34.4 ± 34.0	
Median (IQR)	10.7 (2.9–40.0)	6.11 (1.8–22.2)	9.0 (2.6–32.1)	17.5 (4.8–52.4)	19.2 (4.7–66.2)	
Female (%)						< 0.001[*,†,‡,§]
Mean ± SD	51.9 ± 4.0	52.2 ± 3.6	51.7 ± 3.7	51.7 ± 4.09	51.9 ± 4.7	
Median (IQR)	51.7 (49.4–54.2)	52.10 (49.9–54.3)	51.6 (49.3–54.0)	51.58 (49.1–54.2)	51.7 (48.9–54.7)	
VIB (%)						< 0.001[*,†,‡,§]
Mean ± SD	2.51 ± 1.79	2.04 ± 1.49	2.45 ± 1.66	2.89 ± 1.91	2.92 ± 2.07	< 0.001[**,†,‡,§,‖,¶]
Median (IQR)	2.14 (1.26–3.35)	1.70 (0.97–2.77)	2.12 (1.28–3.23)	2.52 (1.55–3.82)	2.49 (1.49–3.87)	
Categorical variable VIB						
Frequency (column %)	1 058 975 (2.40)	234 786 (2.00)	385 598 (2.40)	169 542 (2.70)	269 050 (2.72)	< 0.001[†,‡,§,‖,¶,#,††]

IQR = interquartile range; POC = people of color; SD = standard deviation; VIB = visual impairment and blindness.

Significant Kruskal–Wallis tests were followed by post hoc pairwise comparisons using Dunn tests with Holm's adjustment for multiple comparisons. Significant analysis of variance tests were followed by post hoc pairwise comparisons using Tukey's adjustment for multiple comparisons. Significant chi-square tests were followed by post hoc pairwise comparisons.

[*] Analysis of variance.

[†]Post hoc pairwise comparisons significant at $P < 0.05$ for quartile 1–quartile 2 comparison.

[‡]Post hoc pairwise comparisons significant at $P < 0.05$ quartile 1–quartile 3 comparison.

[§]Post hoc pairwise comparisons significant at $P < 0.05$ quartile 1–quartile 4 comparison.

[//]Post hoc pairwise comparisons significant at $P < 0.05$ quartile 2–quartile 3 comparison.

[¶]Post hoc pairwise comparisons significant at $P < 0.05$ quartile 2–quartile 4 comparison.

[#]Post hoc pairwise comparisons significant at $P < 0.05$ quartile 3–quartile 4.

[**]Kruskal–Wallis test.

[††]Chi-square test.

Table 3.

Logistic Regression Models Estimating the Effect of Redlining on the Probability of Visual Impairment or Blindness in Unadjusted Models and Models Adjusting for Neighborhood Measures of Race

Variable	Univariate Unadjusted Models	Multivariable People of Color Adjusted Model*	Multivariable Black or African American Adjusted Model*
Redlining score (per 1 unit)	1.181 (1.178–1.184)†	1.134 (1.131–1.138)†	1.180 (1.177–1.183)†
Median age (per 1 year)	0.997 (0.997–0.998)†	1.014 (1.014–1.014)†	1.007 (1.006–1.007)†
Female (%; per 1%)	1.016 (1.016–1.017)†	1.004(1.004–1.005)‡	0.999 (0.998–0.999)†
Population (per 1000)§	0.783 (0.779–0.787)†	0.897(0.892–0.901)†	0.945 (0.940–0.950)†
POC (%; per 1%)	1.006 (1.006–1.007)†	1.008 (1.008–1.008)†	—
Black (%; per 1%)	1.007 (1.007–1.007)†	—	1.006 (1.006e1.007)†

POC = people of color; − = no data.

Data are presented as odds ratio (95% confidence interval). Univariate models: each variable in a separate model. Multivariable models: all variables in a single model.

*All variables in the column are in the same model.

†$P < 0.001$.

‡$0.001 < P < 0.01$.

§Logarithm of population.