Historic Redlining and Urban Health Today in U.S. Cities

Anthony Nardone, Joey Chiang, and Jason Corburn

ABSTRACT

This study explores the potential associations between historic redlining and urban health outcomes in nine U.S. cities: Atlanta, Chicago, Cleveland, Los Angeles, Miami, New York, Oakland, San Francisco, and St. Louis. We hypothesize that historic redlining has influenced current racial and ethnic health inequities that are spatially patterned by neighborhoods. Using shape files for redlining in nine cities, U.S. Census data and the Centers for Disease Control, 500 Cities Project health data, we tested for the strength of the association between historically redlined neighborhoods and 14 health outcomes today. We found associations between historically redlined neighborhoods and current day prevalence of cancer, asthma, poor mental health, and people lacking health insurance. We also found that residents in historically redlined areas of Atlanta, Cleveland, Miami, and the San Francisco-Oakland metropolitan areas were nearly twice as likely to have poor health than in nonredlined areas. Spatial racial segregation and poor health remain critical environmental justice issues impacting communities of color. Our study aims to highlight one historically rooted process that may be contributing to racialized health inequalities today. Our preliminary analysis across multiple cities and multiple health outcomes suggests that the legacy of redlining may be contributing to chronic health inequities within urban areas. Although further research is needed, policy responses must consider how to reverse and repair the legacy of structural racism such as redlining.

Keywords: redlining, health equity, cities, land use

INTRODUCTION

THIS STUDY EXPLORES POTENTIAL associations between historical community "redlining" and current urban health outcomes. The term "redlining" comes from the Home Owners' Loan Corporation (HOLC) categorization, which started in the 1930s during the Great Depression, of some neighborhoods as "high risk" whose residents should not be given access to mortgages, and thus were shaded red on maps.[1,2] Redlining now refers to lending (or insurance) discrimination that bases credit decisions on the location of a property to the exclusion of characteristics of the borrower or property.

The HOLC was a government-established corporation charged with making loans to new homeowners and preventing foreclosures through refinancing mortgages at low interest rates. HOLC also created the *City Survey*

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[1] K.T. Jackson. *Crabgrass Frontier: The Suburbanization of the United States.* (New York: Oxford University Press, 1985).

[2] J. Greer. "The Home Owners' Loan Corporation and the Development of the Residential Security Maps." *Journal of Urban History* 39 (2013): 275–296.

Program, where local bankers and real estate men were appointed to appraisal committees. These committees rated each neighborhood into one of four financial risk and lending categories from the most desirable (labeled A and green colored on maps) through the least desirable (labeled D and red colored on maps). The "desirability" was based almost entirely on race, since neighborhoods that were predominantly African American and immigrant were graded "D" and shaded red (thus redlining), whereas areas that were predominantly white and non-immigrant were graded "A" and outlined in green. The color-coded "residential security maps" were widely adopted by the private banking and mortgage industry and led to "redlined" areas being denied access to loans by local banks, limiting black home ownership and future wealth creation.

Although redlining was banned in the United States as part of the Fair Housing Act of 1968, a majority of those areas deemed "hazardous" (and subsequently "redlined") remain low-to-moderate income and communities of color, whereas those deemed "desirable" remain predominantly white with above-average incomes.[3,4] Redlining was not the only discriminatory policy that adversely impacted urban communities of color. Federal housing policies, including urban renewal as part of the Federal Housing Act of 1949, authorized the systematic demolition of black neighborhoods.[5] Transportation policies, such as the Federal Aid Highway Act of 1956, also authorized the demolition of urban neighborhoods labeled as "unhealthy slums" and replaced them with the burgeoning interstate highway system.[6] The housing and transportation policies were largely justified in the name of public health, since they claimed to be clearing blighted unhealthy areas, but have instead resulted in widespread financial and political divestment from black, indigenous, people of color (BIPOC) communities. Taken together, redlining, housing, transportation, and other urban policies ushered in "white flight" from cities, the widespread displacement of vibrant urban neighborhoods of color, and decades of urban decline.[7]

A range of research has now documented the legacy of redlining and housing policies on racial residential segregation and related disparities in such environmental justice issues as persistent poverty and wealth creation, access to healthy food, mass incarceration, gun violence, qualities of green space, concentrations of pollution, and the determinants of health.[8,9,10,11,12,13,14,15] Redlining should also be understood as part of structural racism that concentrates risks and limits opportunities for communities of color.[16]

In this study, we seek to assess whether discriminatory policies starting in the 1930s that shaped neighborhood development and likely proximity to environmental hazards and goods in the United States are associated with estimated prevalence of health outcomes and behaviors as defined by the Center for Disease Control and Prevention's (CDC) 500 Cities database.[17] We hypothesize that place-based relationships between historic redlining and current racial and ethnic health disparities still exist.[18] Although there have been a few studies documenting how redlining has adversely influenced general environmental quality, housing, and economic status of those in redlined neighborhoods, very few

[3]B. Mitchell, and J. Franco. *HOLC "Redlining" Maps: The Persistent Structure of Segregation and Economic Inequality.* (National Community Reinvestment Coalition, 2018), pp. 1–29.
[4]D. Aaronson, D. Hartley, and B. Mazumder. *The Effects of the 1930s HOLC "Redlining" Maps.* Federal Reserve Bank of Chicago Working Paper No. 2017–12. (Federal Reserve Bank of Chicago, 2017), pp. 1–102.
[5]T.M. Michney, and L. Winling. "New Perspectives on New Deal Housing Policy: Explicating and Mapping HOLC Loans to African Americans." *Journal of Urban History* (2019): DOI: 10.1177/0096144218819429.
[6]R.A. Mohl. "The Expressway Teardown Movement in American Cities: Rethinking Postwar Highway Policy in the Post-interstate Era." *Journal of Planning History* 11 (2012): 89–103.
[7]M.T. Fullilove. "Root Shock: The Consequences of African American Dispossession." *Journal of Urban Health* 78 (2001): 72–80.

[8]Mitchell and Franco (2018). *Op. cit.*
[9]R. Rothstein. *The Color of Law.* (Liveright Publishing Corporation, 2017).
[10]J.S. Hoffman, V. Shandas, and N. Pendleton. "The Effects of Historical Housing Policies on Resident Exposure to Intra-Urban Heat: A Study of 108 Urban Areas." *Climate* 8 (2020): 12.
[11]D. Locke, B. Hall, J.M. Grove, S.T.A. Pickett, L.A. Ogden, C. Aoki, C.G. Boone, and J.P.M. O'Neil-Dunne. "Residential Housing Segregation and Urban Tree Canopy in 37 US Cities." *SocArXiv* (2020): DOI: 10.31235/osf.io/97zcs.
[12]Michney and Winling (2019). *Op. cit.*
[13]S.F. Jacoby, B. Dong, J.H. Beard, D.J. Wiebe, and C.N. Morrison. "The Enduring Impact of Historical and Structural Racism on Urban Violence in Philadelphia." *Social Science & Medicine* 199 (2018): 87–95.
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[15]N. Krieger, G. Van Wye, M. Huynh, P.D. Waterman, G. Maduro, W. Li, R.C. Gwynn, O. Barbot, and M.T. Bassett. "Structural Racism, Historical Redlining, and Risk of Preterm Birth in New York City, 2013–2017." *American Journal of Public Health* 110 (2020): 1046–1053. https://doi.org/10.2105/AJPH.2020.305656
[16]The Aspen Institute defines structural racism as: "A system in which public policies, institutional practices, cultural representations, and other norms work in various, often reinforcing ways to perpetuate racial group inequity. It identifies dimensions of our history and culture that have allowed privileges associated with "whiteness" and disadvantages associated with "color" to endure and adapt over time. Structural racism is not something that a few people or institutions choose to practice. Instead it has been a feature of the social, economic and political systems in which we all exist." Aspen Institute 2004. Structural Racism and Community Building." Roundtable on Community Change. Washington, D.C.: The Aspen Institute.
[17]Center of Disease Control and Prevention. 500 Cities Project: Local Data for Better Health. https://www.cdc.gov/500cities/index.htm (Last accessed on January 23, 2020).
[18]John C. Huggins. "A Cartographic Perspective on the Correlation Between Redlining and Public Health in Austin, Texas–1951." *Cityscape* 19 (2017): 267–280.

studies to our knowledge have investigated how historic redlining may be linked to current-day health outcomes in multiple cities.[19,20,21,22,23] To investigate these potential links, we examined the association between residential redlining, and select, present-day health outcomes in Atlanta, Chicago, Cleveland, Los Angeles, Miami, New York, San Francisco/Oakland metro area, and St. Louis.

METHODS

This ecological study utilized data from several publicly available sources at the census tract level. Nine cities reflecting but not representing four geographic regions across the United States were selected for this analysis, including New York (northeast), Atlanta and Miami (southeast), Cleveland, Chicago, and St. Louis (Midwest), and Oakland, San Francisco, and Los Angeles (west coast). These metropolitan regions were selected to ensure a range of city size and regional variation in our analyses. We also hypothesized that the historic redlining-to-contemporary health relationships might vary by metropolitan region since local governments tend to have a strong influence over community development, housing, and local economic and social opportunities through such tools as zoning, planning processes, and other land use controls.[24] The HOLC Security Map shapefiles were acquired from the University of Richmond's "Mapping Inequality" website.[25]

Neighborhoods appraised by the HOLC were shaded in one of four colors denoting risk of lending: green (best/least financial risk), blue (still desirable), yellow (declining), and red (hazardous/most financial risk). Neighborhoods considered redlined were those shaded in red that receiving a hazardous, or do not lend, designation. We refer to these HOLC-defined risk levels, or colors, as HOLC risk grades, since each map color was assigned a letter grade of A, B, C, and D. The main predictor of interest was HOLC risk grade of each census tract. Every 2010 census tract was assigned a HOLC risk grade by superimposing 2010 census tract geographic centroids onto HOLC security maps.

Health outcome data were acquired from the CDC 500 Cities data set, which provides census tract level age-standardized prevalence estimates for a variety of health outcomes across census tracts in the most populated cities of all 50 states across the country.[26] The CDC notes that the data source is the Behavioral Risk Factor Surveillance System data and the small-area estimates "can be used to identify emerging health problems and to inform development and implementation of effective, targeted public health prevention activities."[27] Five-year estimates of median household income (in 2015 inflation-adjusted dollars) and demographic statistics (2011–2015) were obtained from the American Community Survey.[28]

Health indicators

Of the 21 health indicators included in the 500 Cities data set, we analyzed 14 of them to explore the possible associations between redlining on morbidity. We determined that seven indicators could be excluded, including the percentage with poor self-rated physical health, lost teeth, regular dental visits, routine checkups, cholesterol screenings, mammography, fecal occult/sigmoidoscopy/colonoscopy, and older adults ≥65 years receiving a core set of clinical services, due to overlap with other outcomes. Our 14 selected indicators were divided into three categories: health outcomes, unhealthy behaviors, and preventive measures. The seven health outcomes included estimated prevalence of asthma, cancer, coronary heart disease, diabetes, high blood pressure, poor mental health, and stroke. The four unhealthy behaviors included binge drinking, current smoking, obesity, and poor sleep. The three preventative measures included health insurance status, percentage of individuals receiving a Pap smear in the past 3 years, and percentage of those with high blood pressure who are taking hypertension medication. The techniques for calculating these estimates can be found at the CDC 500 Cities data site.[29]

Geographic centroids from the 2010 Census were superimposed onto HOLC Security Maps for each city included in the analysis. Centroids were subsequently assigned the HOLC risk grade associated with the original neighborhood on the Security Map. Census tracts were excluded if centroids landed outside of HOLC Security Map boundaries. We assessed the distribution of study variables and bivariate associations between HOLC risk grades, percentage of health outcomes, demographic

[19]Nardone et al. (2020). Op. cit.
[20]E. McClure, L. Feinstein, E. Cordoba, C. Douglas, M. Emch, W. Robinson, S. Galea, and A.E. Aiello. "The Legacy of Redlining in the Effect of Foreclosures on Detroit Residents' Self-Rated Health." Heal Place 55 (2018): 9–19.
[21]Huggins (2017). Op. cit.
[22]N. Krieger, E. Wright, J.T. Chen, P.D. Waterman, E.R. Huntley, and M. Arcaya. "Cancer Stage at Diagnosis, Historical Redlining, and Current Neighborhood Characteristics: Breast, Cervical, Lung, and Colorectal Cancer, Massachusetts, 2001–2015." American Journal of Epidemiology (2020): DOI: 10.1093/aje/kwaa045.
[23]N. Krieger, G. Van Wye, M. Huynh, P.D. Waterman, G. Maduro, W. Li, R.C. Gwynn, O. Barbot, and M.T. Bassett (2020). Op. cit.
[24]Weir M. "Power, Money, and Politics in Community Development." In: Urban Problems and Community Development, edited by Ronald F. Ferguson and William T. Dickens (Brookings Institution Press, 1999), 139–192.
[25]R.K. Nelson, R. Winling, R. Marciano, N. Connolly, and E.L. Ayers. Mapping Inequality. American Panorama. https://dsl.richmond.edu/panorama/redlining (Last accessed on March 23, 2019).

[26]Center of Disease Control and Prevention. Op. cit.
[27]Center of Disease Control and Prevention. https://cdcarcgis.maps.arcgis.com/home/item.html?id=04bd589e13c242d98de43e78f90d0d3f (Last accessed on December 1, 2019).
[28]United States Census Bureau/American Fact Finder. "S1903" Median Income in the Past 12 Months (in 2015 Inflation-Adjusted Dollars). (Am. Community Surv. U.S. Census Bureau's American Community Survey Office, 2015).
[29]Center of Disease Control and Prevention. https://www.cdc.gov/500cities/index.htm (Last accessed on January 5, 2020).

TABLE 1. 2010 CENSUS TRACTS WITHIN 1930s HOME OWNERS' LOAN CORPORATION RISK MAPS: 9 U.S. CITIES

	Overall	Midwest	Northeast	Southeast	West coast
	N = 4061	N = 975	N = 1814	N = 148	N = 1124
Median household income[a]	$47,041	$37,117	$52,344	$32,021	$47,973
Average population[b]	3478	2891	3453	3298	3867
% People of color[c]	55.6	52.1	63.5	28.3	52.2
HOLC risk grade (%)					
A	2.4	1.50	1.60	7.40	3.70
B	16.2	12.30	18.20	18.20	16.10
C	49.8	51.40	47.80	41.20	52.80
D	31.6	34.80	32.10	33.10	27.40

West coast includes San Francisco, Oakland, and Los Angeles; Midwest includes Chicago, Cleveland, and St. Louis; southeast includes Atlanta and Miami; northeast includes New York City.
[a]Median household income in 2015 USD.
[b]2010 average population of census tract.
[c]Defined by percentage of those reporting a race other than white from 2013 to 2017 American Community Survey 5-year estimates.
HOLC, Home Owners' Loan Corporation.

data from the 2010 census, and other study covariates using analysis of variance. Census tract choropleth maps were generated with the GISTools R package to assess the qualitative associations between security maps and present health outcomes at the census tract level.

RESULTS

A summary of all census tracts across all nine cities, San Francisco, Oakland, Los Angeles, Chicago, Cleveland, St. Louis, Atlanta, Miami, and New York City, grouped into regions, and their 1930s HOLC risk grade allocations, along with today's demographic and income data, are provided in Table 1. We found that lowest risk grade allocation (A) indicated by green shading on maps comprised a small proportion (<10%) of all categorized census tracts. The percentage of "redlined" or high-risk grade census tracts (those falling within a C or D rating) were relatively constant across all of our selected cities, with nearly half of all neighborhoods categorized as grade C and roughly 30% of all neighborhoods being categorically "redlined." Median household income today also varied across tracts that were assigned a HOLC grade, ranging from $32,021 in the southeast to $52,344 in the northeast. Average census tract populations were smallest in Midwestern cities (2891 people), whereas west coast cities had, on average, 1000 more people per census tract

(3867 people). More than 50% of the population in HOLC census tracts in our cities identified as a person of color today, defined by those identifying as a race other than white, were similar across the west coast, Midwest, and northeast, except in the southeast, where tract populations consisting of people of color is <30% (Table 1).

Census analyses revealed that the lower the HOLC risk grade category, the lower today's average income and the higher the percentage people of color. Median household income in 2010 census tracts that were redlined by HOLC (D grade) is significantly lower ($39,800) than in "green" or low-risk census tracts ($61,200). The percentage people of color was greatest in previously redlined neighborhoods (63.7%) compared with 37.8% in census tracts that received a low risk grade. Finally, the number of people living in each census tract was lowest in high risk grade neighborhoods (Table 2).

Correlation coefficients for health indicators, shown in Table 3, indicate varied association between prior HOLC risk grade and current health. Overall, the strongest associations were observed for the estimated percentage of people >18 years diagnosed with a nondermatologic cancer ($\rho = -0.32$, $p < 0.001$), estimated percentage of people reporting 14 days of poor mental health in the past month ($\rho = 0.26$, $p < 0.001$), and estimated percentage of people lacking health insurance ($\rho = 0.25$, $p < 0.001$). The overall estimated percentage of those with high blood

TABLE 2. NINE CITY CENSUS TRACT HOME OWNERS' LOAN CORPORATION RISK GRADE AND SOCIODEMOGRAPHICS

HOLC risk grade	A and B (low-green) Median (IQR)	C (moderate-yellow) Median (IQR)	D (redlined) Median (IQR)	p
Median income[a]	$61.2 (42.2–85.9)	$46.9 (33.1–62.7)	$39.8 (27.2–48.0)	<0.001
Average population[b]	3.6 (2.5–4.9)	3.5 (2.5–4.7)	3.3 (2.3–4.5)	0.01
% People of color	37.8% (21.4–71.9)	56.4% (32.6–80.2)	63.7% (37.1–87.1)	<0.001

[a]Median household income in 2015-adjusted dollars in $1,000.
[b]In 1000 residents.
IQR, interquartile range.

TABLE 3. CITY-SPECIFIC CORRELATION COEFFICIENTS BETWEEN PRIOR REDLINED CENSUS TRACTS
AND 2018 HEALTH INDICATORS

	Overall**, N=4061	ATL, N=63	CHI, N=716	CLE, N=159	LAX, N=863	MIA, N=85	NYC, N=1814	STL, N=100	SF-Oak, N=261
Health outcomes									
Asthma	0.19	0.41*	0.10	0.42*	0.27*	0.58*	0.19*	0.22	0.36*
Cancer	−0.32	−0.26	−0.22*	−0.24	−0.38*	−0.36*	−0.32*	−0.25	−0.46*
CHD	0.00	0.10	−0.03	0.26*	0.15*	0.28*	−0.09*	0.12	0.05
Diabetes	0.16	0.24	0.07	0.36*	0.31*	0.42*	0.11*	0.17	0.22*
High BP	0.07	0.17	0.00	0.32*	0.11	0.41*	0.03	0.16	0.11
Mental health	0.26	0.41*	0.15*	0.35*	0.40*	0.61*	0.23*	0.28	0.50*
Stroke	0.13	0.24	0.05	0.37*	0.25*	0.46*	0.09*	0.18	0.24*
Unhealthy behaviors									
Binge drinking	−0.08	−0.26	−0.06	−0.39*	−0.24*	−0.42*	−0.01	−0.17	−0.03
Current smoking	0.21	0.39	0.13	0.32*	0.38*	0.58*	0.23*	0.25	0.48*
Obesity	0.21	0.38	0.11	0.40*	0.31*	0.57*	0.18*	0.24	0.41*
<7 Hours sleep	0.24	0.41*	0.14	0.42*	0.33*	0.62*	0.18*	0.23	0.33*
Preventive measures									
Lack of health insurance	0.25	0.37	0.12	0.35*	0.44*	0.41*	0.21*	0.24	0.46*
Pap smear	0.00	−0.25	0.08	0.08	−0.28*	−0.4*	0.07	0.05	0.00
Taking BP medication	−0.14	0.04	−0.08	0.14	−0.31*	0.06	−0.21*	0.00	−0.29*

*Indicates $p \leq 0.001$.
**All p-values were ≤ 0.0001 except for CHD and Pap smear.
ATL, Atlanta; BP, blood pressure; CHD, coronary heart disease; CHI, Chicago; CLE, Cleveland; LAX, Los Angeles; MIA, Miami; NYC, New York City; SF-OAK, San Francisco-Oakland; STL, St. Louis.

pressure, congestive heart disease, and those receiving a Pap smear in the past 3 years were not associated with prior redlining.

However, redlined census tracts within specific cities revealed a mixed set of results (Fig. 1). Redlined areas in Chicago were only weakly associated with cancer diagnosis and poor mental health. In Atlanta, moderately strong correlations were observed for estimated prevalence of asthma, poor mental health, and those reporting an average of <7 hours of sleep, with all other indicators having insignificant correlations with prior redlining. In St. Louis, there were no significant correlations. In the metropolitan areas of Cleveland, Los Angeles, Miami, New York City, and San Francisco-Oakland, the majority of health indicators revealed weak-to-moderate strength correlations with prior redlining status. The bar graphs in Figure 1 depict several of these city level health indicator differences between previously redlined census tracts (risk grade ''D'') and census tracts with low risk grades (''A'' or ''B'').

Regional and metropolitan-level analyses may wash out significant intracity findings. In other words, we also explored where there were specific pockets, or micro areas, within each metropolitan region that might reveal associations between prior redlining and poor health outcomes today. Figures 2–4 aim to illustrate the spatial associations between HOLC Security Maps and current health outcomes as estimated by the 500 Cities data set for the Statistical Metropolitan Areas of San Francisco-Oakland, Los Angeles, and Miami. In Figures 2–4, we included six panels: (A) the original HOLC ''redlining''

map; (B) a digitized version of the HOLC map; (C) 2010 census tracts that fall within the HOLC designated areas; and, (D, E, and F) select 2018 health outcomes by census tract.

The San Francisco-Oakland area (Fig. 2) suggests a significant intra-region variability. The only area of San Francisco that was historically redlined and has consistently poor health outcomes today is the Bay View-Hunters Point area (southeast corner of San Francisco). In the East Bay cities of Oakland, Alameda, and Berkeley, areas that were historically redlined do appear to have worse health outcomes today.

In Los Angeles (Fig. 3), our spatial mapping suggests that census tracts that received higher-risk grades (yellow and red in panel C) closely mirror census tracts with a high prevalence of asthma today (panel D) and diabetes mellitus (panel F). Yet, also in Los Angeles, the neighborhoods that received lower-risk grades (green and blue) closely mirror census tracts with a higher prevalence of cancer diagnosis (panel E). According to the California Communities Environmental Health Screening Tool (CalEnviroScreen), these same areas in Los Angeles are known to have higher concentrations of pollution and health risks.[30] These maps suggest that redlining and other place-based factors likely matter for today's

[30]Office of Environmental Health Hazard Assessment (OEHHA). California Communities Environmental Health Screening Tool (CalEnviroScreen). 2020. Version 3.0. https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-30 (Last accessed on February 23, 2020).

a **% Diagnosed with cancer[a]**

b **% Reporting poor mental health[b]**

c **% Current smokers**

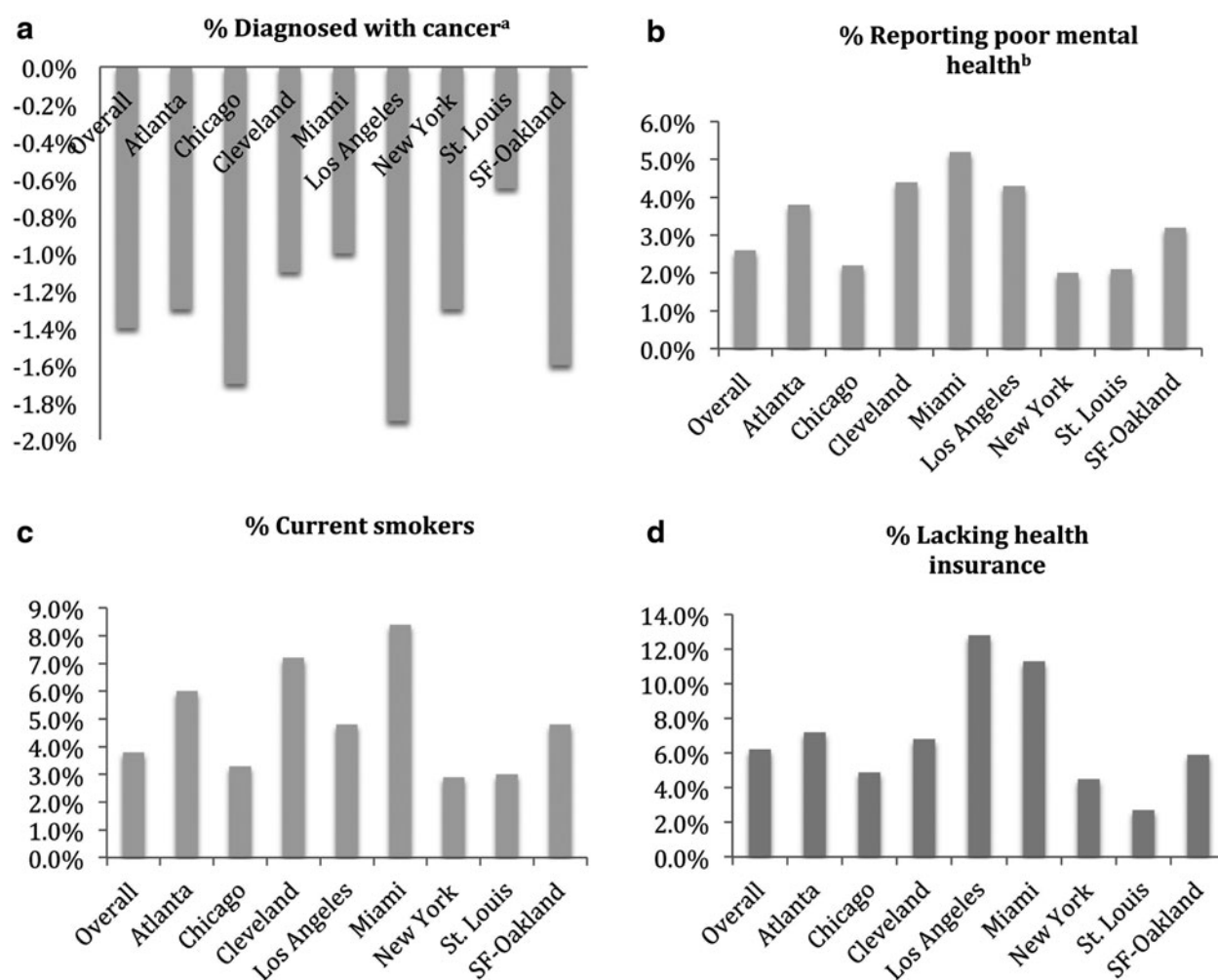**d** **% Lacking health insurance**

FIG. 1. Percentage difference in health outcome today: previous redlined and nonredlined areas. **(a)** Excludes dermatologic cancers. **(b)** Self reported poor mental health for ≥14 days in previous 30 days. **(c)** Currently smoke every day or some days. **(d)** Respondents aged 18–64 years who report having no current health insurance coverage.

distribution of population health, such as the locations of air pollution-producing highways and food outlets, but also that those living in previously low-risk grade census tracts may have better access to cancer screening services and/or treatment options today.

Our spatial mapping in Miami, Florida (Fig. 4), suggest that census tracts with today's highest estimated prevalence of stroke, poor mental health, and poor sleep quality are those that were previously redlined. The areas with some of these poor health outcomes include Liberty City, Opa-locka, and Overtown, all neighborhoods that suffered from racial redlining and related urban renewal projects. These areas remain some of the most racially segregated predominantly African American neighborhoods in Miami-Dade County.[31]

Although our neighborhood-scale mapping is preliminary, it points to the need for a deeper understanding of the sources of intergenerational disadvantage that can adversely impact life chances. For example, Patrick Sharkey in his 2013 book ''Stuck in Place'' notes that young African Americans (from 13 to 28 years) were 10 times as likely to live in poor neighborhoods as young whites were in 2010, and that more than half of black households in the United States have lived in poor neighborhoods for at least two generations.[32] Thus, neighborhood inequality for African Americans is more multigenerational, pointing to the importance of historic policies, such as redlining, that have shaped place-based opportunities.

[31]R.A. Mohl. ''Whitening Miami: Race, Housing and Government Policy in Twentieth-Century Dade County.'' *The Florida Historical Quarterly* 79 (2001): 319–345.

[32]P. Sharkey. *Stuck in Place: Urban Neighborhoods and the End of Progress Toward Racial Equality*. (University of Chicago Press, 2013).
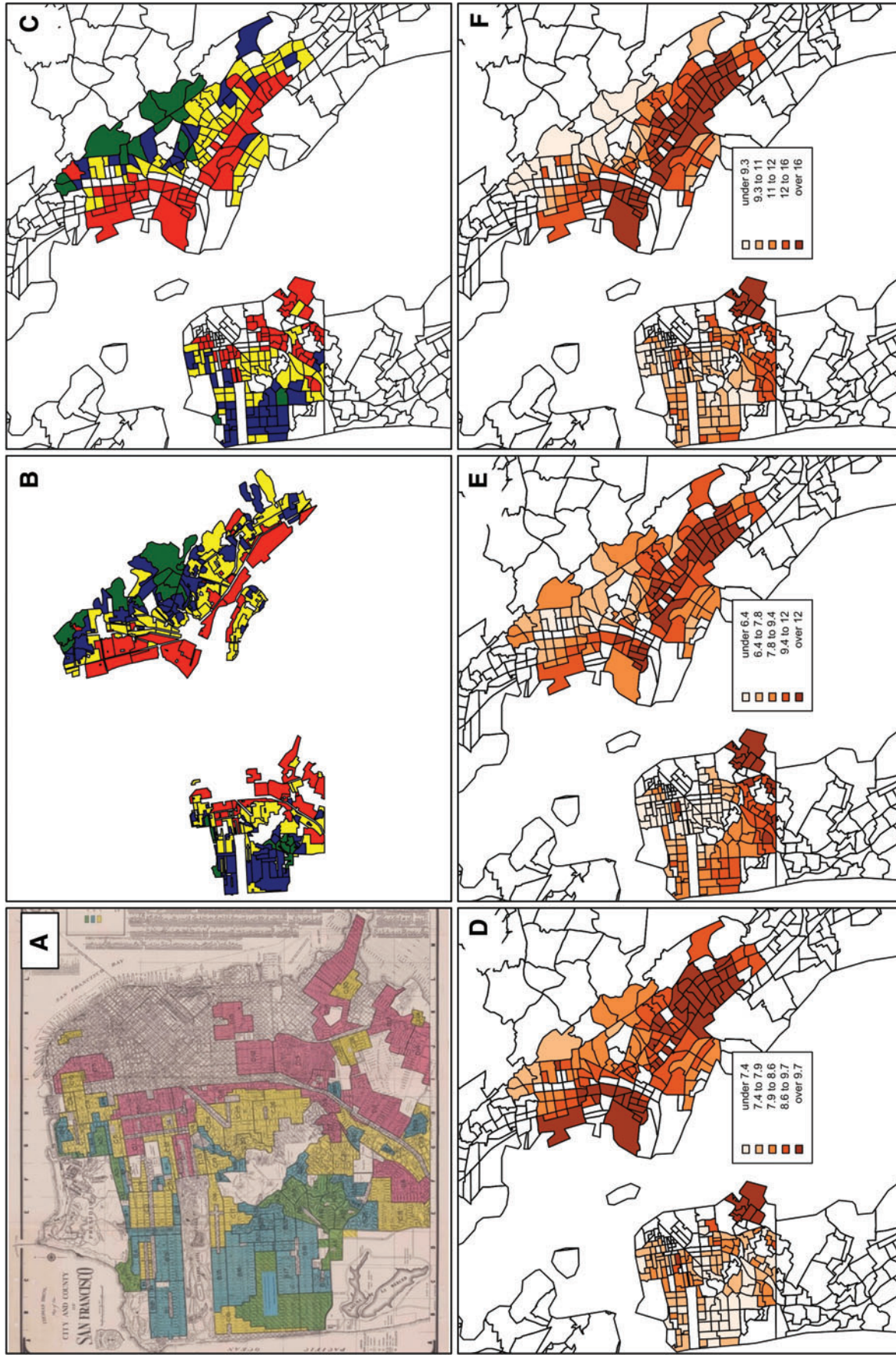
FIG. 2. San Francisco and Oakland: spatial relationship between historic redlining and health. (**A**) HOLC security map. (**B**) Digitized HOLC security map. (**C**) 2017 census tracts categorized into respective HOLC risk grades based on geographic centroid. (**D**) Estimated asthma prevalence. (**E**) Estimated diabetes prevalence. (**F**) Estimated smoking prevalence. HOLC, Home Owners' Loan Corporation. Color images are available online.
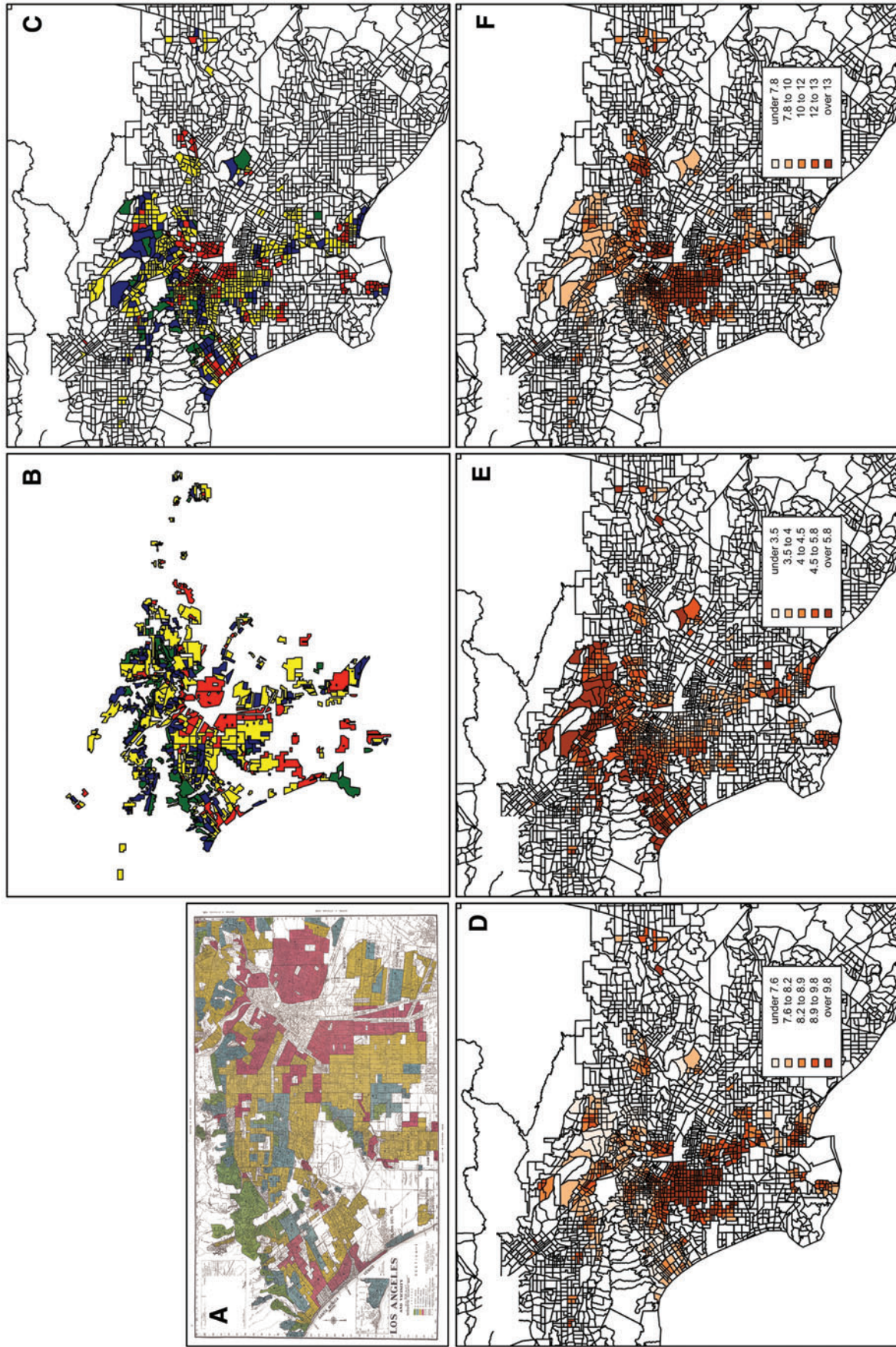
FIG. 3. Los Angeles: spatial relationship between historic redlining and health. **(A)** HOLC security map. **(B)** Digitized HOLC security map. **(C)** 2010 census tracts categorized into respective HOLC risk grades based on geographic centroid. **(D)** Estimated asthma prevalence. **(E)** Estimated cancer prevalence. **(F)** Estimated diabetes prevalence. Color images are available online.
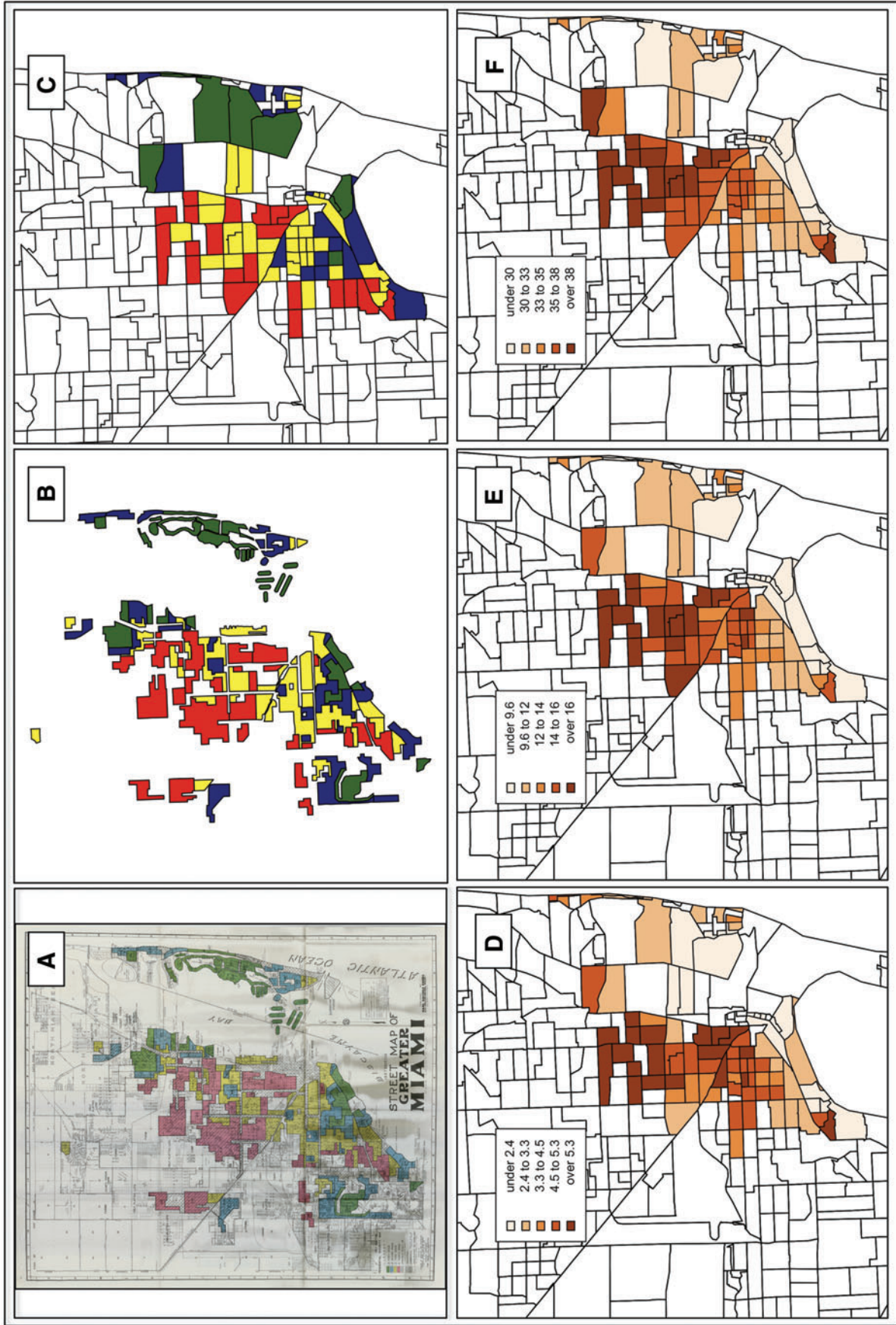
FIG. 4. Miami: spatial relationship between historic redlining and health. (**A**) HOLC security map. (**B**) Digitized HOLC security map. (**C**) 2010 census tracts categorized into respective HOLC risk grades based on geographic centroid. (**D**) Estimated percentage having a stroke. (**E**) Estimated percentage poor self-rated mental health. (**F**) Estimated percentage poor sleep quality=<7 hours. Color images are available online.

DISCUSSION

The goal of this analysis was to explore potential relationships between racial discrimination reflected in HOLC mortgage lending practices in the 1930s with current health indicators in select cities in the United States today. This is the first study to our knowledge that aims to assesses a wide spectrum of health indicators with historic redlining, across multiple cities. Previous study by Huggins *et al.* superimposed cases of tuberculosis in 1951 onto the HOLC Security Map for Austin, Texas, and identified a spatial relationship between disease and redlining.[33] McClure *et al.* analyzed the relationships between historic redlining, foreclosure rates after the Great Recession, and current self-reported health in Detroit, Michigan, and found that redlining helped predict self-rated mental health.[34] Others have focused on the legacy of redlining on one specific health outcome, such as asthma in California, preterm birth in New York City, and cancer stage at diagnosis in Massachusetts.[35,36] Our findings aim to contribute to this growing body of research that explores whether and where redlining human health relationships may exist and how they may vary across and within cities. For example, our work specifically aligns with prior work on cancer stage of diagnosis and historical redlining by Krieger, Wright, *et al.* (2020), who found that individuals living in historically redlined neighborhoods, regardless of relative racial or socioeconomic privilege, were more likely to be diagnosed with cancer at a later stage, and thus, would therefore likely lead to an overall lower prevalence in those places. The associations we find today between health and redlining suggest that policies such as the Community Reinvestment Act, which have promised billions of dollars to improve the well-being of disadvantaged communities around the United States, may not be enough.

Our data are limited, cross-sectional snapshots, and should be interpreted with caution. For example, the CDC 500 Cities data are estimates for census tracts. Our methods for correlating HOLC maps to 2010 census tracts is just one fairly common approach, although we recognize there are other useful models.[37] As an exploratory analysis, we intended to examine potential associations and did not adjust for potential cofounders that might also explain the distribution of poor health in urban neighborhoods, including present-day poverty rates, concentrations of pollution or hazardous waste

sites, or measures of racial segregation. We recognize these are necessary next steps, since there is a rich body of environmental justice research revealing the elevated concentrations of pollution and hazardous infrastructure as well as poor health outcomes, in predominantly black and brown urban neighborhoods.[38]

Yet, understanding the legacy of redlining on communities today may also be important for moving toward a more ''critical environmental justice'' approach, where Pellow calls for more intersectional (i.e., recognizing multiple marginalities) and multiscalar research.[39] Our study suggests that there might be intergenerational traumas from historic policies such as redlining that may be contributing to both the presence of physical exposures (i.e., concentrations of hazards) but also the psychosocial stress that accompanies low socioeconomic status. Research now points to how community-level social inequalities act as stressors that adversely impact our immune systems, compromising health, and contributing to premature aging.[40] The traumas from racially discriminatory policies, such as redlining, may be a source of toxic stress that is influencing the health of communities today.

Another key takeaway from our analyses is that environmental justice and health equity research should not only be linked, but also that work must include a multiscalar historical analyses. Our preliminary study suggests that although redlining should be viewed as part of structural racism, including the legacies of slavery, Jim Crow, and explicit and implicit discrimination and segregation, *how* these historic policies and practices impact population health may be different from place to place.[41] A richly historical analyses can offer a deeper understanding into the long-term processes through which racialized environmental health inequalities came to be, and what explicit policies are needed to reverse decades of inequitable policies and provide reparations.[42,43]

There are other limitations to our analyses and findings that need further research. First our selected cities might

[33]Huggins (2017). *Op. cit*.

[34]McClure *et al.* (2018). *Op. cit*.

[35]Nardone *et al.* (2020). *Op. cit*.

[36]N. Krieger, G. Van Wye, M. Huynh, P.D. Waterman, G. Maduro, W. Li, R.C. Gwynn, O. Barbot, and M.T. Bassett (2020). *Op. cit.*

[37]Kirsten M M Beyer, Yuhong Zhou, Kevin Matthews, Amin Bemanian, Purushottam W Laud, and Ann B Nattinger. ''New Spatially Continuous Indices of Redlining and Racial Bias in Mortgage Lending: Links to Survival After Breast Cancer Diagnosis and Implications for Health Disparities Research.'' *Health Place* 40 (2016): 34–43.

[38]R. Morello-Frosch and R. Lopez. ''The Riskscape and the Color Line: Examining the Role of Segregation in Environmental Health Disparities.'' *Environmental Research* 102 (2006): 181–196.

[39]D.N. Pellow. ''Toward a Critical Environmental Justice Studies: Black Lives Matter as an Environmental Justice Challenge.'' *Du Bois Review: Social Science Research on Race* 13 (2016): 221–236.

[40]W.R. Ellis and W.H. Dietz. ''A New Framework for Addressing Adverse Childhood and Community Experiences: The Building Community Resilience Model.'' *Academic Pediatrics* 17 (2017): S86–S93.

[41]Z.D. Bailey, N. Krieger, M. Agénor, J. Graves, N. Linos, and M.T. Bassett. ''Structural Racism and Health Inequities in the USA: Evidence and Interventions.'' *Lancet* 389 (2017): 1453–1463.

[42]M. Chowkwanyun. ''The Strange Disappearance of History from Racial Health Disparities Research.'' *Du Bois Review: Social Science Research on Race* 8 (2011): 253–270.

[43]K. Wailoo. *Dying in the City of the Blues: Sickle Cell Anemia and the Politics of Race and Health*. (University of North Carolina Press, 2001).

be a biased sample, but we selected these to achieve a diversity of population sizes and geographic locations. Although there are a large number of census tracts included, our results may not reflect greater trends across the entire country or regions not yet assessed. Another limitation of our analysis is that the variance of prevalence estimates provided by the 500 Cities data set can be wide. Our use of the prevalence point estimates, therefore, do not reflect this variance and may overestimate the relationships identified.

CONCLUSION

Addressing the root causes of urban health inequities in the United States remains a critical challenge for environmental health and justice. Racial residential segregation remains a fundamental cause of health inequities and redlining should be understood as a practice that left a physical and social imprint on urban health for generations. This study has attempted to explore one method for estimating the population health impacts today from historic redlining. Clearly, more research needs to be done, but our analyses should stimulate interest from urban health scholars and practitioners about how best to measure the health impacts today from historic urban policies. This exploratory analysis suggests that redlining may have left an indelible imprint on the health of some urban neighborhoods today, and more must be done to understand and reverse this inequitable legacy.

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