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ORIGINAL RESEARCH

Social Determinants of Cardiovascular Health: A Longitudinal Analysis of Cardiovascular Disease Mortality in US Counties From 2009 to 2018

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BACKGROUND: Disparities in cardiovascular disease (CVD) outcomes persist across the United States. Social determinants of health play an important role in driving these disparities. The current study aims to identify the most important social determinants associated with CVD mortality over time in US counties.

METHODS AND RESULTS: The authors used the Agency for Healthcare Research and Quality's database on social determinants of health and linked it with CVD mortality data at the county level from 2009 to 2018. The age-standardized CVD mortality rate was measured as the number of deaths per 100 000 people. Penalized generalized estimating equations were used to select social determinants associated with county-level CVD mortality. The analytic sample included 3142 counties. The penalized generalized estimating equation identified 17 key social determinants of health including rural–urban status, county's racial composition, income, food, and housing status. Over the 10-year period, CVD mortality declined at an annual rate of 1.08 (95% CI, 0.74–1.42) deaths per 100 000 people. Rural counties and counties with a higher percentage of Black residents had a consistently higher CVD mortality rate than urban counties and counties with a lower percentage of Black residents. The rural–urban CVD mortality gap did not change significantly over the past decade, whereas the association between the percentage of Black residents and CVD mortality showed a significant diminishing trend over time.

CONCLUSIONS: County-level CVD mortality declined from 2009 through 2018. However, rural counties and counties with a higher percentage of Black residents continued to experience higher CVD mortality. Median income, food, and housing status consistently predicted higher CVD mortality.

Key Words: cardiovascular disease mortality ■ longitudinal data analysis ■ racial disparities ■ rural–urban disparities ■ social determinants of health

Racial, ethnic, and regional disparities in cardiovascular disease (CVD) outcomes persist across the United States.[1,2] In 2017, 11.5% of non-Hispanic White adults, 9.5% of non-Hispanic Black adults, 7.4% of Hispanic adults, and 6.0% of non-Hispanic Asian adults had heart disease, with non-Hispanic White adults experiencing a downward trend in heart disease during the 2010s.[3] Moreover, non-Hispanic Black adults were more than twice as likely as non-Hispanic Asian and Pacific Islander adults to die of heart disease.[3] Additionally, rural residents experienced higher CVD death rates than urban residents, and Black adults in rural or segregated areas maintained higher CVD mortality than their White counterparts.[4,5]

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CLINICAL PERSPECTIVE

What Is New?

- We used the Agency for Healthcare Research and Quality's database on social determinants of health, with social determinants of health indicators measured from 2009 to 2018 at the county level, to examine their important role in determining racial, ethnic, and regional disparities.
- Penalized generalized estimating equations were used to identify important social determinants of health associated with cardiovascular disease (CVD) mortality in the United States.
- The study found that despite county-level CVD mortality rates declining in the past decade, rural counties and counties with a higher percentage of Black residents continued to experience higher CVD mortality.

What Are the Clinical Implications?

- Decline in CVD mortality was not uniform across different geographic regions and racial and ethnic groups.
- Community deprivation, food insecurity, and housing instability consistently predicted higher CVD mortality and drove rural–urban, racial, and ethnic disparities in CVD mortality.

Nonstandard Abbreviations and Acronyms

AHRQ	Agency for Healthcare Research and Quality
FIPS	Federal Information Processing Standards
GEE	generalized estimating equation
MEDPAR	Centers for Medicare & Medicaid Services' Medicare Provider Analysis and Review
NCHS	National Center for Health Statistics
SNAP	Supplemental Nutrition Assistance Program
SDOH	social determinants of health

Social determinants of health (SDOH) play an important role in driving racial, ethnic, and regional disparities.[6] The leading SDOH-based disparities include a complex interplay of multiple domains at various levels, including but not limited to socioeconomic status, structural racism, and neighborhood environment.[7] Moreover, health care systems have become increasingly interested in understanding the role of SDOH in disease onset, progression, and outcomes.[8] In primary care settings, integrated, value-based care models are gradually reshaping how health care is delivered and financed to improve quality of care.[9,10] Addressing unmet social needs (such as food insecurity, housing instability, lack of public transportation, and poverty) is increasingly being recognized as a critical way of improving cardiovascular health among populations experiencing health disparities.[3,11,12]

While it is understood that SDOH may drive disparities in CVD outcomes in many ways, a nuanced understanding of which SDOH indicators may be more important in determining CVD mortality over time is needed to identify promising approaches to address disparities in CVD outcomes. The current study used a novel variable selection approach designed for high-dimensional longitudinal data to identify key social determinants associated with CVD mortality at the US-county level.

METHODS

Data Sources

We used data from the 2009 to 2018 SDOH database from the Agency for Healthcare Research and Quality (AHRQ).[13] AHRQ compiled and released the SDOH database in 2020 to better understand the relationship between community-level factors, health care quality and delivery, and individual health to then address emerging health issues. The SDOH database is publicly available and includes data from existing federal data sets and other public data sources spanning multiple years.[13] Variables in the data set are organized into 5 SDOH domains: (1) social context, such as age, race and ethnicity, and veteran status; (2) economic context, such as income and unemployment; (3) education; (4) physical infrastructure, such as housing, food insecurity, and transportation; and (5) health care context, such as health insurance coverage and health care access.[13] Mortality data were obtained from the Interactive Atlas of Heart Disease and Stroke at the Centers for Disease Control and Prevention (CDC),[14] which were originally compiled from 2 data sources: (1) the National Vital Statistics System at the National Center for Health Statistics, and (2) the hospital discharge data from the Centers for Medicare & Medicaid Services' Medicare Provider Analysis and Review (MEDPAR) file.[14] We linked the SDOH data with corresponding mortality data at the county level. All data and materials used in this analysis are publicly available at the AHRQ website https://www.ahrq.gov/sdoh/index.html and CDC website https://www.cdc.gov/dhdsp/maps/atlas/index.htm. The AHRQ SDOH database is HIPAA (Health Insurance Portability and Accountability Act) compliant, and therefore review by an institutional review board is not required.

SDOH Variables

The SDOH data contained a total of 345 variables. We selected variables to be included in the analytic sample based on the following inclusion and exclusion criteria. First, variables that were measured repeatedly for 10 years were included. Second, variables with >60% missing values were excluded. Third, variables that had the same or similar definitions (eg, percentage of residents who were native-born and percentage of residents who were foreign-born) as the ones included in the model were dropped. As a result, 78 variables were included in the analytic sample.

Discrepancies in the number of counties during the 10-year period were attributable to changes in county Federal Information Processing Standards (FIPS) codes in certain years. We treated these observations as follows and described these changes in Table S1.[15] Bedford city, Virginia (FIPS code: 51515) was merged with Bedford County, Virginia (FIPS code: 51019) in 2013. We excluded both observations since there were not enough data available when we linked them with the SDOH indicators. Wade-Hampton Census Area, Alaska (FIPS code: 02270) and Shannon County, South Dakota (FIPS code: 46113) were renamed Kusilvak, Alaska (FIPS code: 02158), and Oglala Lakota County, South Dakota (FIPS code: 46102), respectively.

The rural–urban status of a county was defined according to the Urban–Rural Classification Scheme for Counties used by the National Center for Health Statistics (NCHS) in 2013.[16] County urbanization levels were defined by 6 categories: (1) large central metro; (2) large fringe metro; (3) medium metro; (4) small metro; (5) micropolitan; and (6) noncore.[16] Counties in categories 1 through 4 were classified as urban, and counties in categories 5 and 6 were classified as rural.

The racial and ethnic composition of a county was measured by the percentage of population reporting Black race, percentage of population reporting Hispanic ethnicity, percentage of population reporting Asian race, and percentage of population reporting White race in a county, originally obtained from the American Community Survey.[17]

Outcomes

The age-standardized mortality rate was measured as the number of deaths per 100 000 people, adjusted for differences in the age distribution of the population. Mortality attributable to CVD was identified using the *International Classification of Diseases, Tenth Revision (ICD-10)*, codes (I00-I78).[14,18]

Statistical Analysis

Maps were used to visualize changes in CVD mortality rate and associated geographic and racial disparities at the county level between 2009 and 2018. The overall median CVD mortality rate (239.5; interquartile range [IQR], 208.3–277.0) was used as the bivariate threshold, and a 30% cutoff value was used to define the racial composition of each county, measured by the percentage of Black residents.[19] In 2018, the number of counties with a higher CVD mortality (>239.5) was smaller than those in 2009 in both rural and urban counties, regardless of the racial composition of the county. Trends in mean CVD mortality in rural versus urban counties, as well as trends in counties with ≥30% Black residents versus counties with <30% Black residents, were plotted to visualize changes in CVD mortality over 10 years.

Penalized generalized estimating equations (GEEs) were used to simultaneously select key social determinants associated with county-level CVD mortality. Descriptive analysis was used to describe characteristics of those selected SDOH between rural and urban counties. In our study, the large number of SDOH indicators presented a challenge in model fitting and interpretation. Therefore, with a large number of predictors, we preferred to select the variables with the strongest associations with CVD mortality among the 345 candidate SDOH indicators. Penalized GEEs were used for variable selection given that our data set was longitudinal and we had a large number of potential covariates.[20] GEEs were then used to fit the linear regression model for CVD mortality and estimate coefficients. First-order autoregressive correlation structure was used in this model. We also tested interaction terms to account for certain nonlinear associations between the variables. In particular, we tested the changes in CVD mortality between rural and urban counties and between those with a high/low percentage of racial minorities over time; we also considered and tested the interactions between rural–urban status and median household income as well as rural–urban status and food insecurity. We also tested multicollinearity with the variables selected from the penalized GEE analysis and identified a final set of variables. We used the variance inflation factor to measure the multicollinearity among variables and excluded those variables with a variance inflation factor >10.

A 2-tailed $P<0.05$ was considered statistically significant. Data management and analysis were performed with R version 4.1.2 (R Foundation for Statistical Computing), SAS version 9.4 (SAS Institute Inc), and ArcGIS Pro version 2.9.0 (Esri Inc).

RESULTS

The analytic sample included 3142 counties, of which 1166 were urban and 1976 were rural. Figure 1 shows the geographic distribution of age-standardized CVD mortality per 100 000 people by race and rural–urban status of US counties in 2009 and 2018. A slight decline

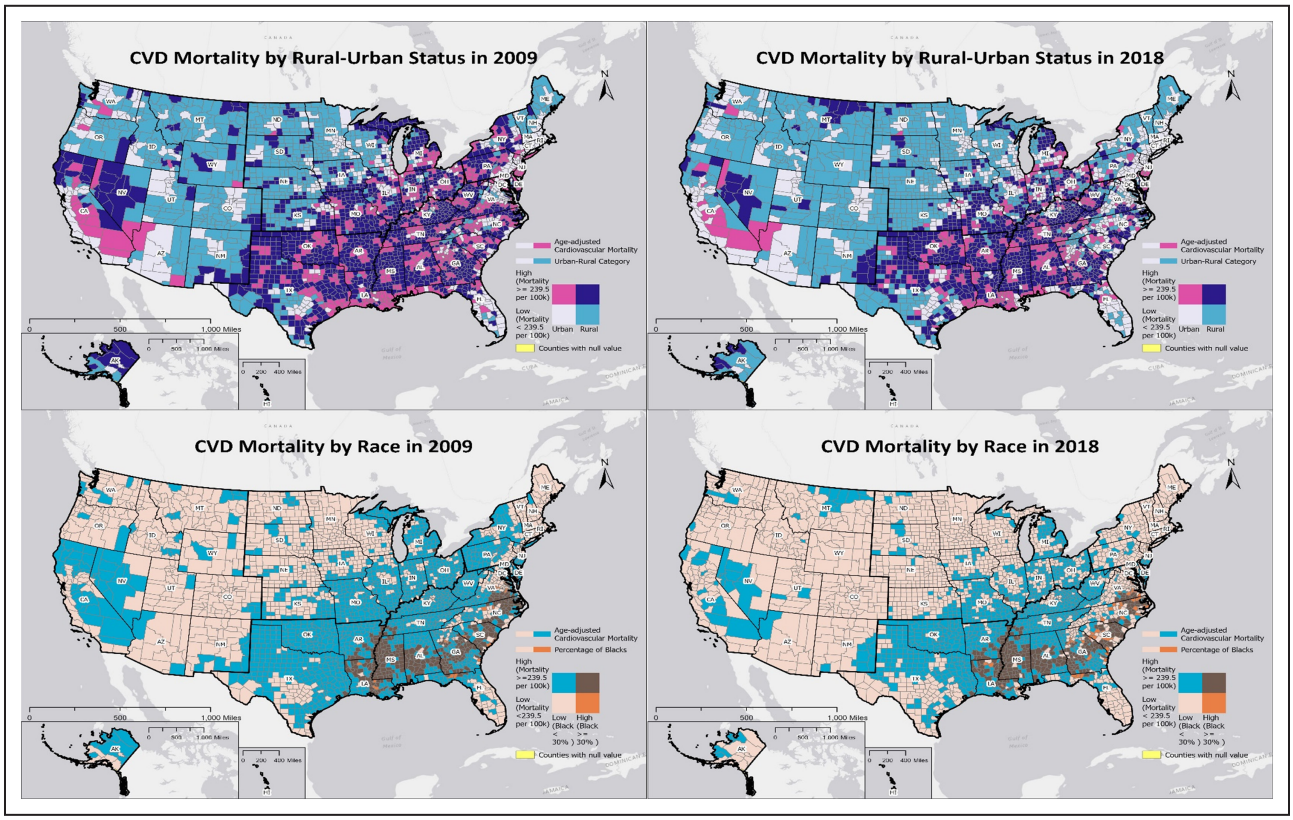

Figure 1. Geographic distribution of age-adjusted CVD mortality across counties in the United States, 2009 versus 2018. CVD indicates cardiovascular disease.

was observed in the South and the Northeast of the United States. In the West, CVD mortality decreased among a number of counties in California and Nevada. In addition, in Alaska and the East North Central states of the Midwest region, a reduction in CVD mortality was observed. The number of high CVD mortality counties in 2009 and 2018 is shown in Table S2.

Figure 2 presents the trends in mean CVD mortality by rural–urban status and racial composition of US counties from 2009 to 2018 (mean and median over time are shown in Table S3). Overall, a downward trend in CVD mortality across counties from 2009 to 2018 was observed. However, CVD mortality was persistently higher in rural counties than urban counties and in counties with >30% of Black residents than in counties with <30% of Black residents. There appeared to be no significant change in CVD mortality gaps between rural and urban counties and counties with a high (≥30%) versus low (<30%) percentage of Black residents over the past decade.

Table 1 describes the selected SDOH variables associated with CVD mortality. Within the social context domain, selected variables include the percentage of families with children that are single-parent families; percentage of the population reporting Black race, Hispanic ethnicity, and White race; percentage of population who are US nationals (born in the United States, Puerto Rico, or US Virgin Islands); and percentage of population who were foreign-born. In the economic context domain, county's rural–urban status, median household income in the past 12 months (in $1000 US; inflation-adjusted to file data year, 2009–2018), percentage of households that received food stamps/Supplemental Nutrition Assistance Program (SNAP) in the past 12 months, percentage of unmarried partner households that received food stamps/SNAP benefits, and percentage of population with income to poverty ratio: "<1.00" or "≥2.00" were selected. In the education context domain, the percentage of population with only a high school diploma (aged ≥25 years) was selected. In the physical infrastructure context domain, percentages of housing units that are mobile homes, vacant housing units, renter-occupied housing units with children, and workers aged ≥16 and older with at least a 60-minute commute time by public transportation were selected. In the health care context domain, the ratio of the number of Medicare Advantage enrollees over the number of original Medicare-eligible people[21] and the number of people living with diagnosed HIV per 1000 people were selected. After testing for multicollinearity from the regression model, variables measuring the population

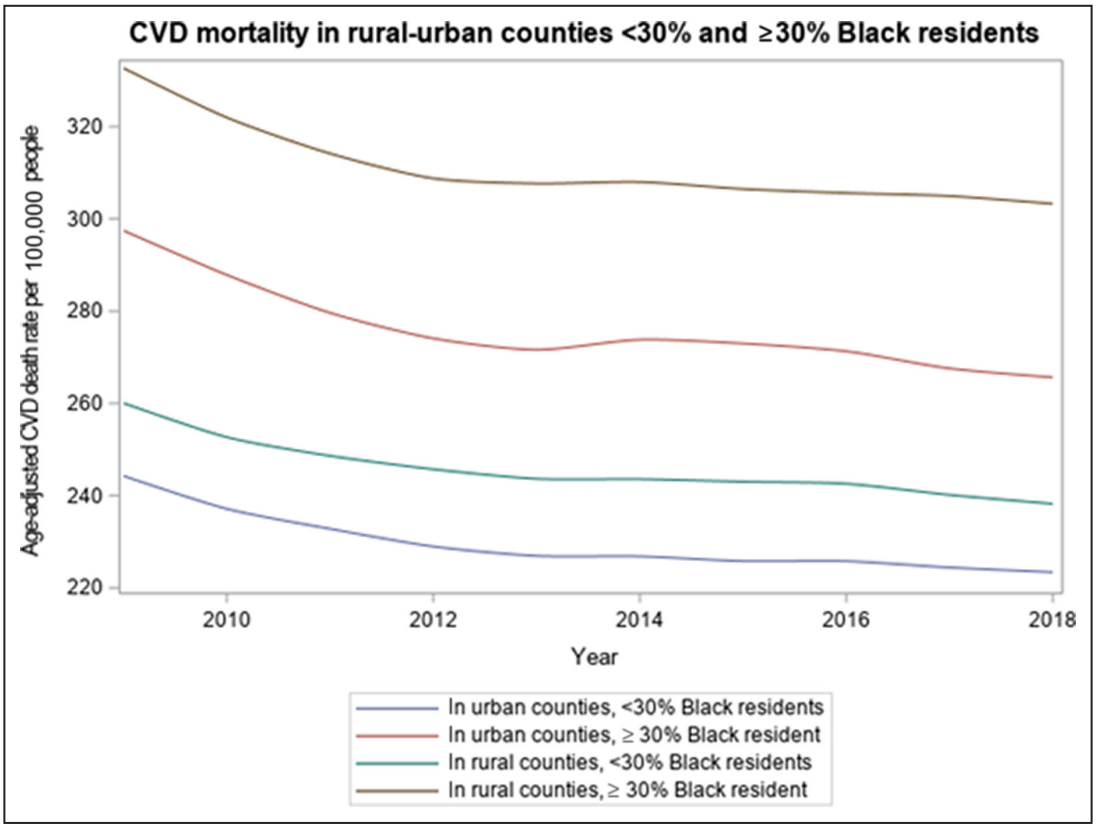

Figure 2. Trend in age-adjusted adjusted CVD mortality disparities by geographic and racial group over 2009 to 2018. CVD indicates cardiovascular disease.

of US nationals (percentage of population consisting of US citizens born in the United States, Puerto Rico, or US Virgin Islands) and the poverty rate (percentage of population with income to poverty ratio: <1.00 or ≥2.00) in the county were dropped.

Table 2 presents the medians of the selected SDOH variables between rural and urban counties from 2009 to 2018. The overall median household income was higher in urban counties ($50.18; IQR, 42.59–59.23) than that in rural counties ($41.79; IQR, 36.34–48.03). The percentage of Black residents in a county was about 5 times higher in urban counties (5.39; IQR, 1.54–14.34) compared with that in rural counties (1.11; IQR, 0.39–5.60). Similarly, the percentage of people living with diagnosed HIV was ≈10 times higher in urban counties (0.10; IQR, 0.03–0.32) than in rural counties (0.01; IQR, 0.00–0.03). Furthermore, the percentages of unmarried partner households on food stamps/SNAP, households on food stamps/SNAP, single-parent families with children, and renter-occupied housing units with children were similar between rural and urban counties during the 10-year study period.

We fitted GEE adjusting for the county-level SDOH variables with the findings shown in Table 3. From 2009 to 2018, CVD mortality was declining (β=–1.08 [95% CI, –1.42 to –0.74], *P*<0.0001). The CVD mortality in rural counties compared with urban counties remained persistently higher (β=4.26 [95% CI, 0–8.51], *P*=0.0498). Although the percentage of Black residents was positively associated with CVD mortality (β=1.11 [95% CI, 0.81–1.41], *P*<0.0001), the inverse associations between the percentage of Hispanic and White populations and CVD mortality were not significant. Moreover, CVD mortality was negatively associated with SDOH such as the median household income (β=–0.64 [95% CI, –0.78 to –0.49], *P*<0.0001), and percentage of unmarried partner households on food stamps/SNAP (β=–0.28 [95% CI, –0.38 to –0.18], *P*<0.0001), being foreign-born (β=–1.19 [95% CI, –1.55 to –0.82], *P*<0.0001), having a vacant housing unit (β=–0.70 [95% CI, –0.90 to –0.51], *P*<0.0001), and the ratio of Medicare coverage among the Medicare-eligible population (β=–0.18 [95% CI, –0.26 to –0.10], *P*<0.0001). In contrast, counties with a higher proportion of households on food stamps/SNAP (β=0.51 [95% CI, 0.17–0.86], *P*=0.0032), residents having only a high school diploma (β=1.43 [95% CI, 1.21–1.65], *P*<0.0001), residents living in mobile homes (β=0.83 [95% CI, 0.59–1.08], *P*<0.0001), residents living in renter-occupied housing units with children (β=0.18 [95% CI, 0.06–0.30], *P*=0.0039), and people living with diagnosed HIV (β=0.88 [95% CI, 0.45–1.25], *P*<0.0001)

Table 1. Selected Variables From the Agency for Healthcare Research and Quality's Social Determinants of Health Database Using Penalized GEEs

Domains	Selected variables
Identifier	Year
Geography	Urban–Rural Classification Scheme from NCHS 2013
Social context	Families with children that are single-parent families, %
	Population reporting Black race, %
	Population reporting Hispanic ethnicity, %
	Population reporting White race, %
	Population consisting of US citizens born in United States, Puerto Rico, or US Islands, %
	Population that is foreign-born, %
Economic context	Median household income in the past 12 months (in $1000 US, inflation-adjusted to file data year, 2009–2018)
	Households that received food stamps/SNAP, past 12 mo, %
	Unmarried partner households that received food stamps/SNAP benefits, %
	Population with income to poverty ratio: <1.00, %
	Population with income to poverty ratio: ≥2.00, %
Education context	Population with only high school diploma (aged ≥25 y), %
Physical infrastructure context	Housing units that are mobile homes, %
	Housing units vacant, %
	Renter-occupied housing units with children, %
	Workers aged ≥16 y with at least 60-min commute time by public transportation, %
Health care context	Medicare, derived field that equals the ratio of enrollees over Medicare-eligible × 100
	Number of people living with diagnosed HIV, per 1000 people

GEEs indicates generalized estimating equations; NCHS 2013, National Center for Health Statistics in 2013; and SNAP, Supplemental Nutrition Assistance Program.

were more likely to have a higher CVD mortality as compared with their counterparts, respectively.

After selecting the key SDOH indicators, we included all of the possible interaction terms to account for potential nonlinear associations between the variables. Most variables in the model were not significantly modified by other SDOH indicators (Table S4). We presented the GEE model that included interactions with rural–urban status and racial composition of a county in Table 4. The changes in CVD mortality between rural and urban counties were not significantly different (β=−0.19 [95% CI, −0.83 to 0.44], *P*=0.5541). Although the annual change in CVD mortality among counties with a high percentage of White residents was not significant (β=−0.02 [95% CI, −0.04 to 0.01], *P*=0.2238), the change in counties with a high percentage of Black residents was significantly decreased over time (β=−0.05 [95% CI, −0.08 to −0.02], *P*=0.0029). β for the interaction term between median household income and rural–urban status of a county was −0.36 (95% CI, −0.65 to −0.06; *P*=0.0177). In contrast, although the percentage of households who received food stamps/SNAP among those unmarried partner households significantly reduced CVD mortality in a county, the protective effect was larger in urban than in rural counties (β for the interaction term between the percentage of households on food stamps/SNAP and rural–urban status of a county (0.27 [95% CI, 0.10–0.44], *P*=0.0015)).

DISCUSSION

The CVD mortality rate declined in the United States from 2009 to 2018, and this decline was not uniform across different geographic regions and populations. Specifically, the CVD mortality rate was higher but declined faster in counties with a higher percentage of Black residents. While rural counties continued to experience a higher CVD mortality rate, changes in the rural–urban CVD mortality gap were not statistically significant over the past decade. Moreover, SDOH indicators such as education, food insecurity, housing instability, health insurance, and income were consistently associated with county-level CVD mortality. CVD mortality was significantly lower in counties with a higher median household income, and in counties with higher percentages of foreign-born residents, people having a vacant housing unit, and people with Medicare coverage who are Medicare eligible. CVD mortality was significantly higher in counties with a higher proportion of households on food stamps/SNAP, residents having only a high school diploma, residents living in mobile homes, residents living in renter-occupied housing units with children, and people living with diagnosed HIV. The association

Table 2. Medians of Selected Social Determinants of Health From Penalized GEEs by Rural–Urban Counties, 2009–2018

Area	Variable	Median (IQR) of selected social determinants of health, 2009–2018										
		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total
Urban	Median household income, in $1000 US, inflation-adjusted	47.00 (40.55–55.46)	47.8 (41.16–55.91)	48.89 (41.77–57.15)	49.20 (42.10–57.66)	49.37 (41.99–57.58)	49.8 (42.29–58.42)	50.25 (42.37–58.80)	51.41 (43.72–60.39)	53.42 (45.38–62.59)	55.27 (46.92–64.99)	50.18 (42.59–59.23)
	Black race, %	5.14 (1.49–14.15)	5.06 (1.40–14.25)	5.20 (1.50–14.20)	5.23 (1.45–14.37)	5.26 (1.52–14.31)	5.34 (1.55–14.33)	5.53 (1.56–14.40)	5.56 (1.58–14.38)	5.66 (1.66–14.47)	5.69 (1.73–14.65)	5.39 (1.54–14.34)
	Hispanic ethnicity, %	3.91 (1.88–11.27)	4.44 (2.18–11.71)	4.64 (2.29–12.05)	4.81 (2.33–12.29)	4.97 (2.47–12.65)	5.12 (2.58–12.99)	5.27 (2.68–13.18)	5.35 (2.75–13.33)	5.52 (2.84–13.46)	5.67 (2.93–13.66)	5.03 (2.51–12.68)
	White race, %	85.82 (73.52–93.00)	85.22 (73.04–93.00)	85.36 (73.20–92.94)	85.54 (72.77–93.02)	85.10 (72.64–92.80)	84.62 (72.53–92.59)	84.62 (72.07–92.39)	83.86 (72.09–92.26)	83.52 (71.73–92.08)	83.31 (71.31–91.84)	84.76 (72.54–92.59)
	Unmarried partner households, received food stamps/SNAP	25.04 (18.29–32.87)	27.03 (19.79–34.29)	29.47 (21.75–36.29)	31.59 (24.36–38.68)	33.38 (26.38–41.06)	34.27 (26.97–41.52)	34.39 (27.38–41.22)	33.44 (26.49–40.74)	32.47 (25.44–39.90)	30.91 (24.36–38.43)	31.35 (23.73–38.79)
	Households, received food stamps/SNAP	9.42 (6.46–13.08)	10.17 (7.15–13.99)	11.16 (8.01–15.02)	12.31 (9.02–16.36)	13.21 (9.73–17.53)	13.68 (10.13–17.98)	13.85 (10.11–18.02)	13.64 (9.98–17.92)	13.19 (9.60–17.10)	12.63 (9.12–16.57)	12.29 (8.74–16.57)
	Foreign-born, %	4.37 (2.24–8.12)	4.58 (2.30–8.60)	4.69 (2.37–8.68)	4.84 (2.41–8.75)	4.92 (2.46–8.81)	4.98 (2.60–9.01)	4.99 (2.63–9.01)	4.93 (2.62–9.08)	4.93 (2.59–9.17)	5.01 (2.66–9.20)	4.80 (2.48–8.87)
	Only high school diploma, aged 25 y, %	32.8 (27.66–37.90)	32.60 (27.37–37.66)	32.38 (27.10–37.22)	31.87 (26.99–36.86)	31.84 (26.91–36.98)	31.61 (26.88–36.89)	31.55 (26.65–36.58)	31.4 (26.46–36.47)	31.3 (26.06–36.13)	31.03 (25.97–36.35)	31.79 (26.82–36.94)
	Housing units: mobile homes, %	7.20 (2.93–15.00)	6.79 (2.89–14.57)	6.66 (2.77–14.63)	6.57 (2.74–14.52)	6.42 (2.74–14.21)	6.37 (2.61–14.04)	6.32 (2.60–13.99)	6.33 (2.59–13.86)	6.13 (2.52–13.48)	6.3 (2.46–13.58)	6.49 (2.70–14.19)
	Housing units: vacant, %	10.60 (7.88–14.41)	10.80 (8.10–14.85)	11.11 (8.29–15.26)	11.18 (8.30–15.13)	11.19 (8.34–15.36)	11.41 (8.29–15.73)	11.33 (8.16–15.73)	11.36 (8.10–15.8)	11.51 (8.05–16.32)	11.5 (7.99–16.71)	11.15 (8.15–15.54)
	Single-parent families with children, %	27.75 (22.29–33.69)	28.25 (22.70–34.62)	28.73 (22.95–34.75)	29.34 (23.45–35.40)	29.87 (24.11–36.41)	30.35 (24.52–36.71)	30.5 (24.61–36.81)	30.27 (24.42–36.71)	29.84 (23.75–36.29)	29.77 (23.72–36.14)	29.39 (23.63–35.79)
	Renter-occupied housing units with children, %	36.19 (30.84–42.57)	36.36 (31.16–42.21)	36.33 (31.34–42.19)	36.72 (31.46–41.77)	36.88 (31.54–42.10)	36.45 (31.39–42.21)	36.16 (31.36–41.41)	35.97 (30.88–41.13)	35.68 (30.69–40.73)	35.12 (29.89–40.15)	36.13 (31.02–41.53)
	People living with diagnosed HIV, per 1000 people	0.09 (0.03–0.29)	0.09 (0.03–0.27)	0.09 (0.03–0.30)	0.09 (0.03–0.29)	0.10 (0.03–0.30)	0.1 (0.03–0.31)	0.11 (0.03–0.34)	0.11 (0.03–0.36)	0.12 (0.03–0.37)	0.12 (0.04–0.37)	0.10 (0.03–0.32)
	Public transportation, at least 60-min commute time, aged ≥16 y	22.49 (6.87–39.32)	23.78 (7.07–40.74)	23.53 (7.72–41.86)	23.47 (7.39–42.11)	25.72 (7.90–43.65)	25.6 (8.29–42.79)	26.13 (8.16–42.86)	27.08 (8.44–43.24)	27.27 (8.57–45.92)	26.44 (7.60–45.46)	25.00 (7.70–42.86)
	Medicare, ratio of enrollees over Medicare eligible, %	18.11 (11.31–30.33)	19.46 (11.99–32.41)	19.97 (12.11–33.23)	21.14 (13.33–34.65)	23.55 (15.08–36.86)	26.11 (16.64–38.23)	27.84 (18.11–39.63)	28.76 (18.77–39.97)	30.18 (20.39–42.06)	31.24 (21.24–42.46)	24.80 (15.31–37.80)

(*Continued*)

Table 2. Continued

Area	Variable	Median (IQR) of selected social determinants of health, 2009–2018										
		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total
Rural	Median household income, in $1000 US, inflation-adjusted	38.85 (34.01–43.65)	39.79 (34.95–44.55)	40.77 (35.63–45.76)	41.07 (35.73–46.41)	41.46 (36.05–47.09)	41.85 (36.47–48.00)	42.17 (36.58–48.52)	43.27 (37.35–49.75)	44.89 (38.74–51.42)	46.49 (40.11–53.01)	41.79 (36.34–48.03)
	Black race, %	1.00 (0.25–5.61)	1.01 (0.26–5.83)	1.07 (0.37–5.55)	1.03 (0.37–5.50)	1.05 (0.39–5.57)	1.09 (0.42–5.73)	1.18 (0.44–5.62)	1.22 (0.43–5.51)	1.24 (0.46–5.45)	1.25 (0.50–5.54)	1.11 (0.39–5.60)
	Hispanic ethnicity, %	2.21 (1.10–6.10)	2.42 (1.22–6.35)	2.54 (1.31–6.86)	2.63 (1.33–7.10)	2.75 (1.45–7.39)	2.86 (1.52–7.62)	3.02 (1.60–7.81)	3.11 (1.70–7.94)	3.25 (1.77–8.14)	3.34 (1.83–8.45)	2.83 (1.46–7.39)
	White race, %	92.95 (79.41–96.62)	92.96 (80.45–96.64)	92.90 (81.1–96.66)	93.08 (81.33–96.62)	92.93 (81.34–96.52)	92.73 (81.46–96.36)	92.56 (81.25–96.21)	92.51 (81.18–96.13)	92.22 (81.14–95.97)	92.20 (80.99–95.85)	92.67 (80.95–96.36)
	Unmarried partner households, received food stamps/SNAP	28.71 (20.41–36.79)	30.00 (22.02–38.41)	31.86 (23.97–40.49)	34.53 (25.93–42.73)	35.94 (27.27–44.14)	36.74 (28.09–44.74)	36.17 (27.87–44.66)	36.04 (27.48–43.80)	34.58 (25.91–42.87)	33.26 (25.41–41.79)	33.80 (25.22–42.26)
	Households, received food stamps/SNAP	10.83 (7.50–15.25)	11.52 (7.90–15.81)	12.32 (8.53–17.06)	13.48 (9.35–18.32)	14.43 (9.96–19.26)	14.74 (10.40–19.75)	14.76 (10.26–19.86)	14.36 (10.24–19.59)	14.16 (9.93–18.95)	13.70 (9.41–18.51)	13.44 (9.15–18.29)
	Foreign-born, %	2.17 (1.26–4.26)	2.24 (1.26–4.44)	2.32 (1.34–4.58)	2.33 (1.35–4.59)	2.35 (1.36–4.62)	2.39 (1.38–4.66)	2.43 (1.43–4.72)	2.50 (1.47–4.68)	2.55 (1.51–4.81)	2.57 (1.49–4.81)	2.37 (1.38–4.64)
	Only high school diploma, aged ≥25 y, %	37.59 (33.62–41.53)	37.39 (33.24–41.53)	37.02 (33.02–41.14)	36.88 (32.56–40.73)	36.72 (32.42–40.78)	36.49 (32.60–40.78)	36.58 (32.71–40.88)	36.46 (32.51–40.73)	36.43 (32.27–40.66)	36.32 (32.03–40.42)	36.80 (32.70–40.93)
	Housing units: mobile homes, %	13.59 (7.88–20.26)	13.33 (7.81–20.48)	13.27 (7.66–20.61)	13.29 (7.64–20.39)	13.22 (7.57–20.39)	13.17 (7.68–20.57)	13.11 (7.42–20.40)	12.97 (7.40–20.48)	12.85 (7.34–20.37)	12.79 (7.24–20.45)	13.18 (7.56–20.44)
	Housing units: vacant, %	17.31 (12.64–24.50)	17.42 (12.81–24.77)	17.68 (13.04–25.34)	17.77 (13.14–25.20)	17.72 (13.16–25.06)	17.95 (13.38–25.46)	18.27 (13.50–25.72)	18.54 (13.81–26.00)	19.13 (14.19–26.54)	19.67 (14.59–27.15)	18.15 (13.38–25.66)
	Single-parent families with children, %	26.93 (21.78–32.73)	27.34 (21.94–33.44)	27.99 (22.43–34.10)	28.73 (22.96–34.88)	29.19 (23.29–35.46)	29.72 (23.82–35.97)	29.73 (23.75–36.06)	29.62 (23.96–36.15)	29.31 (23.36–35.65)	29.32 (23.24–35.61)	28.80 (22.98–35.14)
	Renter-occupied housing units with children, %	36.02 (29.71–41.96)	35.42 (29.62–41.57)	35.45 (29.74–41.20)	35.46 (29.69–41.06)	35.39 (30.04–40.80)	35.15 (29.53–40.39)	34.80 (29.15–40.19)	34.43 (28.83–39.90)	34.10 (28.62–39.83)	33.65 (27.88–39.26)	35.01 (29.27–40.66)
	People living with diagnosed HIV, per 1000 people	0.01 (0.00–0.02)	0.01 (0.00–0.03)	0.01 (0.00–0.03)	0.01 (0.00–0.03)	0.01 (0.00–0.03)	0.01 (0.00–0.03)	0.01 (0.00–0.03)	0.01 (0.00–0.03)	0.01 (0.00–0.03)	0.01 (0.00–0.03)	0.01 (0.00–0.03)
	Public transportation, at least 60-min commute time, aged ≥16 y	0.00 (0.00–30.64)	0.00 (0.00–33.33)	2.40 (0.00–31.25)	3.03 (0.00–29.86)	3.97 (0.00–31.25)	4.35 (0.00–32.14)	5.10 (0.00–33.33)	4.91 (0.00–34.04)	6.06 (0.00–35.62)	5.92 (0.00–35.29)	3.53 (0.00–32.94)
	Medicare, ratio of enrollees over Medicare- eligible, %	10.12 (5.92–17.13)	10.49 (6.20–18.09)	10.70 (6.02–18.43)	11.96 (6.93–19.56)	14.45 (7.79–21.89)	16.29 (8.93–24.40)	17.77 (9.73–26.01)	18.58 (10.15–26.36)	19.96 (10.77–28.13)	21.07 (10.80–29.76)	14.61 (7.66–23.42)

GEEs indicates generalized estimating equations; IQR, interquartile range; and SNAP, Supplemental Nutrition Assistance Program.

Table 3. Selected Social Determinants of Health Associated With Age-Adjusted CVD Mortality: GEEs, 2009–2018

Parameters	Estimate, β (95% CI)	*P* value
Intercept	242.54 (214.96–270.11)	<0.0001‡
Year	−1.08 (−1.42 to −0.74)	<0.0001‡
Urban	Reference	
Rural	4.26 (0–8.51)	0.0498*
Median household income, in $1000 US, inflation-adjusted	−0.64 (−0.78 to −0.49)	<0.0001‡
Black race, %	1.11 (0.81–1.41)	<0.0001‡
Hispanic ethnicity, %	−0.01 (−0.18 to 0.17)	0.925
White race, %	−0.19(−0.45 to 0.06)	0.1384
Unmarried partner households, received food stamps/SNAP, %	−0.28 (−0.38 to −0.18)	<0.0001‡
Households, received food stamps/SNAP, %	0.51 (0.17–0.86)	0.0032†
Foreign-born, %	−1.19 (−1.55 to −0.82)	<0.0001‡
Only high school diploma, aged ≥25 y, %	1.43 (1.21–1.65)	<0.0001‡
Housing units: mobile homes, %	0.83 (0.59–1.08)	<0.0001‡
Housing units: vacant, %	−0.70 (−0.90 to −0.51)	<0.0001‡
Single-parent families with children, %	−0.01 (−0.14 to 0.12)	0.8826
Renter-occupied housing units with children, %	0.18 (0.06–0.30)	0.0039†
People living with diagnosed HIV, per 1000 people	0.88 (0.45–1.25)	<0.0001‡
Public transportation, at least 60-min commute time, aged ≥16 y, %	−0.01 (−0.03 to 0.01)	0.4685
Medicare, the derived field, which is the ratio of enrollees over Medicare-eligible, %	−0.18 (−0.26 to −0.10)	<0.0001‡

CVD indicates cardiovascular disease; GEEs, generalized estimating equations; and SNAP, Supplemental Nutrition Assistance Program.
*P<0.05; †P<0.01; ‡P<0.001.

between these SDOH factors and CVD mortality, except for median household income, did not differ by counties' rural–urban status or racial composition.

The CDC reported that from 2011 to 2019, age-adjusted mortality rates for heart disease declined in half of US states and the District of Columbia, did not change in 24 states, and increased in 1 state.[22] CVD outcomes differ by geographic location, with the absolute difference in CVD mortality rates between rural areas and large metropolitan areas almost doubling between 1999 and 2017.[23] It is well known that rural–urban health disparities are multidimensional. Underlying SDOH mechanisms driving the higher CVD mortality in rural areas may include low socioeconomic status, limited access to quality health care, and increased levels of neighborhood deprivation.[24]

We observed in our study that the negative association between median household income and CVD

Table 4. Interactions of Selected Social Determinants of Health With Associated Age-Adjusted CVD Mortality: GEEs, 2009–2018

Parameters	Estimate, β (95% CI)	*P* value
Intercept	233.27 (203.72–262.83)	<0.0001‡
Year	0.88 (−1.53 to 3.29)	0.4725
Urban	Reference	
Rural	12.9 (−3.11 to 28.91)	0.1144
Year × urban	Reference	
Year × rural	−0.19 (−0.83 to 0.44)	0.5541
Median household income, in $1000 US, inflation-adjusted	−0.61 (−0.77 to −0.45)	<0.0001‡
Median household income × urban	Reference	
Median household income × rural	−0.36 (−0.65 to −0.06)	0.0177*
Black race, %	1.36 (1.03–1.69)	<0.0001‡
Black race × y	−0.05 (−0.08 to −0.02)	0.0029†
Hispanic ethnicity, %	0.01 (−0.16 to 0.19)	0.8827
White race, %	−0.08 (−0.37 to 0.21)	0.5793
White race × y	−0.02 (−0.04 to 0.01)	0.2238
Unmarried partner households, received food stamps/SNAP, %	−0.46 (−0.62 to −0.31)	<0.0001‡
Unmarried partner households, received food stamps/SNAP × urban	Reference	
Unmarried partner households, received food stamps/SNAP × rural	0.27 (0.10–0.44)	0.0015†
Households, received food stamps/SNAP, %	0.52 (0.18–0.87)	0.0032†
Foreign-born, %	−1.23 (−1.6 to −0.86)	<0.0001‡
Only high school diploma, aged ≥25 y, %	1.43 (1.21–1.66)	<0.0001‡
Housing units: mobile homes, %	0.79 (0.55–1.04)	<0.0001‡
Housing units: vacant, %	−0.66 (−0.85 to −0.46)	<0.0001‡
Single-parent families with children, %	−0.01 (−0.14 to 0.12)	0.8449
Renter-occupied housing units with children, %	0.17 (0.05–0.29)	0.0051†
People living with diagnosed HIV, per 1000 people	0.91 (0.52–1.29)	<0.0001‡
Public transportation, at least 60-min commute time, aged ≥16 y, %	−0.01 (−0.03 to 0.01)	0.4009
Medicare, ratio of enrollees over Medicare-eligible, %	−0.17 (−0.25 to −0.09)	<0.0001‡

CVD indicates cardiovascular disease; GEEs, generalized estimating equations; and SNAP, Supplemental Nutrition Assistance Program.
*P<0.05; †P<0.01; ‡P<0.001.

mortality was more pronounced in rural counties, suggesting that income or poverty plays a role in these disparities. It is suggested that lower socioeconomic status is a source of chronic stress that promotes a proinflammatory state.[25] The relationship between socioeconomic status and CVD risk has been shown to differ in urban

versus rural areas.[26] The growing income inequity within and across regions explains much of the regional disparities in CVD mortality. A study found that, in 1969, individuals in the most deprived areas had a 11% higher CVD mortality than individuals from the most affluent areas; however, between 2007 and 2011, the former group saw a 40% higher CVD mortality than the latter.[27]

Our analysis identified that households who were on SNAP and residents living in mobile homes were significantly associated with higher CVD mortality at the county level. It has also been reported in the literature that housing and food insecurity are independently associated with poor cardiovascular health outcomes.[28,29] Recent studies suggested that food insecurity and housing insecurity created chronic stress and led to many chronic conditions (eg, hypertension, diabetes, depression, and anxiety) that increased CVD risk and mortality.[28,29] Future research on CVD-related SDOH needs to collect more granular measures such as food insecurity and housing instability and target nutrition programs, food, and housing policies as potential pathways to reduce the burden of CVD.

Lack of access to high-quality care is another key driver of rural–urban disparities in CVD mortality. Rural residents face more barriers to access timely CVD diagnosis and treatment. Urban areas typically have a higher physician density. The urban density of an area affects both the amenities offered and competition from physicians in surrounding areas, which affects the quality of services that physicians can provide as a result.[30–32] In addition, patients with heart disease are more likely to get their follow-up care in places with a higher physician density.[33,34] But patients living in rural areas are more likely to live in health professional shortage areas,[32] even though the number of primary care physicians has grown in rural areas[30–32]; in fact, the rural–urban gap in access to primary care has increased over the past decade.[35] Therefore, rural patients might experience disadvantages in CVD health. This suggests the need to improve access to primary care in rural areas.[30,31] The physical environment of a neighborhood impacts CVD disparities via opportunities for maintaining a healthy lifestyle. Associations between rurality and obesity, for example, vary by degree of rurality, socioeconomic status, and geography, suggesting that a uniform approach to addressing rural–urban health disparities may be suboptimal.[30] Specifically, more developed neighborhoods offer access to mixed use land, transportation systems, recreational facilities, and walkable space, which all promote physical activity, a key driver of CVD risk reduction.[36–38] The characteristics of the built environment in neighborhoods also influence dietary patterns.[39] Food environment factors, such as fast-food restaurant density[40] and proximity to supermarkets, could affect eating behaviors and CVD risk factors through various pathways.[41]

Although we observed that CVD mortality was declining more rapidly in counties with a higher percentage of Black residents, CVD mortality was still considerably higher in these counties than those in counties with a lower percentage of Black residents. Glynn et al[42] found that age-adjusted, heart failure–related mortality rates were higher in Black patients between 1999 and 2017. Prior research found that the association between residential segregation and cardiovascular risk varied according to race.[7] For example, reduction in CVD mortality among Black adults has been shown to be associated with place-based legacies of slavery.[43] A national study found that racial differences in hypertension were significantly smaller in low- than high-segregation areas.[44] At the census-tract level, racial isolation was associated with a higher risk of CVD for both non-Hispanic White and Black Americans.[45] Further research into the relationship between racial disparities and CVD mortality is warranted.

This study has several limitations. First, we have a large number of missing values in the 10-year SDOH database. Further analysis needs to include exploring historic data sources to fill in these data gaps or applying advanced imputation approaches to account for missing values to improve model prediction. Second, our unit of analysis was the county, which prevented us from conducting causal inference analysis at the individual level. With SDOH data available at the census tract and smaller geographic levels and linked SDOH data with electronic medical records,[46,47] future studies can unfold the multilevel and sociobiological pathways between SDOH indicators and CVD health. Third, the SDOH indicators compiled by AHRQ were obtained from administrative data sources, which were not self-identified but codified by others and were subject to measurement errors. Fourth, while variable selection methods are popular in explanatory regression models because they simplify variable interpretation,[48] some of these methods are also controversial as they may lead to biased parameter estimates.[49,50]

Despite these limitations, going forward, we recommend efforts aimed at moving beyond documenting disparities to identifying pathways for improving health equity across the life course. Research needs to better elucidate the role of community and structural factors in disease onset, progression, and outcomes. Moreover, as CVD mortality continues to decline, it is increasingly important to reduce CVD-related morbidity rates, health care costs, and disparities.

CONCLUSIONS

CVD mortality rates declined in the United States, but these declines have not been uniform across different populations and rural–urban counties. CVD mortality was associated with SDOH indicators such as education, food insecurity, housing instability, health

insurance, income, race, and geographic region. Identifying social determinants that could be addressed across different geographic regions and populations could prove useful to making further improvements in reducing CVD mortality, particularly in populations and communities where CVD mortality decline has not taken place or has not been pronounced.

ARTICLE INFORMATION

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Supplemental Material

Table S1.
Table S2.
Table S3.
Table S4.

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SUPPLEMENTAL MATERIAL

Table S1. Changes in County FIPS Codes.

FIPS	Counties	Specific Details
02158	Kusilvak Census Area, Ak	Wade-Hampton Census Area, AK (FIPS: 02270) was renamed to Kusilvak Census Area in 2015.
46102	Oglala Lacota County, SD	Shannon county, SD (FIPS: 46113) was renamed to Oglala Lacota County in 2015.
51019	Bedford County, VA	Bedford city, VA (FIPS: 51515) was merged to Bedford County in 2013.

Note: FIPS denotes Federal Information Processing Standards.

Table S2. Number of Counties of Rural-Urban County /Black Majorities Status by Year for Median value of Age-adjusted CVD Mortality.

		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Urban	< Mean*	583	656	690	725	757	758	793	790	794	795
	≥ Mean†	583	510	476	441	409	408	373	376	372	371
Rural	< Mean	803	900	938	974	1024	1033	1041	1050	1089	1107
	≥ Mean	1173	1076	1038	1002	952	943	935	926	887	869
Black < 30%	< Mean	1368	1522	1588	1656	1729	1746	1780	1776	1825	1838
	≥ Mean	1451	1296	1233	1168	1092	1078	1045	1048	1001	986
Black ≥ 30%	< Mean	18	34	40	43	52	45	54	64	58	64
	≥ Mean	305	290	281	275	269	273	263	254	258	254
Urban	< Median	517	588	636	668	689	688	725	715	737	740
	≥ Median	649	578	530	498	477	478	441	451	429	426
Rural	< Median	704	794	865	884	924	940	962	968	990	994
	≥ Median	1272	1182	1111	1092	1052	1036	1014	1008	986	982
Black < 30%	< Median	1205	1360	1473	1517	1574	1587	1644	1636	1672	1682
	≥ Median	1614	1458	1348	1307	1247	1237	1181	1188	1154	1142
Black ≥ 30%	< Median	16	22	28	35	39	41	43	47	55	52
	≥ Median	307	302	293	283	282	277	274	271	261	266

* Overall mean (245.78) of Age-adjusted CVD mortality, per 100,000 people, for a decade, 2009-2018.

† Overall median (239.50) of Age-adjusted CVD mortality, per 100,000 people, for a decade, 2009-2018.

The sum of total county numbers varies across different groups due to missing values.

CVD denotes cardiovascular disease.

Table S3. Mean/Median of Different Age-adjusted CVD Mortality by Rural-Urban County /Black Majorities Status, 2009-2018.

Variable		Age-adjusted CVD Mortality per 100,000 people, mean (95% CI) and median (interquartile range, IQR) No.				
		2009	2010	2011	2012	2013
Mean	Urban, Black < 30%	244.27 (241.64, 246.91)	237.15 (234.62, 239.69)	232.82 (230.27, 235.38)	228.99 (226.43, 231.55)	226.94 (224.37, 229.52)
	Urban, Black ≥ 30%	297.47 (289.59, 305.35)	287.88 (279.86, 295.89)	279.65 (271.73, 287.57)	274.10 (266.27, 281.94)	271.65 (264.07, 279.23)
	Rural, Black < 30%	260.05 (257.64, 262.46)	252.69 (250.38, 254.99)	248.64 (246.37, 250.91)	245.74 (243.48, 248.00)	243.66 (241.38, 245.94)
	Rural, Black ≥ 30%	332.69 (326.19, 339.19)	322.00 (315.31, 328.69)	314.19 (307.33, 321.05)	308.80 (301.97, 315.62)	307.68 (300.64, 314.72)
Median	Urban, Black < 30%	241.40 (211.70, 271.90)	234.40 (206.30, 263.20)	230.60 (201.90, 259.40)	227.20 (197.20, 255.20)	224.00 (195.20, 252.50)
	Urban, Black ≥ 30%	300.55 (271.30, 326.45)	288.80 (257.70, 315.30)	280.65 (249.40, 306.30)	271.40 (246.30, 300.40)	270.75 (242.80, 298.75)
	Rural, Black < 30%	252.00 (223.80, 289.10)	245.90 (216.80, 282.40)	242.90 (212.90, 277.90)	240.90 (208.80, 275.80)	237.75 (207.85, 274.00)
	Rural, Black ≥ 30%	334.20 (306.10, 358.70)	319.60 (292.15, 347.20)	309.50 (284.80, 341.80)	304.40 (278.20, 333.90)	303.80 (279.90, 335.90)
		2014	2015	2016	2017	2018
Mean	Urban, Black < 30%	226.84 (224.22, 229.46)	225.82 (223.23, 228.42)	225.80 (223.23, 228.38)	224.43 (221.84, 227.01)	223.41 (220.86, 225.97)
	Urban, Black ≥ 30%	273.82 (265.56, 282.07)	272.99 (264.56, 281.43)	271.31 (262.96, 279.67)	267.59 (259.40, 275.78)	265.65 (257.56, 273.74)
	Rural, Black < 30%	243.59 (241.27, 245.92)	243.04 (240.69, 245.39)	242.59 (240.23, 244.94)	240.18 (237.85, 242.50)	238.24 (235.94, 240.53)
	Rural, Black ≥ 30%	308.01 (300.87, 315.14)	306.51 (299.08, 313.93)	305.62 (298.36, 312.89)	304.97 (297.92, 312.02)	303.31 (296.29, 310.32)
Median	Urban, Black < 30%	223.80 (194.70, 251.50)	223.70 (194.80, 249.40)	222.70 (195.30, 250.20)	221.20 (194.80, 250.40)	220.95 (193.85, 250.00)

Urban, Black ≥ 30%	271.40 (246.00, 299.00)	270.30 (241.40, 302.10)	268.00 (237.60, 297.80)	263.00 (233.80, 297.70)	264.70 (233.50, 294.00)
Rural, Black < 30%	236.55 (206.40, 275.80)	235.30 (205.90, 273.80)	235.40 (206.70, 273.30)	235.00 (204.60, 269.50)	232.80 (203.20, 268.30)
Rural, Black ≥ 30%	303.20 (281.40, 331.10)	303.40 (274.80, 331.40)	301.50 (274.60, 336.70)	301.80 (268.50, 333.80)	300.90 (265.75, 332.25)

Note: CVD denotes cardiovascular disease; IQR denotes interquartile range.

Table S4. Interactions of Selected Social Determinants of Health with Associated Age-Adjusted Cardiovascular Disease Mortality: Generalized Estimating Equations, 2009-2018.

Parameters	β (95% CI)	*P* value
Intercept	264.88 (222.14, 307.62)	< .0001‡
Year	-5.13 (-9.87, -0.39)	0.0338*
Year × Urban	Ref.	
Year × Rural	3.35 (-5.11, 11.81)	0.4381
Urban	Ref.	
Rural	-18.14 (-83.38, 47.10)	0.5857
Median household income, in 1,000 dollars, inflation-adjusted	-1.01 (-1.25, -0.78)	< .0001‡
Median household income × Year	0.08 (0.05, 0.10)	< .0001‡
Median household income × Urban	Ref.	
Median household income × Rural	-0.56 (-1.02, -0.09)	0.0201*
Median household income × Year × Urban	Ref.	
Median household income × Year × Rural	0.06 (0.00, 0.12)	0.0584
Black, %	1.33 (0.93, 1.73)	< .0001‡
Black × Year	-0.06 (-0.10, -0.03)	0.0007‡
Black × Urban	Ref.	
Black × Rural	0.12 (-0.55, 0.79)	0.7211
Black × Year × Urban	Ref.	
Black × Year × Rural	0.02 (-0.06, 0.09)	0.6854
Hispanic, %	-0.01 (-0.28, 0.26)	0.9366
Hispanic × Year	0.02 (-0.01, 0.04)	0.2002
Hispanic × Urban	Ref.	
Hispanic × Rural	-0.19 (-0.70, 0.31)	0.4501
Hispanic × Year × Urban	Ref.	
Hispanic × Year × Rural	0.02 (-0.06, 0.10)	0.6124
White, %	-0.16 (-0.51, 0.20)	0.3803

White × Year	-0.02 (-0.05, 0.01)	0.1885
White × Urban	Ref.	
White × Rural	0.38 (-0.21, 0.97)	0.2067
White × Year × Urban	Ref.	
White × Year × Rural	-0.04 (-0.11, 0.04)	0.3325
Unmarried partner households, received food stamps/SNAP	-0.52 (-0.85, -0.19)	0.0022‡
Unmarried partner households, received food stamps/SNAP × Year	0.06 (0.00, 0.12)	0.0338*
Unmarried partner households, received food stamps/SNAP × Urban	Ref.	
Unmarried partner households, received food stamps/SNAP × Rural	0.15 (-0.29, 0.59)	0.5157
Unmarried partner households, received food stamps/SNAP × Year × Urban	Ref.	
Unmarried partner households, received food stamps/SNAP × Year × Rural	-0.03 (-0.11, 0.05)	0.4946
Households, received food stamps/SNAP	-0.19 (-0.94, 0.56)	0.6132
Households, received food stamps/SNAP × Year	0.10 (-0.02, 0.21)	0.1079
Households, received food stamps/SNAP × Urban	Ref.	
Households, received food stamps/SNAP × Rural	0.46 (-0.69, 1.60)	0.4316
Households, received food stamps/SNAP × Year × Urban	Ref.	
Households, received food stamps/SNAP × Year × Rural	0.04 (-0.14, 0.23)	0.6521
Foreign-born, %	-0.66 (-1.18, -0.14)	0.0124*
Foreign-born × Year	-0.10 (-0.15, -0.06)	< .0001‡
Foreign-born × Urban	Ref.	
Foreign-born × Rural	-0.67 (-1.76, 0.41)	0.2225
Foreign-born × Year × Urban	Ref.	
Foreign-born × Year × Rural	0.13 (-0.04, 0.31)	0.1429
Only high school diploma, ages 25 and over, %	1.65 (1.26, 2.05)	< .0001‡
Only high school diploma × Year	-0.01 (-0.05, 0.04)	0.7903
Only high school diploma × Urban	Ref.	
Only high school diploma × Rural	-0.52 (-1.15, 012)	0.1130
Only high school diploma × Year × Urban	Ref.	
Only high school diploma × Year × Rural	0.04 (-0.05, 0.13)	0.4192

Housing units: Mobil homes, %	0.79 (0.35, 1.22)	0.0004‡
Housing units: Mobil homes × Year	0.01 (-0.04, 0.06)	0.6674
Housing units: Mobil homes × Urban	Ref.	
Housing units: Mobil homes × Rural	-0.19 (-0.76, 0.38)	0.5191
Housing units: Mobil homes × Year × Urban	Ref.	
Housing units: Mobil homes × Year × Rural	0.00 (-0.08, 0.08)	0.9701
Housing units: Vacant, %	-0.94 (-1.34, -0.54)	< .0001‡
Housing units: Vacant × Year	0.03 (0.00, 0.07)	0.0721
Housing units: Vacant × Urban	Ref.	
Housing units: Vacant × Rural	0.45 (-0.05, 0.96)	0.0772
Housing units: Vacant × Year × Urban	Ref.	
Housing units: Vacant × Year × Rural	-0.05 (-0.11, 0.01)	0.0814
Single-parent families with children, %	-0.23 (-0.53, 0.07)	0.1382
Single-parent families with children × Year	0.02 (-0.03, 0.07)	0.5005
Single-parent families with children × Urban	Ref.	
Single-parent families with children × Rural	0.38 (-0.08, 0.85)	0.1084
Single-parent families with children × Year × Urban	Ref.	
Single-parent families with children × Year × Rural	-0.04 (-0.12, 0.04)	0.2955
renter-occupied housing units with children, %	0.34 (0.09, 0.58)	0.0076†
renter-occupied housing units with children × Year	-0.04 (-0.07, 0.00)	0.0361*
renter-occupied housing units with children × Urban	Ref.	
renter-occupied housing units with children × Rural	0.30 (-0.09, 0.69)	0.1262
renter-occupied housing units with children × Year × Urban	Ref.	
renter-occupied housing units with children × Year × Rural	-0.06 (-0.13, 0.01)	0.0808
People living with diagnosed HIV, per 1,000 people	1.06 (0.53, 1.59)	< .0001‡
People living with diagnosed HIV × Year	-0.04 (-0.09, 0.02)	0.1761
People living with diagnosed HIV × Urban	Ref.	
People living with diagnosed HIV × Rural	6.47 (-0.84, 13.79)	0.0827
People living with diagnosed HIV × Year × Urban	Ref.	
People living with diagnosed HIV × Year × Rural	-2.81 (-8.41, 2.80)	0.3261
Public transportation, at least 60-min commute time, ages 16 and over	-0.01 (-0.06, 0.05)	0.8644

Public transportation, at least 60-min commute time × Year	0.00 (-0.01, 0.01)	0.8947
Public transportation, at least 60-min commute time × Urban	Ref.	
Public transportation, at least 60-min commute time × Rural	0.02 (-0.07, 0.10)	0.6926
Public transportation, at least 60-min commute time × Year × Urban	Ref.	
Public transportation, at least 60-min commute time × Year × Rural	0.00 (-0.02, 0.01)	0.6252
Medicare, the derived field which is ratio of enrollees over eligible, %	-0.28 (-0.39, -0.16)	< .0001‡
Medicare, ratio of enrollees over eligible × Year	0.03 (0.02, 0.04)	< .0001‡
Medicare, ratio of enrollees over eligible × Urban	Ref.	
Medicare, ratio of enrollees over eligible × Rural	-0.05 (-0.27, 0.18)	0.6765
Medicare, ratio of enrollees over eligible × Year × Urban	Ref.	
Medicare, ratio of enrollees over eligible × Year × Rural	-0.03 (-0.06, 0.00)	0.0819

Note: * $p < 0.05$; † $p < 0.01$; ‡ $p < 0.001$. SNAP denotes Supplemental Nutrition Assistance Program.