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ORIGINAL RESEARCH

Association Between Social Vulnerability Index and Cardiovascular Disease: A Behavioral Risk Factor Surveillance System Study

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BACKGROUND: Social and environmental factors play an important role in the rising health care burden of cardiovascular disease. The Centers for Disease Control and Prevention developed the Social Vulnerability Index (SVI) from US census data as a tool for public health officials to identify communities in need of support in the setting of a hazardous event. SVI (ranging from a least vulnerable score of 0 to a most vulnerable score of 1) ranks communities on 15 social factors including unemployment, minoritized groups status, and disability, and groups them under 4 broad themes: socioeconomic status, housing and transportation, minoritized groups, and household composition. We sought to assess the association of SVI with self-reported prevalent cardiovascular comorbidities and atherosclerotic cardiovascular disease (ASCVD).

METHODS AND RESULTS: We performed a retrospective cohort analysis of adults (≥18 years) in the Behavioral Risk Factor Surveillance System 2016 to 2019. Data regarding self-reported prevalent cardiovascular comorbidities (including diabetes, hypertension, hyperlipidemia, smoking, substance use), and ASCVD was captured using participants' response to a structured telephonic interview. We divided states on the basis of the tertile of SVI (first—participant lives in the least vulnerable group of states, 0–0.32; to third—participant lives in the most vulnerable group of states, 0.54–1.0). Multivariable logistic regression models adjusting for age, race and ethnicity, sex, employment, income, health care coverage, and association with federal poverty line were constructed to assess the association of SVI with cardiovascular comorbidities. Our study sample consisted of 1 745 999 participants ≥18 years of age. States in the highest (third) tertile of social vulnerability had predominantly Black and Hispanic adults, lower levels of education, lower income, higher rates of unemployment, and higher rates of prevalent comorbidities including hypertension, diabetes, chronic kidney disease, hyperlipidemia, substance use, and ASCVD. In multivariable logistic regression models, individuals living in states in the third tertile of SVI had higher odds of having hypertension (odds ratio (OR), 1.14 [95% CI, 1.11–1.17]), diabetes (OR, 1.12 [95% CI, 1.09–1.15]), hyperlipidemia (OR, 1.09 [95% CI, 1.06–1.12]), chronic kidney disease (OR, 1.17 [95% CI, 1.12–1.23]), smoking (OR, 1.05 [95% CI, 1.03–1.07]), and ASCVD (OR, 1.15 [95% CI, 1.12–1.19]), compared with those living in the first tertile of SVI.

CONCLUSIONS: SVI varies across the US states and is associated with prevalent cardiovascular comorbidities and ASCVD, independent of age, race and ethnicity, sex, employment, income, and health care coverage. SVI may be a useful assessment tool for health policy makers and health systems researchers examining multilevel influences on cardiovascular-related health behaviors and identifying communities for targeted interventions pertaining to social determinants of health.

Key Words: cardiovascular disease ■ risk factors ■ social vulnerability ■ SVI

CLINICAL PERSPECTIVE

What Is New?

- Adverse social determinants of health, including financial insecurity, poor access to health care, neighborhood deprivation, and race- and ethnicity-based discrimination, predispose marginalized communities to adverse health outcomes. We sought to assess whether the Social Vulnerability Index, a composite measure of a community's social determinants of health, is associated with cardiovascular health.
- We analyzed a nationally representative sample to evaluate the association between the Social Vulnerability Index and self-reported cardiovascular comorbidities (including diabetes, hypertension, hyperlipidemia, smoking, and substance use) and atherosclerotic cardiovascular disease.

What Are the Clinical Implications?

- We found that the Social Vulnerability Index varies across the US states and is associated with prevalent cardiovascular comorbidities and atherosclerotic cardiovascular disease, independent of age, sex, income, health care coverage, or race and ethnicity, such that higher social vulnerability was associated with worse cardiovascular health.
- The Social Vulnerability Index may be a useful assessment tool for health policy makers and health systems researchers examining multilevel influences on cardiovascular-related health behaviors and identifying communities for targeted interventions pertaining to social determinants of health.

Nonstandard Abbreviations and Acronyms

ADI	Area Deprivation Index
BRFSS	Behavioral Risk Factor Surveillance System
CDC	Centers for Disease Control and Prevention
SDOH	social determinants of health
SVI	Social Vulnerability Index
SVI-Ts	Social Vulnerability Index tertiles

Cardiovascular diseases are the leading cause of mortality and a significant contributor to disability, with a 2-fold increase in global prevalence and a 1.5-fold increase in associated mortality between 1990 and 2019.[1] In the United States, it is the cause of death of nearly 900 000 adults, and carries a health care cost burden of ≈$213 billion annually.[2] This trend

is concerning, as there have been significant therapeutic advancements in the primary and secondary prevention of cardiovascular disease. It may be reflective of a change in societal and environmental factors that impact dietary patterns and levels of physical activity. Further, there are significant disparities in access to health care across race and ethnicity and economic groups, which may impact the overall cardiovascular health of the population.[3] Adverse social circumstances, referred to as social determinants of health (SDOH), including financial insecurity, poor access to health care, neighborhood deprivation, and race- and ethnicity-based discrimination, predispose marginalized communities to adverse health outcomes.[3,4] Thus, an in-depth assessment of SDOH that influence cardiovascular health can help identify populations that may benefit the most from targeted public health interventions.

The Centers for Disease Control and Prevention (CDC) developed the Social Vulnerability Index (SVI) from US census data to help public health officials identify communities that may be at high risk for hazardous events such as disease outbreak and natural disasters. It takes into account important SDOH such as education, employment, population density, housing, and race and ethnicity composition.[5]

Although originally designed to allocate resources such as food, water, and emergency personnel to communities in the event of a natural disaster, social vulnerability has been shown to be a significant determinant of health outcomes, including cognition, disability, and overall mortality.[6,7]

Many of the components of the SVI closely associate with a population's ability to access health care resources, be adherent to the recommended therapeutic plan of action, or follow up consistently with the health care system; which may consequently affect risk of cardiovascular disease. For example, communities with lower levels of education and income may not have sufficient health care literacy or financial means for health care and a healthy and balanced diet. Therefore, it is possible that the SVI could inform not only emergency preparedness, but also efforts to impact chronic diseases such as the epidemic of cardiometabolic diseases. The present study sought to evaluate the association of SVI with cardiovascular risk factors and atherosclerotic cardiovascular disease (ASCVD) across the United States using a large, nationally representative sample.

METHODS

All data and materials used in this article have been made publicly available and can be accessed at https://www.cdc.gov/brfss/data_documentation/index.htm (Behavioral Risk Factor Surveillance System data) and

https://www.atsdr.cdc.gov/placeandhealth/svi/at-a-glance_svi.html (Social Vulnerability Index data).

The Behavioral Risk Factor Surveillance System (BRFSS) survey, established by the CDC, is a nationwide telephone-based questionnaire of a representative sample of US residents regarding health-related risk behaviors, chronic health conditions, and use of preventive services. BRFSS includes participants in all 50 states as well as the District of Columbia and 3 US territories, making it the largest telephone-based survey in the world. The BRFSS allows population level investigations on the association of behavioral risk factors with various diseases. It is a deidentified and publicly available (http://www.cdc.gov/brfss) data set, and hence exempted from the institutional review board approval. The estimates provided by the BRFSS have previously been validated against other established surveys such as the National Health and Nutrition Examination Survey and the National Health Interview Survey.[8,9]

We used self-reported data from the 2016 to 2019 BRFSS surveys. Baseline and demographic characteristics, including participant age, race and ethnicity, employment, education status, and income level, were self-reported. ASCVD status was classified on the basis of participants responding to the question, "Have you ever had coronary heart disease or myocardial infarction or stroke?" Cardiovascular comorbidities were identified on the basis of the following questions: "Have you ever been told by a doctor, nurse, or other health professional that you have high blood pressure?"; "Have you ever been told by a doctor, nurse, or other health professional that you have diabetes?"; "Have you ever been told by a doctor, nurse, or other health professional that your blood cholesterol is high?"; and "Have you ever been told by a doctor, nurse, or other health professional that you have kidney disease, excluding kidney stones, bladder infection, or incontinence?" Smoking status was ascertained by asking the participants, "Do you now smoke cigarettes every day, some days, or not at all?" Those who replied "every day" or "some days" were considered current smokers. E-cigarette status was ascertained by asking the participants, "Do you now use e-cigarettes or other vaping products every day, some days, or not at all?" Those who replied "every day" or "some days" were considered current e-cigarette users. Current marijuana use was defined as the use of marijuana or hashish for ≥1 days in the past 30 days.

We used SVI data from the CDC's Agency for Toxic Substances and Disease Registry,[10] which ranks every US census tract on 15 social attributes using the American Community Survey data and groups them into 4 related themes: socioeconomic status (below poverty, unemployed, income, and no high school diploma); household composition and disability (aged ≥65 years, aged ≤17 years, aged >5 years with a disability, and single-parent households), minoritized groups and language (minoritized groups and individuals speak English "less than well"), and housing type and transportation (multiunit structure, mobile home, crowding, no vehicle, and group quarters) (Table 1).

Based on the methodology that measures census tract rankings, the SVI files also provide county-level rankings, which can then be used to generate state-level rankings across the entire United States for the 15 individual variables and 4 themes—the overall state-level SVI. The percentile rank ranges from 0 to 1, with higher values exhibiting greater vulnerability than the lower values. For the purpose of this study, we used state-level SVI rankings to link it with the demographic and health-behavior related data for each state provided in the BRFSS; that is, while health-related data were analyzed at an individual participant level, the SVI was used as an ecological variable depending on which state the participant resided in.

We analyzed these cross-sectional data using survey weights for BRFSS provided by the CDC to account for the survey design and ensure the representativeness of the data to the US population. The distribution of health-related behavioral risk factors in groups on the basis of SVI tertiles (SVI-Ts; first—participant lives in the least vulnerable group of states, 0–0.32; to third—participant lives in the most vulnerable group of states, 0.54–1.0) was ascertained. A multivariable logistic regression model adjusting for age, race and ethnicity, sex, employment, income, health care coverage, and association with federal poverty line (all variables were collected at the individual level) was used to study the

Table 1. Summary of Themes and Underlying Social Factors That Constitute the Social Vulnerability Index[5]

Themes	Social factors
Socioeconomic status	Below poverty line
	Unemployed
	Income
	No high school diploma
Household composition and disability	Aged ≥65 y
	Aged ≤17 y
	Civilian with a disability
	Single-parent households
Minoritized groups and language	Minoritized groups
	Aged ≥5 y who speaks English "less than well"
Housing type and transportation	Multiunit structures
	Mobile homes
	Crowding
	No vehicle
	Group quarters

association of social vulnerability with the presence of cardiovascular comorbidities, including diabetes, hypertension, smoking, hyperlipidemia, substance use, and ASCVD. We further mapped the prevalence of diabetes, hypertension, and ASCVD stratified by SVI-Ts across the US states. As a prespecified exploratory analysis, we evaluated the associations of each individual component of the overall SVI with cardiovascular comorbidities, including diabetes, hypertension, smoking, hyperlipidemia, and ASCVD. To compare the SVI with other measures of SDOH, we performed secondary analyses to evaluate the association of cardiovascular comorbidities across tertiles of the Area Deprivation Index (ADI),[11] with the aim of assessing which score is a better state-wide discriminator of the study sample's SDOH. All

analyses were conducted using Stata version 16.1 (StataCorp, College Station, TX).

RESULTS

Our study sample included 1 745 999 participants aged >18 years. The baseline characteristics of the participants stratified by SVI-Ts are listed in Table 2. Compared with states in the second and first SVI-Ts, states in the third SVI-T (most vulnerable) had a higher proportion of Black (13.4% versus 11.4% versus 7.4%) and Hispanic (22.5% versus 10.8% versus 7.5%) participants, lower proportion of college-educated participants (25.7% versus 29.4% versus 30.7%), higher proportion of families with <$10 000 annual income (6.6% versus 4.6% versus 3.5%), and higher rates of unemployment (20.1% versus

Table 2. Self-Reported Baseline and Demographic Characteristics Across Tertiles of SVI

	First tertile (SVI 0.00–0.32)	Second tertile (SVI 0.33–0.53)	Third tertile (SVI 0.54–1)	*P* value
Female sex, n (%)	313 224 (51.1)	309 462 (51.4)	330 269 (51.2)	0.32
Race and ethnicity, n (%)				
White	486 925 (78.1)	424 895 (69.6)	396 913 (55.0)	<0.001
Black	23 269 (7.8)	39 966 (11.4)	74 122 (13.4)	
Hispanic	23 808 (7.5)	38 917 (10.8)	62 875 (22.5)	
Other*	29 325 (6.6)	46 298 (8.2)	39 027 (9.1)	
Age, n (%)				<0.001
18–34 y	88 867 (29.6)	90 434 (29.3)	97 220 (30.2)	
35–44 y	66 194 (15.9)	64 182 (15.9)	68 819 (16.7)	
45–54 y	86 593 (16.2)	88 222 (16.5)	88 859 (16.5)	
55–64 y	124 716 (17.3)	120 209 (17.1)	119 095 (16.1)	
≥65 y	206 641 (30.0)	199 050 (21.1)	211 083 (20.5)	
Education status, n (%)				<0.001
<High school	29 610 (9.5)	37 453 (11.6)	58 573 (15.5)	
High school–college	318 958 (59.7)	302 365 (59.1)	324 781 (58.9)	
>College	222 370 (30.7)	219 960 (29.4)	199 439 (25.7)	
Income level, n (%)				
<$10k	15 657 (3.5)	19 601 (4.6)	28 736 (6.6)	<0.01
$10–$15k	19 756 (3.6)	21 663 (4.2)	29 108 (5.6)	
$15–$20k	29 242 (5.9)	32 388 (7.0)	40 256 (8.0)	
$20–$25k	38 332 (7.2)	41 771 (8.7)	48 220 (9.9)	
$25–$35k	48 715 (9.3)	48 127 (9.8)	53 034 (10.7)	
$35–$50k	69 939 (13.5)	64 138 (13.1)	66 281 (13.0)	
$50–$75k	83 834 (16.8)	74 653 (15.5)	71 011 (14.2)	
>$75k	171 688 (40.2)	165 761 (37.1)	138 376 (32.1)	
Employment status, n (%)				
Employed	304 944 (61.5)	280 218 (58.1)	265 693 (55.9)	<0.01
Unemployed	77 151 (14.2)	89 787 (17.3)	115 086 (20.1)	
Student	13 870 (5.7)	15 392 (5.8)	15 569 (5.5)	
Retired	171 230 (18.5)	170 815 (18.8)	181 926 (18.4)	

Data are presented as unweighted N (weighted proportions). SVI indicates Social Vulnerability Index.
*Other indicated BRFSS has delieneated remaining ethnicities.

Table 3. Self-Reported Cardiovascular Comorbidities and Health Related Behaviors Across Tertiles of SVI

	First tertile (SVI 0.00–0.32)	Second tertile (SVI 0.33–0.53)	Third tertile (SVI 0.54–1)	P value
Hypertension, n (%)	112 788 (30.3)	102 793 (32.0)	124 619 (33.4)	<0.01
Hyperlipidemia, n (%)	98 736 (30.1)	91 183 (31.3)	104 305 (31.9)	<0.01
Diabetes, n (%)	70 107 (9.6)	74 066 (10.9)	89 824 (12.1)	<0.01
Current smoker, n (%)	74 172 (14.8)	77 868 (16.4)	89 078 (15.9)	<0.01
Current E-cigarette use, n (%)	11 275 (5.3)	13 029 (5.7)	13 386 (5.8)	<0.01
Current marijuana use, n (%)	9326 (8.5)	3663 (9.7)	9933 (11.3)	<0.01
Chronic kidney disease, n (%)	19 340 (2.6)	21 314 (2.9)	25 569 (3.3)	<0.01
ASCVD, n (%)	60 877 (7.6)	63 336 (8.5)	76 052 (8.8)	<0.01

Data are presented as unweighted N (weighted proportions). ASCVD indicates atherosclerotic cardiovascular disease; and SVI, social vulnerability index.

17.3% versus 14.2%). They also had a higher prevalence of cardiovascular comorbidities, including hypertension (33.4% versus 32% versus 30.3%), diabetes (12.1% versus 10.9% versus 9.6%), chronic kidney disease (CKD; 3.3% versus 2.9% versus 2.6%), hyperlipidemia (31.9% versus 31.3% versus 30.1%), and ASCVD (8.8% versus 8.5% versus 7.6%) (Table 3).

Geographical mapping of states by SVI-Ts showed that the largest concentration of states with more social vulnerabilities were clustered across the southwestern and southeastern parts of the United States (Figure S1). The distribution of the prevalence of diabetes, hypertension, and ASCVD by SVI-Ts (Figures 1 and 2) showed a similar trend.

In multivariable logistic regression models adjusting for age, race and ethnicity, sex, employment, income, health care coverage, and association with the federal poverty line, the participants residing in states in the third SVI-T had higher odds of hypertension (odds ratio [OR], 1.14 [95% CI, 1.11–1.17]), diabetes (OR, 1.12 [95% CI, 1.09–1.15]), hyperlipidemia (OR, 1.09 [95% CI, 1.06–1.12]), CKD (OR, 1.17 [95% CI, 1.12–1.23]), smoking (OR, 1.05 [95% CI, 1.03–1.07]), e-cigarette use (OR, 1.22 [95% CI, 1.16–1.29]), marijuana use (OR, 1.57 [95% CI, 1.49–1.67]), and ASCVD (OR, 1.15 [95% CI, 1.12–1.19]), compared with the participants residing in states in the first SVI-T (Table 4). Further, the odds of the constituent participants having these comorbidities increased across increasing SVI-Ts (Table 4). In the prespecified exploratory analysis stratified by individual themes of SVI (Table 5), we found that the socioeconomic status and household composition were more strongly associated with the prevalence of cardiovascular comorbidities and health-related behaviors, whereas the minoritized groups and housing/transport component were associated with higher odds of use of e-cigarettes and marijuana, as well as self-reported CKD, but not with other cardiovascular comorbidities and health-related behaviors. For the minoritized groups and housing/transport components, higher vulnerability was associated with lower odds of cigarette smoking. In the secondary analyses comparing the SVI to the ADI, we found that the

ADI was numerically more strongly associated with certain cardiovascular comorbidities such as hypertension, diabetes, and hyperlipidemia, while the SVI had a stronger association with other conditions such as CKD and marijuana use (Table S1).

DISCUSSION

In the present study, we found that social vulnerability was associated with worse overall and cardiovascular health, such that participants residing in US states with a higher SVI had a higher prevalence of chronic conditions and at-risk health behaviors including diabetes, hypertension, hyperlipidemia, smoking, e-cigarette use, marijuana use, ASCVD, and CKD. Further, this pattern of disease prevalence had a geographical trend, such that the southwestern and southeastern states consistently had higher social vulnerability and a higher prevalence of cardiovascular disease, compared with the rest of the country.

The causal relationships between traditional risk factors (such as smoking, diabetes, hypertension, and dyslipidemia) and ASCVD have been extensively studied, allowing clinicians and health policy makers to devise and implement counteractive measures. However, the association of disease processes with socioeconomic and environmental factors remains incompletely understood. A large part of this problem is the complex interplay of multiple social, cultural, environmental, and economic factors. The SVI is unique in its holistic approach leveraging 4 important themes, with 15 underlying subcomponents that can help quantify the complex interplay of the social determinants of health and can be used to assess a community's ability to adequately support its population in the face of natural disasters. In our study, we found that the socioeconomic and household components were more strongly associated with the prevalence of cardiovascular comorbidities, compared with housing and transport and minoritized group components. The socioeconomic theme takes into account a community's average income and education status. Studies have shown that
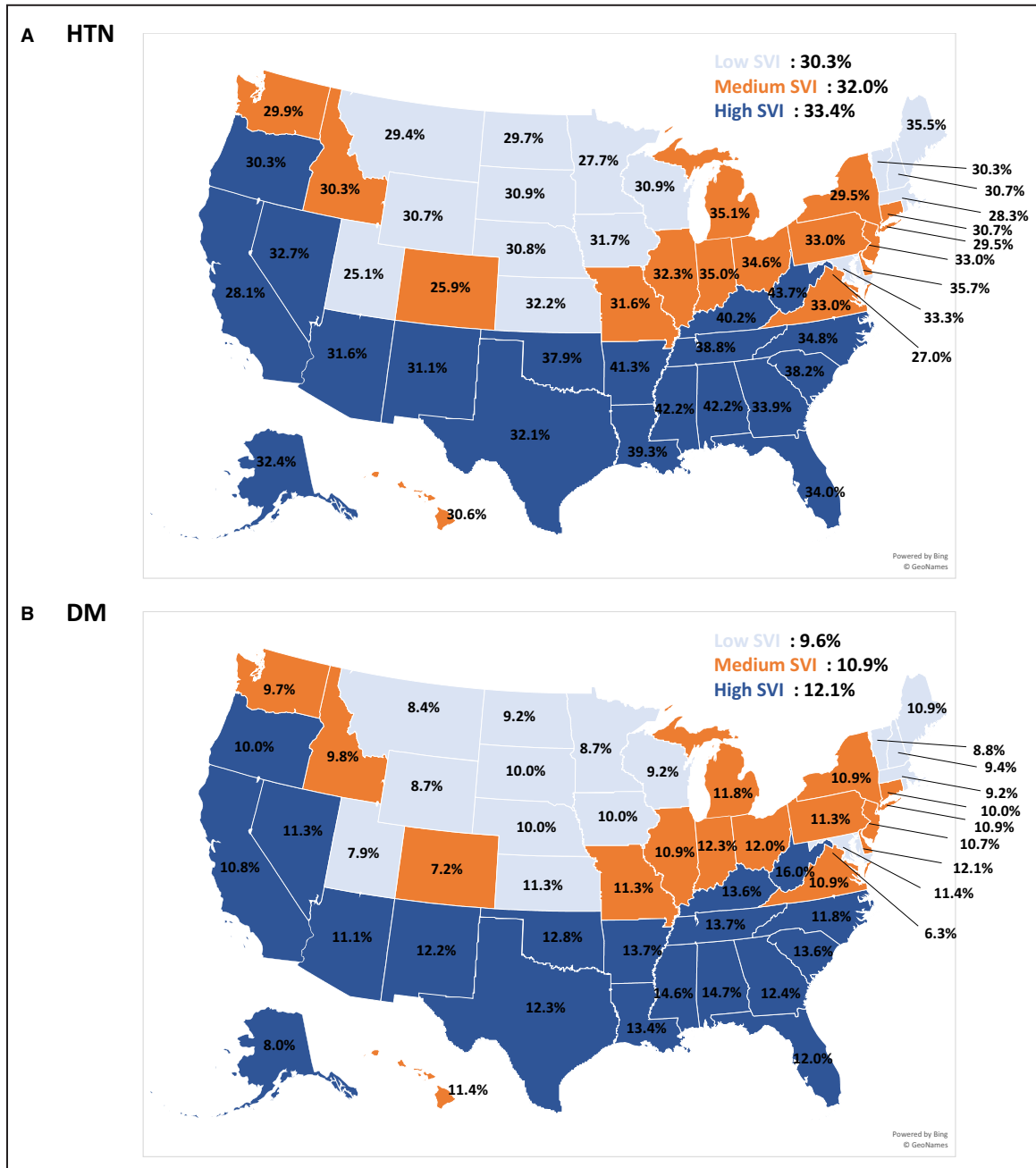
Figure 1. State-level variation in tertiles of social vulnerability index and prevalence of self-reported hypertension (A) and diabetes (B).
SVI indicates Social Vulnerability Index.

higher education levels and health care literacy are inversely associated with the incidence of ASCVD.[12] An individual's economic status affects their ability to follow a nutritious dietary pattern, seek health care, and adhere to guideline-directed medical therapy.[13] The household composition theme is reflective of the number of dependents in a household and other life stressors, including being a single parent and caring for the elderly, factors that have been associated with higher risk for ASCVD.[14] Based on our findings and previous

literature, the authors believe that education attainment, economic status, and the number of dependents have a greater impact on a population's health status than other components of the SVI. Racial and ethnic minoritized groups, including Blacks, Hispanics, and Asians, have a higher prevalence of traditional cardiovascular risk factors and lower use of guideline-directed treatment, and may face language and cultural barriers in accessing the care they need.[15] Finally, the housing and transportation theme incorporates the impact of
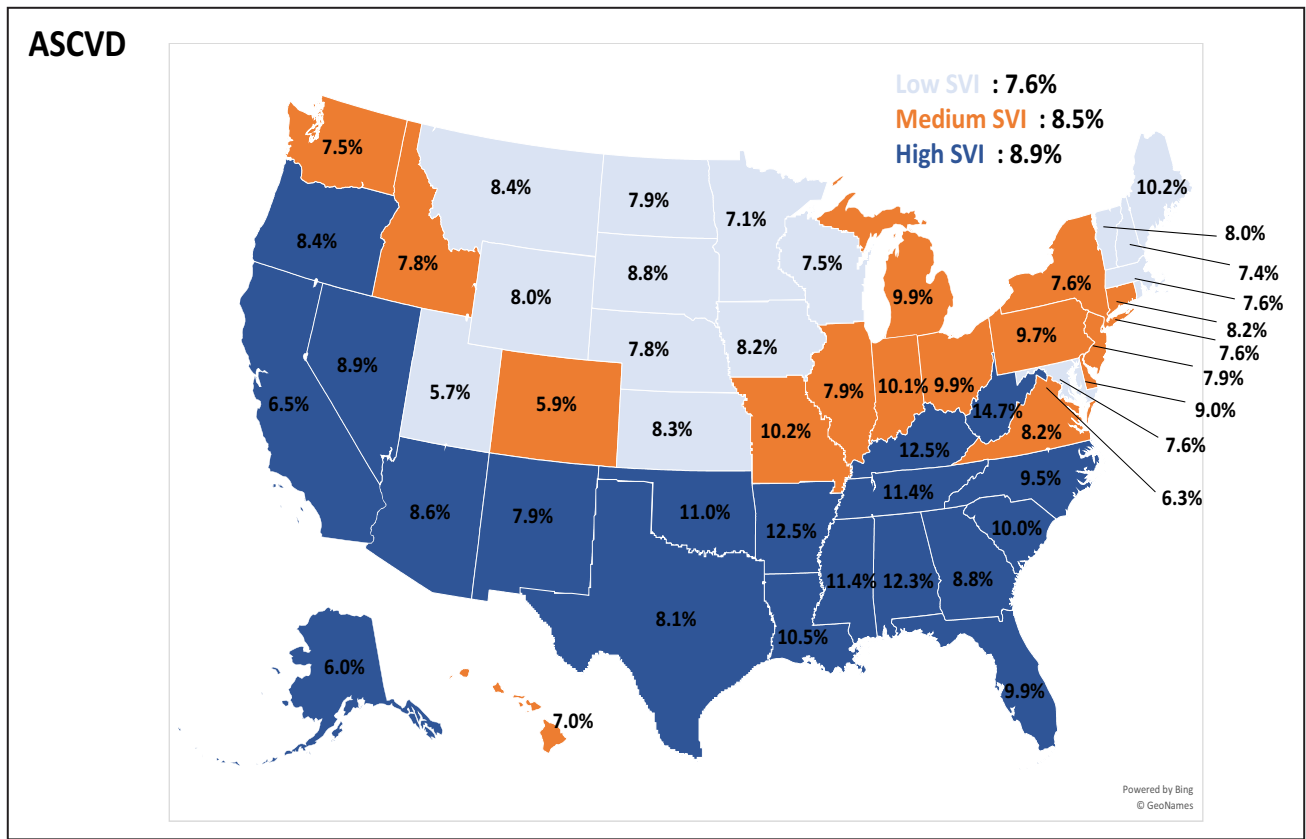
Figure 2. **State-level variation in tertiles of the SVI and prevalence of self-reported atherosclerotic cardiovascular disease.**
ASCVD indicates atherosclerotic cardiovascular disease; and SVI, Social Vulnerability Index.

the physical and cultural environment. Disadvantaged neighborhoods have been shown to have higher population density; lower access to transportation; fewer sidewalks and recreation spaces for physical activity; fewer grocery stores with affordable, healthy food; and lack of social support and community cohesion—all of which increase the risk for cardiovascular disease directly or indirectly.[16] Thus, even though the SVI was developed as a tool to identify populations at greater risk in the setting of natural disasters, the findings of our study suggest it can be used for identifying populations in greater need of preventive care to lower the morbidity and mortality related to cardiovascular disease and its associated risk factors.

Other measures of SDOH, such as the ADI[11] or Social Deprivation Index,[17] although similar in theme, are not as comprehensive as the SVI. While the ADI predominantly focuses on economic deprivation,[11] the Social Deprivation Index covers limited social characteristics (poverty, <12 years of education, single-parent household, rented housing unit, the overcrowded housing unit, households without a car, and nonemployed adults aged <65 years), limiting their scope when compared with SVI.[17] The SVI covers some unique variables, such as minoritized groups, English language insufficiency, elderly (aged >65 years), children (aged <18 years), and aged >5 years with a disability, allowing a more global assessment of social vulnerability for a given community. Further, being a composite of 4 individual themes, the SVI allows a more granular exploration of individual components of SDOH that can impact a population's health status and provide actionable information to health policy makers.

A previous cross-sectional analysis from the Canadian PACEinMM (Patient-Centered Innovations for Persons With Multimorbidity) study showed that in a cohort of 301 adult participants from Canada, the SVI strongly correlated with the prevalence of chronic conditions, such as obesity, depression/anxiety, and cardiovascular diseases.[18] Their study used a related but modified version of the SVI compared with the one developed by the CDC.[18] Another study by Gay et al[19] used the SVI to explain county-level variation in youth physical fitness across the public schools of Georgia. In their study of 2126 public schools, they found that SVI themes explained most of the variation (R^2 values, 11.5% to 26.6%) in youth physical fitness levels.

Previous studies have also shown that lower economic status is consistently associated with higher ASCVD risk.[20] A multicenter study from the United States and Finland found that lower economic status was associated with a higher prevalence of ASCVD,

Table 4. Odds Ratios (95% CIs) for the Association of Tertiles of SVI With Self-Reported Chronic Comorbidities

	Odds ratio (95% CI)	
	Unadjusted	Adjusted
Hypertension		
SVI <0.33	1.00 (ref)	1.00 (ref)
SVI 0.33–0.53	1.08 (1.06–1.10)	1.03 (1.01–1.06)
SVI ≥0.54	1.15 (1.13–1.18)	1.14 (1.11–1.17)
Hyperlipidemia		
SVI <0.33	1.00 (ref)	1.00 (ref)
SVI 0.33–0.53	1.06 (1.04–1.08)	1.04 (1.01–1.06)
SVI ≥0.54	1.09 (1.06–1.11)	1.09 (1.06–1.12)
Diabetes		
SVI <0.33	1.00 (ref)	1.00 (ref)
SVI 0.33–0.53	1.15 (1.13–1.18)	1.06 (1.03–1.08)
SVI ≥0.54	1.29 (1.26–1.32)	1.12 (1.09–1.15)
Current smoker		
SVI <0.33	1.00 (ref)	1.00 (ref)
SVI 0.33–0.53	1.12 (1.10–1.15)	1.11 (1.09–1.14)
SVI ≥0.54	1.08 (1.06–1.10)	1.05 (1.03–1.07)
Current E-cigarette use		
SVI <0.33	1.00 (ref)	1.00 (ref)
SVI 0.33–0.53	1.10 (1.05–1.15)	1.15 (1.09–1.21)
SVI ≥0.54	1.09 (1.04–1.14)	1.22 (1.16–1.29)
Current marijuana use		
SVI <0.33	1.00 (ref)	1.00 (ref)
SVI 0.33–0.53	1.16 (1.09–1.23)	1.17 (1.09–1.25)
SVI ≥0.54	1.37 (1.31–1.44)	1.57 (1.49–1.67)
CKD		
SVI <0.33	1.00 (ref)	1.00 (ref)
SVI 0.33–0.53	1.11 (1.07–1.15)	1.05 (1.01–1.10)
SVI ≥0.54	1.27 (1.22–1.32)	1.17 (1.12–1.23)
ASCVD		
SVI <0.33	1.00 (ref)	1.00 (ref)
SVI 0.33–0.53	1.13 (1.10–1.15)	1.09 (1.06–1.12)
SVI ≥0.54	1.18 (1.15–1.21)	1.15 (1.12–1.19)

ASCVD indicates atherosclerotic cardiovascular disease; CKD, chronic kidney disease; and SVI, Social Vulnerability Index. Model is adjusted for age, sex, race and ethnicity, employment, income, association with federal poverty line, and health plan coverage.

nonfatal myocardial infarction, and sudden cardiac death.[20] Importantly, the impact of economic status on an individual's health may be modifiable, such that improvement in economic condition may lead to better health status. This was shown in a study of 5579 adults without cardiovascular disease who were enrolled in the Health and Retirement Study.[21] In their study, Machado et al. found that participants who experienced upward wealth mobility (by at least 1 quintile) had independently lower cardiovascular risk compared with participants with stable wealth from 50 to 64 years of age, and participants who experienced downward wealth mobility had higher cardiovascular risk after 65 years of age.[21] This relation with economic status could in part be related to lack of access to quality care, inability to afford medications as well as lower use of guideline-directed medical therapy.[13] In addition to an individual's economic status, an individual's physical and cultural environment are also associated with health status.[11,16] Epidemiologic data from the ARIC (Atherosclerosis Risk in Communities) and the Jackson Heart Study have shown that individuals residing in disadvantaged neighborhoods have worse cardiometabolic health at baseline and have higher risk of incident ASCVD on long-term follow-up.[16,22] Low-income neighborhoods often have fewer supermarkets, and consequently limited access to fresh fruits and vegetables, which may in turn contribute to increased ASCVD risk.[23,24] People with socioeconomic disadvantage are more prone to smoking, heavier alcohol use, obesity, and physical inactivity and may have limited access to preventive care, which can contribute to the development of cardiovascular diseases.[25] The SVI, by providing a composite metric encompassing important social determinants of health, may serve as a valuable tool for both researchers, health systems, and health policy makers to allocate resources for targeted interventions to combat the epidemic of cardiometabolic and other noncommunicable diseases.

Limitations

Our results must be interpreted in the context of several important limitations. This was a cross-sectional study, and therefore directionality and causality cannot be inferred. For instance, the probability of reverse association exists, that is, higher social vulnerability attributable to higher prevalence of comorbidities. In any epidemiologic study, there is a possibility of residual confounding. The SVI and health behaviors of populations residing in the respective states may be influenced by migration patterns and other unaccounted factors. The data pertaining to health conditions and health-related behaviors from BRFSS is self-reported and is susceptible to respondent bias. Finally, the SVI is calculated on a census tract level, and we have extrapolated these to state-level data by using the composite US database, in which all tracts are ranked against one another, allowing for state-level evaluation of SVI. Thus, our results cannot be used to inform county and census-level inferences. Because of privacy concerns, BRFSS data are not available to us at the county level (ie, we have only state of residence available for each participant). Consequently, we merged BRFSS with state-level SVI rankings to allow for a homogenous comparison of social vulnerability with prevalent cardiovascular comorbidities.

Table 5.   Odds Ratios (95% CIs) for the Association of Tertiles of Individual Components of the Overall SVI (Modified SVI) With Self-Reported Cardiovascular Comorbidities

	Socioeconomic status component Odds ratio (95% CI)	Household composition component Odds ratio (95% CI)	Minoritized groups component Odds ratio (95% CI)	Housing/transportation component Odds ratio (95% CI)
	Adjusted	Adjusted	Adjusted	Adjusted
Hypertension				
SVI <0.33	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
SVI 0.33–0.53	1.03 (1.01–1.05)	1.06 (1.03–1.09)	1.01 (0.98–1.04)	1.05 (1.02–1.07)
SVI ≥0.54	1.14 (1.11–1.17)	1.23 (1.20–1.27)	0.98 (0.95–1.01)	0.97 (0.95–0.99)
Hyperlipidemia				
SVI <0.33	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
SVI 0.33–0.53	1.01 (0.99–1.04)	0.95 (0.93–0.98)	1.04 (1.01–1.06)	1.04 (1.01–1.06)
SVI ≥0.54	1.08 (1.05–1.11)	1.08 (1.05–1.11)	1.03 (0.99–1.06)	1.03 (0.99–1.05)
Diabetes				
SVI <0.33	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
SVI 0.33–0.53	1.06 (1.03–1.09)	1.06 (1.03–1.09)	0.97 (0.95–0.99)	1.02 (1.00–1.05)
SVI ≥0.54	1.14 (1.11–1.17)	1.20 (1.17–1.23)	0.97 (0.94–0.99)	0.98 (0.95–1.00)
Current E-cigarette use				
SVI <0.33	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
SVI 0.33–0.53	1.11 (1.05–1.16)	0.98 (0.93–1.04)	1.08 (1.03–1.14)	1.05 (0.99–1.11)
SVI ≥0.54	1.19 (1.12–1.25)	1.14 (1.08–1.20)	1.07 (1.01–1.14)	1.07 (1.02–1.13)
Current marijuana use				
SVI <0.33	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
SVI 0.33–0.53	1.10 (1.02–1.16)	1.43 (1.35–1.51)	0.85 (0.79–0.91)	0.98 (0.92–1.05)
SVI ≥0.54	1.49 (1.41–1.57)	0.74 (0.69–0.79)	1.53 (1.42–1.65)	1.65 (1.54–1.76)
Current smoker				
SVI <0.33	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
SVI 0.33–0.53	1.11 (1.09–1.13)	1.04 (1.02–1.07)	0.85 (0.83–0.87)	1.09 (1.06–1.11)
SVI ≥0.54	1.17 (1.15–1.19)	1.17 (1.14–1.20)	0.80 (0.78–0.82)	0.90 (0.87–0.92)
CKD				
SVI <0.33	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
SVI 0.33–0.53	1.04 (1.01–1.06)	1.12 (1.06–1.18)	0.98 (0.94–1.02)	1.02 (0.98–1.07)
SVI ≥0.54	1.03 (1.01–1.05)	1.19 (1.13–1.24)	1.08 (1.03–1.13)	1.06 (1.01–1.11)
ASCVD				
SVI <0.33	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
SVI 0.33–0.53	1.07 (1.04–1.10)	1.06 (1.02–1.09)	0.98 (0.96–1.01)	1.10 (1.07–1.13)
SVI ≥0.54	1.16 (1.13–1.20)	1.20 (1.17–1.24)	0.95 (0.93–0.98)	0.99 (0.97–1.03)

Model is adjusted for age, sex, race and ethnicity, employment, income, association with federal poverty line, and health plan coverage. ASCVD indicates atherosclerotic cardiovascular disease; CKD, chronic kidney disease; ref, reference value; and SVI, Social Vulnerability Index.

CONCLUSIONS

The SVI varies across the US states and is associated with cardiovascular comorbidities and atherosclerotic cardiovascular disease, independent of age, race and ethnicity, sex, employment, income, and health care coverage. The SVI may be a useful assessment tool for health policy makers, health systems, and researchers examining multilevel influences on health behaviors, and identifying and allocating resources to communities at risk of cardiovascular diseases attributable to social determinants of health.

ARTICLE INFORMATION

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Supplemental Material

Table S1
Figure S1

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SUPPLEMENTAL MATERIAL

Table S1. Odds ratios (95% confidence interval) comparing the association of tertiles of social vulnerability index and area deprivation index with chronic comorbidities.

Odds Ratio (95% Confidence Interval)			
SVI		ADI	
Hypertension	**Adjusted**	**Hypertension**	**Adjusted**
SVI <0.33	1.00 (ref)	ADI <0.40	1.00 (ref)
SVI 0.33-0.53	1.03 (1.01,1.06)	ADI 0.40-0.65	1.12 (1.09,1.16)
SVI ≥0.54	1.14 (1.11,1.17)	ADI ≥0.65	1.28 (1.25,1.32)
Hyperlipidemia		**Hyperlipidemia**	
SVI <0.33	1.00 (ref)	ADI <0.40	1.00 (ref)
SVI 0.33-0.53	1.04 (1.01,1.06)	ADI 0.40-0.65	1.04 (1.01,1.07)
SVI ≥0.54	1.09 (1.06,1.12)	ADI ≥0.65	1.11 (1.08,1.14)
Diabetes mellitus		**Diabetes mellitus**	
SVI <0.33	1.00 (ref)	ADI <0.40	1.00 (ref)
SVI 0.33-0.53	1.06 (1.03,1.08)	ADI 0.40-0.65	1.09 (1.05,1.12)
SVI ≥0.54	1.12 (1.09,1.15)	ADI ≥0.65	1.20 (1.17,1.23)
Current Smoker		**Current Smoker**	
SVI <0.33	1.00 (ref)	ADI <0.40	1.00 (ref)
SVI 0.33-0.53	1.11 (1.09,1.14)	ADI 0.40-0.65	1.18 (1.15,1.21)
SVI ≥0.54	1.05 (1.03,1.07)	ADI ≥0.65	1.34 (1.31,1.38)

Current E-cigarette use		Current E-cigarette use	
SVI <0.33	1.00 (ref)	ADI <0.40	1.00 (ref)
SVI 0.33-0.53	1.15 (1.09- 1.21)	ADI 0.40-0.65	1.19 (1.12- 1.26)
SVI ≥0.54	1.22 (1.16- 1.29)	ADI ≥0.65	1.16 (1.10- 1.22)
Current Marijuana use		Current Marijuana use	
SVI <0.33	1.00 (ref)	ADI <0.40	1.00 (ref)
SVI 0.33-0.53	1.17 (1.09- 1.25)	ADI 0.40-0.65	0.53 (0.50- 0.57)
SVI ≥0.54	1.57 (1.49- 1.67)	ADI ≥0.65	0.40 (0.37- 0.43)
CKD		CKD	
SVI <0.33	1.00 (ref)	ADI <0.40	1.00 (ref)
SVI 0.33-0.53	1.05 (1.01,1.10)	ADI 0.40-0.65	1.04 (0.99,1.10)
SVI ≥0.54	1.17 (1.12,1.23)	ADI ≥0.65	1.06 (1.01,1.11)
ASCVD		ASCVD	
SVI <0.33	1.00 (ref)	ADI <0.40	1.00 (ref)
SVI 0.33-0.53	1.09 (1.06,1.12)	ADI 0.40-0.65	1.13 (1.10,1.18)
SVI ≥0.54	1.15 (1.12,1.19)	ADI ≥0.65	1.27 (1.24,1.31)

Model is adjusted for age, sex, race, employment, income, association with federal poverty line, and health plan coverage. Key: SVI: social vulnerability index; ASCVD: atherosclerotic cardiovascular disease; CKD: chronic kidney disease.

Figure S1. Overall state level variation in tertiles of social vulnerability index.

Low SVI : (0-0.32)
Medium SVI : (0.33- 0.53)
High SVI : (0.54- 1.00)

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