Maternal and Child Health Journal (2019) 23:1516–1524
https://doi.org/10.1007/s10995-019-02792-7

Application of the Social Vulnerability Index for Identifying Teen Pregnancy Intervention Need in the United States

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Published online: 21 June 2019

Abstract
Objectives Originally developed to assess emergency preparedness, evidence suggests the Social Vulnerability Index (SVI) may also be useful to investigate multilevel environmental and social influences on health risk behaviors and outcomes. This ecological study explores the application of the SVI as a predictor of teen pregnancy rates across counties in the United States (U.S.) and identifies areas with greatest need for community-based interventions. *Methods* County-level SVI and teen birth rate data were obtained from the Centers for Disease Control and Prevention. Regression analysis was conducted to examine associations between teen birth rates and social vulnerability, geographic region, and the four themes which compromise the index: socioeconomic status, household composition, minority status, and housing. Dot maps of teen birth rates and SVI by quartiles were used to examine spatial distribution across counties. *Results* Each increase in SVI quartile was associated with an additional 11.5 births per 1000 females ages 15–19. Higher social vulnerability was significantly associated with higher teen birth rates to varying degrees across the U.S., with largest effect sizes observed in East South Central ($\beta = 62.56$; SE = 6.28; $p < 0.001$) and West South Central ($\beta = 66.75$; SE = 5.33; $p < 0.001$) Census divisions. Among index themes, socioeconomic status ($\beta = 25.56$; SE = 1.16; $p < 0.001$), household composition ($\beta = 23.49$; SE = 1.00; $p < 0.001$), and minority/language status ($\beta = 10.99$; SE = 0.83; $p < 0.001$) were positively associated with teen birth. No association was observed with housing/transportation. *Conclusions* The SVI offers a novel tool for identifying at-risk populations most in need of resources and guiding community-based teen pregnancy interventions across the U.S.

Keywords Teen pregnancy · Social Vulnerability Index · Spatial analysis · Social determinants of health · Community health needs assessment

Significance

Originally developed as a measure of emergency and disaster preparedness to identify vulnerable and at-risk populations in greatest need of public health resources, the Social Vulnerability Index (SVI) has been used to explore socio-ecological influences on a variety of health behaviors and outcomes. Findings from this ecological study suggest, when applied to teen pregnancy, the SVI may be a useful measure to identify high-risk communities and for assessing the effectiveness of health policy interventions in the United States.

Introduction

Despite a recent 8% decline in United States (U.S.) teen birth rates from 2014 to 2015, three-fourths of teen pregnancies are still reported to be unintended and the burden of teen pregnancy continues to disproportionately affect certain subgroups of the population (Martin et al. 2017; Romero et al. 2016; Finer and Zolna 2016; Lindberg et al. 2018). Birth rates among adolescents who are black, Hispanic, and American Indian are still more than double the rates of non-Hispanic whites (Kearney and Levine 2015; Ngui et al. 2017). Teen mothers are two and half times more likely to have low English proficiency and literacy compared to

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adolescents of the same age, and only 50% of adolescent girls who become pregnant will go on to earn their high school diploma by age 22 (Maness et al. 2016; Xie et al. 2014; Bennett et al. 2013). Teen pregnancy is estimated to cost taxpayers in the U.S. close to $11 billion resulting from increased health care service utilization, foster care, rates of incarceration of children born to adolescent parents, and lost tax revenue due to lower economic potential of teen mothers (Kearney and Levine 2015; Maness et al. 2016; Hoffman 2011). Even when controlling for race, education, access to prenatal care, and tobacco and alcohol use, pregnant adolescents are at increased risk for poor maternal health outcomes including preterm birth, low infant birth weight, still birth and neonatal mortality (Gilbert et al. 2004; Malabarey et al. 2012; Chen et al. 2007).

While historical teen pregnancy prevention efforts have focused on individual-level risk factors, emerging evidence reveals that differences in social and environmental conditions can lead to major health inequities that contribute to differences in teen birth rates (Maness et al. 2016; Gold et al. 2001; Penman-Aguilar et al. 2013). Area-level factors such as residing in neighborhoods that are socioeconomically-deprived, segregated, overcrowded, coming from single-parent households and housing instability are associated with elevated risks of teen pregnancy (Penman-Aguilar et al. 2013; Miller et al. 2001; Janevic et al. 2010; Sipsma et al. 2017). Geographically, higher teen birth rates are observed in the South region of the U.S. while lower teen birth rates are observed in the northeast (Ventura et al. 2014; Khan et al. 2018; Amin et al. 2017). Changes in teen birth rates also vary widely by state, with an 18% decrease in teen birth rates between 2014 and 2015 in Vermont compared to an essentially unchanged rate in 13 states and the District of Columbia (Ventura et al. 2014; Amin et al. 2017). By county, teen birth rates range from a low of four births per 1000 teenage girls in Hampshire County, Massachusetts to a high of 124 births per 1000 in Brooks County, Texas (Robert Wood Johnson Foundation 2017). Moreover, policies that impact teen pregnancy rates, such as public spending and family planning services, vary by state and local geography (Johnson et al. 2017). Therefore, it is important to consider spatial variation in risk and protective factors when designing teen pregnancy prevention interventions, and to identify standardized tools by which to benchmark community progress across the country (Johnson et al. 2017; Khan et al. 2018).

The Center for Disease Control and Prevention's (CDC) SVI measures census tract and county-level social vulnerability, defined as a set of community-level factors that make an individual less resilient to external stresses on health (U.S. Department of Health and Human Services 2014; Grabovschi et al. 2013; Bergstrand et al. 2015). The index is comprised of 14 ecological variables, grouped into four themes: socioeconomic status, household composition, minority/language status, and housing/transportation (U.S. Department of Health and Human Services 2014). Originally developed as a measure of emergency and disaster preparedness to identify vulnerable and at-risk populations in greatest need of resources, the index has since been used to explore socioecological influences on health behaviors and outcomes across the U.S., such as adolescent physical activity, obesity, geriatric health, and access to quality clinical care (Bergstrand et al. 2015; Tate 2012; An and Xiang 2015a, b; Khan et al. 2015; Gay et al. 2016; Chau et al. 2014). The comprehensive and publicly-accessible nature of the SVI make it a particularly useful metric for policymakers, researchers, and the general public. Although the four factors used to measure social vulnerability—socioeconomic status, household composition, minority/language status, and housing/transportation—have each been independently linked with adolescent reproductive health, the SVI has never been used to examine community-level variations in teen pregnancy risk.

This study explores the application of the SVI as a predictor of teen pregnancy rates across counties in the U.S. and identifies areas with greatest need for community-based interventions for teen pregnancy. We hypothesized that communities with elevated social vulnerability would have higher teen birth rates and that the strength of this association would vary by region.

Methods

Measures

County-level data on teen birth rates among females ages 15 to 19 years for 2007–2015 were obtained from the CDC's National Center for Health Statistics natality files. Natality data on teen births, drawn from U.S. births records, were downloaded by county of women's residence and sorted by maternal age at time of birth. Teen birth rates were calculated with respect to the population of each county, thus allowing for comparisons between counties of varying size. Detailed information about the NCHS public-use data on natality can be found on the CDC WONDER online portal at http://wonder.cdc.gov/natality-current.

SVI values for 2014 were obtained from the CDC's Agency for Toxic Substances and Disease Registry's Geospatial Research, Analysis, and Services Program. SVI is calculated for each U.S. Census tract based on the rank order of 14 ecological variables and grouped into four themes (Table 1): (1) socioeconomic status, (2) household composition, (3) minority/language status, and (4) housing/transportation (U.S. Department of Health and Human Services 2014). Each Census tract receives a separate ranking value

Table 1 Social Vulnerability Index (SVI) themes and factors

SVI theme	Factor	Indicator	Definition
Theme 1	Socioeconomic status	Below poverty	Percent of persons below federally-defined poverty line, a threshold that varies by size and age of household composition
		Unemployed	Unemployed civilian population over age 16 actively seeking work divided by total civilian population
		Mean income	Mean income computed for each individual in census tract
		No high school diploma	Percent of persons age 25 or over with less than a 12th grade diploma
Theme 2	Household composition and disability	Aged 65 or older	Percent of persons age 65 or older
		Aged 17 or younger	Percent of persons age 17 or younger
		Civilian with a disability	Percent of civilian population not in an institution who are age 5 or older with a disability
		Single-parent households	Percent of male or female householders with no spouse present with children under 18
Theme 3	Minority status and language	Minority	Percent of population reported as "black or African American alone," "American Indian or Alaska Native alone," "Asian alone," "Native Hawaiian or Pacific Islander alone, "some other race alone," "two or more races," or "Hispanic or Latino alone"
		Low english proficiency	Percent of persons over age 5 who speak English "not well" or "not at all"
Theme 4	Housing and transportation	Multi-unit structures	Percent housing units with 10 or more units in structure
		Mobile homes	Percent housing units that are mobile homes
		Crowding	Percent total occupied households with more than one person per room
		No access to vehicle	Percent households with no vehicle available
		Group quarters	Percent of persons who are in institutional group quarters (e.g., correctional institutions, nursing homes) and non-institutional group quarters (e.g., college dormitories, military quarters)

for each of the four SVI themes in addition to an overall SVI score. Values for overall SVI range from 0 to 1, with higher values representing greater social vulnerability. In this study, U.S. counties were selected as the smallest level of measurement since teen birth data are not publicly available at the Census tract level. County-level SVI scores were categorized into four quartile groups based on 25th percentile cutoffs representing low (1–24%), mid-low (25–49%), mid-high (50–74%), and high (75–100%) social vulnerability. Further information on the CDC's SVI can be found at http://svi.cdc.gov.

This study uses the CDC's publicly available datasets which are compliant with the Health Insurance Portability and Accountability Act (HIPAA) and is not based on clinical study or patient data. Thus, this research has been deemed exempt by Yale University's Institutional Review Board.

Data Analysis

Descriptive statistics were calculated to assess differences in characteristics of residential counties among the SVI quartile groups. Analysis of variance was used to test for differences between quartile groups. Linear regression models were used to examine associations between social vulnerability and teen birth rates by quartile, for each of the four themes which compromise the index (socioeconomic status, household composition, minority/language status, and housing/transportation), and by four geographic regions (Northeast, Midwest, South and West) and their respective nine U.S. Census divisions (New England, Middle Atlantic, East North Central, West North Central, South Atlantic, East South Central, West South Central, Mountain, and Pacific). To confirm normality and the appropriate use of the linear model, a Q–Q plot and Kolmogorov–Smirnov test were conducted. Pearson's bivariate correlation analysis was conducted to test for any correlative relationship between the four themes and confirm independence of the test variables. All statistical analyses were conducted using IBM SPSS Statistics Version 24.

Computer generated dot maps of social vulnerability and teen pregnancy were produced using ArcGIS Version 10.5 and used to examine the spatial distribution across U.S. counties. Dot maps, with increasing dot size representing greater prevalence and with placement of the dot in the center of each county, were selected as the method of spatial visualization to reduce cartographic bias by

avoiding analysis that relies on size of county geographic area.

Results

Descriptive Analysis

Our sample consisted of all 3139 counties in the United States including the District of Columbia. Table 2 shows the characteristics of counties by SVI quartile. The teen birth rate in the highest SVI quartile (57 births per 1000 females ages 15–19) was approximately 1.5 times greater than the national average, and 2.5 times greater than the rate in the lowest SVI quartile (23 births per 1000 females ages 15–19).

Seventy-seven percent of high social vulnerability counties were in the South region of the U.S., compared to 61% of low social vulnerability counties that were in the Midwest. The percentage of rural counties was greatest among the lowest index quartile, though scores did not differ greatly based on rural designation. As expected, greater social vulnerability was associated with lower median household incomes, lower high school graduation rates and a higher percentage of uninsured residents, single parent households, and residents with severe housing problems. The percentage of non-white minorities was greater in counties with increased social vulnerability compared to overall averages, with the largest proportion of Black, Hispanic, Asian, and Pacific Islanders within the high social vulnerability category. Additionally, the percentage of individuals with low English language proficiency grew with each increase in SVI quartile.

Association Between Social Vulnerability and Teen Birth Rates

Residential county social vulnerability was positively associated with teen birth across the 3139 counties of the U.S (Fig. 1), with effects increasing with each increase in SVI quartile (linear effect: $\beta = 60.14$; SE = 1.36; $p < 0.001$). Each quartile increase was associated with an additional 11.5 births per 1000 females 15–19 years of age, a nearly 50% increased risk.

Among the four themes that compromise the overall index score, socioeconomic status ($\beta = 25.56$; SE = 1.16; $p < 0.001$), household composition ($\beta = 23.49$; SE = 1.00; $p < 0.001$), and minority/language status ($\beta = 10.99$; SE = 0.83; $p < 0.001$) were positively associated with teen birth, though not as strongly as overall SVI ($\beta = 60.14$; SE = 1.36; $p < 0.001$) (Table 3). Housing/transportation status was not significantly associated with teen birth. Pearson's bivariate correlation analysis confirmed that each index theme was independent and not strongly correlated with any of the others.

Geographic Distributions

County-level dot maps show high density clustering of high teen birth rates and social vulnerability (Fig. 2a, b), particularly in the South U.S. Census region. The regression analyses likewise revealed the relationship between teen birth rates and social vulnerability varied by geographic region. In Table 4, the regional variance in the association between SVI and teen birth is further specified by four Census regions and nine Census division. The strongest associations were observed in East South Central ($\beta = 62.56$; SE = 6.28; $p < 0.001$) and West South Central ($\beta = 66.75$; SE = 5.33; $p < 0.001$), where teen birth rates were a respective 58% and 69% higher than national average. The weakest associations were observed in East North Central ($\beta = 53.62$; SE = 3.40; $p < 0.001$) and Pacific ($\beta = 53.89$; SE = 7.44; $p < 0.001$) Census divisions (Table 4).

Despite strong associations between social vulnerability and teen pregnancy across the U.S., some regions presented county outliers within SVI quartiles. For example, along the Pacific coast, a number of counties with high social vulnerability had lower than average teen birth rates, while there were a number of counties with low social vulnerability in the Midwest with high teen birth rates (Fig. 2a, b).

Discussion

Our findings are consistent with other recent research that suggests the SVI may be used as a marker for more than preparedness for natural disasters and other emergencies (Grabovschi et al. 2013; Bergstrand et al. 2015; An and Xiang 2015a, b; Khan et al. 2015; Gay et al. 2016; Chau et al. 2014). Our study demonstrates a significant positive association between residential social vulnerability and teen birth rates. Compared to national average, counties in the high and mid high-SVI quartiles had 44% and 11% higher teen birth rates, respectively.

Three of the four themes that compromise the SVI (socioeconomic status, household composition and minority/language status) were significantly associated with teen birth. While some evidence suggests that housing and transportation access can be associated with sexual risk behavior, our study did not find a significant association between housing/transportation access and teen birth rates across U.S. counties (Brahmbhatt et al. 2014; Nebbitt et al. 2010; Thompson et al. 2008). This difference may be due to the specific Census Variables included in the SVI theme for housing/transportation, many of which may not be associated with high risk sexual behavior.

Table 2 Characteristics of U.S. counties by SVI quartile, mean (SD)

County characteristic	All counties (n = 3139)	SVI quartile group			
		High vulnerability (n = 786)	Mid-high vulnerability (n = 785)	Mid-low vulnerability (n = 782)	Low vulnerability (n = 786)
Teen birth rate per 1000 females ages 15–19**	39.46 (18.13)	57.03 (15.47)	43.91 (14.39)	32.69 (11.89)	23.09 (9.39)
Region[a] (%)					
Northeast**	6.9	1.4	5.1	11.3	9.6
Midwest**	33.6	7.0	25.0	39.8	61.4
South**	45.3	77.3	56.9	33.3	14.7
West*	14.3	14.3	13.0	15.5	14.2
Rural (%)**	58.57 (31.47)	56.57 (31.53)	58.94 (31.30)	56.10 (30.81)	62.54 (31.87)
Race/ethnicity (%)					
White**	76.84 (19.88)	67.24 (20.39)	75.50 (21.24)	80.75 (17.47)	83.57 (16.13)
Black**	8.95 (14.25)	15.78 (18.16)	9.29 (14.50)	6.33 (10.72)	4.62 (9.52)
Hispanic**	9.19 (13.57)	11.79 (15.95)	10.41 (15.91)	7.80 (11.28)	6.88 (9.53)
Native American	2.21 (7.34)	2.23 (6.88)	2.07 (7.15)	2.13 (7.44)	2.38 (7.83)
Asian	1.46 (2.79)	1.59 (3.10)	1.41 (3.03)	1.56 (2.89)	1.27 (2.04)
Pacific Islander	0.13 (0.95)	0.21 (1.81)	0.12 (0.42)	0.12 (0.50)	0.084 (0.12)
Low English proficiency (%)	3.40 (4.84)	5.16 (6.83)	3.82 (4.98)	2.86 (3.50)	1.78 (4.85)
Socioeconomic factors					
Median household income ($)**	48,631 (12,383)	45,676 (12,705)	46,376 (11,575)	50,000 (12,170)	53,334 (11,887)
Unemployed (%)**	5.52 (1.99)	6.12 (2.12)	5.87 (1.89)	5.43 (1.87)	4.70 (1.75)
High school graduation (%)**	86.20 (8.22)	84.98 (9.05)	86.65 (7.98)	86.54 (7.65)	86.77 (7.93)
Health care access and quality					
Uninsured residents (%)**	18.0 (5.16)	16.53 (4.59)	15.25 (5.37)	13.41 (4.92)	12.49 (4.76)
Primary care physician rate per 100,000 population**	55.16 (34.85)	53.12 (32.68)	52.49 (32.45)	58.02 (38.59)	56.92 (34.95)
Household composition					
Single-parent households**	32.6 (10.32)	36.60 (11.13)	33.74 (10.24)	31.32 (8.85)	28.91 (9.36)
Age 17 or younger	22.44 (3.43)	22.69 (3.44)	22.45 (3.59)	22.29 (3.41)	22.32 (3.27)
Age 65 or older**	17.98 (4.52)	17.31 (4.56)	18.07 (4.72)	17.86 (4.32)	18.67 (4.36)
Housing and transportation					
Severe housing problems (%)**	14.48 (4.75)	15.86 (4.84)	14.82 (4.53)	14.82 (4.46)	13.10 (4.73)

Data sources: 2017 County Health Rankings (www.countyhealthrankings.org), Centers for Disease Control Compressed Natality database (http://wonder.cdc.gov/wonder/)

*Difference between groups is significant at $p < 0.05$

**Difference between groups is significant at $p < 0.01$

[a]Regions are defined using U.S. Census Regions (https://www2.census.gov/geo/pdfs/maps-data/maps/reference/us_regdiv.pdf)

Geospatially, high social vulnerability was associated with higher teen birth rates to varying degrees across all of the U.S. Census regions and divisions, with greatest effect sizes observed in the Southern part of the country. Regional variation in the association between social vulnerability and teen pregnancy may be due to a number of economic and policy-related factors. As local and state governments invest in social and public health services such as family planning programs, comprehensive sex education, and afterschool youth programs that build stronger social support, reduce

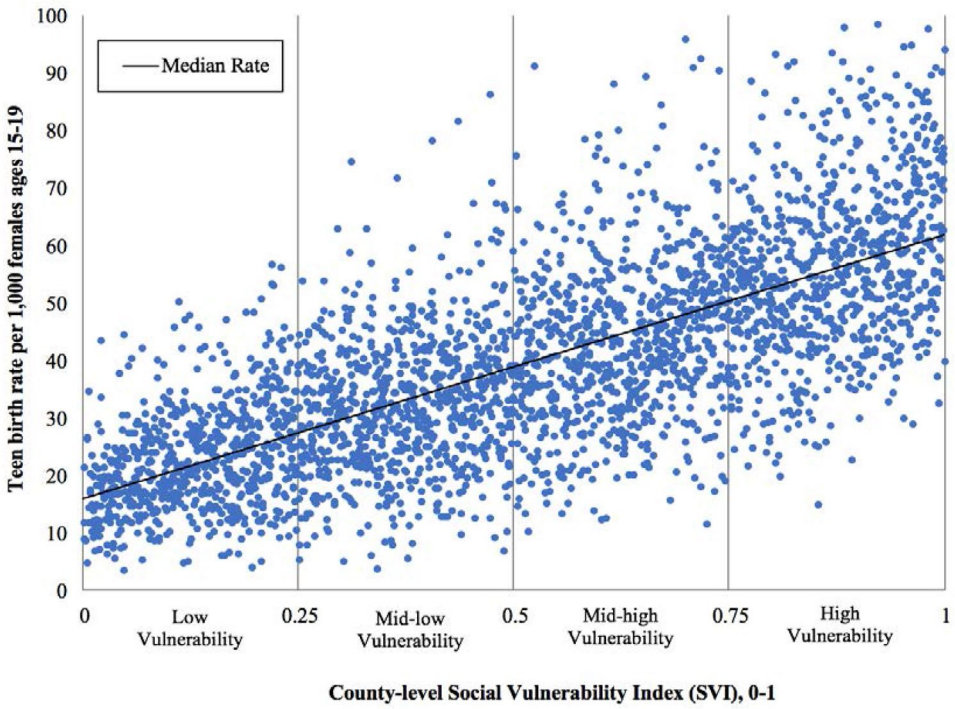

Fig. 1 Association between social vulnerability and teen birth rates in the U.S.[a,b]. [a]$y = 45.95x + 15.94$; $r = 0.721$; $R^2 = 0.520$, [b]Each increase in SVI quartile was associated with an additional 11.5 births per 1000 females ages 15–19 ($\beta = 60.14$; SE = 1.36; $p < 0.001$)

Table 3 Association between SVI themes and teen birth rates

SVI theme		β	SE	95% CI
	Overall SVI	60.14**	1.36	(57.47–62.81)
Theme 1	Socioeconomic status	25.56**	1.16	(23.30–27.83)
Theme 2	Household composition	23.49**	1.00	(21.53–25.45)
Theme 3	Minority/language status	10.99**	0.83	(9.36–12.61)
Theme 4	Housing/transportation	1.087	0.97	(−0.823–2.99)

SVI themes are outlined by the agency for toxic substances and disease registry of the Centers for Disease Control and Prevention (www.svi.cdc.gov)

SE standard error, *CI* confidence interval

**$p < 0.001$

adolescent engagement in sexual risk behaviors, and provide access to reproductive health resources (e.g., contraception and counseling), it is possible that teen pregnancy rates may be moderated despite high social vulnerability.

Our findings should be interpreted in light of some limitations. The data are cross-sectional in nature; thus, causal inferences cannot be made. The county-level is the smallest unit of analysis for which nationwide data on teen births are publicly available. As with all ecological studies, inferences about the nature of individuals cannot be deduced from the aggregate of the community or group being examined. Nonetheless, ecological analysis is often the method of choice when the unit of analysis is a geographically defined area (i.e., U.S. counties) where public health action is being considered. Another limitation is that, by nature of conducting a study of all counties in the U.S., regression model residuals of spatially contiguous units may be spatially autocorrelated. Thus, there is a possibility of downward-biased estimates of the standard errors. Though the SVI is a validated metric constructed using multiple dimensions of social vulnerability, SVI is only one means of measuring social vulnerability and may not be fully-comprehensive of all indicators. Nevertheless, the publicly-accessible, free, and interactive nature of the SVI make this a useful metric to identify communities in need of public health resources and evaluate efforts to address social vulnerability and associated adverse outcomes.

Conclusion

To our knowledge, this is the first study to apply the SVI to assess teen pregnancy in the United States. The patterns of association revealed between the SVI and teen pregnancy rates are notable and an important contribution to current scientific literature on social determinants, which indicate that whole communities rather than segments of a community are impacted by social and environmental determinants of health. As a key indicator of public health preparedness, social vulnerability may profoundly impact the quality of adolescent reproductive health including teen pregnancy risk. Findings from this study highlight the importance of designing policy interventions that target persistent social vulnerability in communities at elevated risk for teen pregnancy and provide greater understanding

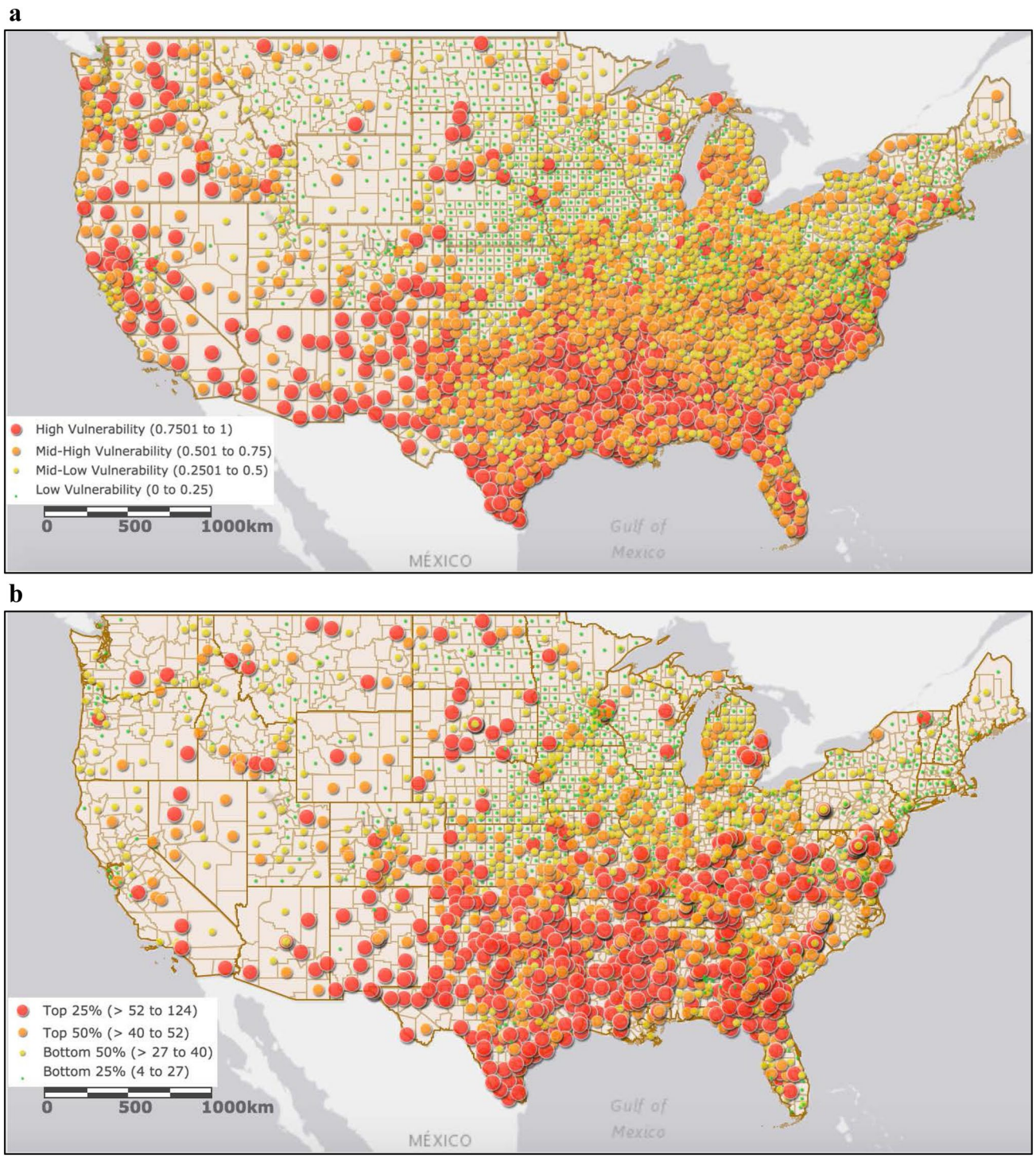

Fig. 2 **a** Map of U.S. county social vulnerability by quartile. **b** Map of U.S. country teen birth rates by quartile

of geographic variations in teen pregnancy outcomes. Future studies should explore applications of the SVI to identify populations in greatest need of teen pregnancy-related resources and for assessing the effectiveness of health policy interventions in the United States.

The rhetoric used to draw attention to public health concerns such as teen pregnancy can have powerful impacts in shifting the urgency with which politicians, researchers, and the general public demand to address the issue. The SVI measure may be used to validate language of resilience

Table 4 Association between social vulnerability and teen birth rates by Census region and division

Census region, division	n (%)	β	SE	95% CI
Northeast				
Division 1: New England	67 (2.1)	58.99**	9.79	(39.39–78.58)
Division 2: Middle Atlantic	150 (4.8)	61.16**	8.02	(45.30–77.00)
Midwest				
Division 3: East North Central	437 (13.9)	53.62**	3.40	(46.92–60.30)
Division 4: West North Central	618 (19.7)	55.71**	2.45	(50.90–60.52)
South				
Division 5: South Atlantic	588 (18.7)	55.71**	3.34	(49.15–62.28)
Division 6: East South Central	364 (11.6)	62.56**	6.28	(50.21–74.91)
Division 7: West South Central	470 (15.0)	66.75**	5.33	(56.26–77.22)
West				
Division 8: Mountain	281 (8.9)	56.05**	4.67	(46.85–65.33)
Division 9: Pacific	167 (5.3)	53.89**	7.44	(39.09–68.49)

Geographic regions as defined by U.S. Census Bureau. Nine Census divisions: New England—ME, NH, VT, MA, RI; Middle Atlantic—NY, PA, CT, NJ; East North Central—WI, IL, MI, IN, OH; West North Central—ND, SD, NE, KS, MN, IA, MO; South Atlantic—DE, MD, DC, WV, VA, NC, SC, GA, FL; East South Central—KY, TN, MS, AL; West South Central—TX, OK, AR, LA; Mountain—MT, ID, WY, NV, UT, AZ, CO, NM; Pacific—WA, OR, CA, AK, HI

**$p < 0.001$

regarding teen pregnancy, framing teen pregnancy risk as an unmet need within a community and seeking to empower the socially vulnerable rather than victimizing adolescent girls based on their health or pregnancy status. Findings from this study support an ongoing need for evidence-based teen pregnancy interventions in communities that are most vulnerable.

Acknowledgements This research was supported by the Yale Global Health Field Experience Award and Yale Global Health Seed Funding grant. The authors would like to thank Kristina Talbert-Slagle for project support and thoughtful critique of earlier drafts and Renee Mehra for mapping assistance.

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