Journal of the American Heart Association

ORIGINAL RESEARCH

Disparate Cardiovascular Hospitalization Trends Among Young and Middle-Aged Adults Within and Across Race and Ethnicity Groups in Four States in the United States

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BACKGROUND: Inpatient hospitalizations for cardiovascular disease (CVD) decreased nationally in the past decade. However, data are lacking on whether national declines represent trends within and across race and ethnicity populations from different US regions.

METHODS AND RESULTS: Using State Inpatient Databases, Census Bureau and Behavioral Risk Factor Surveillance System data for Florida, Kentucky, New Jersey, and North Carolina, we identified all CVD hospitalizations and population characteristics for adults aged 18 to 64 years between January 1, 2009 and December 31, 2018. We calculated yearly CVD hospitalization rates for each state for the overall population, by sex, race, and ethnicity. We modeled yearly trends in age-adjusted CVD hospitalization rate in each state using negative binomial regression. State base populations were similar by age (mean age: 40–42 years) and sex (50%–51% female) throughout the study period. There were 314 973 and 288 843 total CVD hospitalizations among the 4 states in 2009 and 2018, respectively. Crude hospitalization rates declined in all states (age 18–44 years NJ: –33.4%; KY: –17.0%; FL: –11.9%; NC: –11.2%; age 45–64 years NJ: –29.8%; KY: –20.3%; FL: –12.2%; NC: –11.6%) over the study period. In age-adjusted models, overall hospitalization rates declined significantly in NJ –2.5%/y (95% CI, –2.9 to –2.1) and in KY –1.6%/y (–1.9 to –1.2) with no significant declining trend in FL and NC. Similar findings were present by sex. Among non-Hispanic White populations, mean yearly decline in hospitalization rate was significant in all states except FL, with the greatest declines in NJ (–3.8%/y [–4.4 to –3.2], *P* values for state–year interaction <0.0001). By contrast, a significant declining trend was present for non-Hispanic Black and Hispanic populations only in NJ (*P* values for state–year interaction <0.001). We found similar differences in trend between states in sensitivity analyses incorporating additional demographic and comorbid characteristics.

CONCLUSIONS: Decreases in CVD hospitalization rates in the past decade among nonelderly adults varied considerably by state and appeared largely driven by declines among non-Hispanic White populations. Overall declines did not represent divergent trends between states within non-Hispanic Black and Hispanic populations. Recognition of differences not just between but also within race and ethnicity populations should inform national and local policy initiatives aimed at reducing disparities in CVD outcomes.

Key Words: behavioral risk factor surveillance system ■ cardiovascular epidemiology ■ cardiovascular hospitalization ■ health disparities ■ health policy ■ middle-aged adult ■ young adult

Cardiovascular disease (CVD) is the leading primary cause of inpatient hospitalization and mortality among adults in the United States.[1,2] In the past decade, the total number of inpatient hospitalizations for CVD decreased nationally, with recent data suggesting a decline from ≈5.6 to 5.0 million total hospitalizations

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Supplemental Material is available at https://www.ahajournals.org/doi/suppl/10.1161/JAHA.122.027342

For Sources of Funding and Disclosures, see page 10.

JAHA is available at: www.ahajournals.org/journal/jaha

CLINICAL PERSPECTIVE

What Is New?

- Trends in overall cardiovascular hospitalization rates in the past decade among young and middle-aged adults varied significantly by state, and declines appeared to be driven primarily by improvements in rates among non-Hispanic White populations.
- There were divergent cardiovascular hospitalization trends between states within non-Hispanic Black and Hispanic populations where hospitalization rates did not improve significantly or even worsened in some states despite an overall decline in rates for the state population as a whole.

What Are the Clinical Implications?

- Among young and middle-aged adults, there were disparate cardiovascular hospitalization trends not only within race and ethnicity groups *between* states but also worsening of disparate hospitalization rates between these populations *within* states.
- Because these differences were not driven by changes in major state-level socioeconomic factors or comorbidities over time, state health or other policy directives may have contributed to these differential outcomes within race and ethnicity groups between states.
- Recognition of differences not just between but also within race and ethnicity groups will be important in formulating successful national and local policy initiatives aimed at reducing disparities in cardiovascular outcomes.

Nonstandard Abbreviations and Acronyms

BRFSS	Behavioral Risk Factor Surveillance System

between 2008 and 2018.[1] Many CVD events are considered preventable with risk factor mitigation, especially in adults <65 years of age who account for over one-third of CVD hospitalizations.[3,4] Decreasing the burden of CVD has been a focus of major national public health initiatives in the past decade and presently.[5–7] A significant change in federal health policy also occurred during this time with the Affordable Care Act signed into law in 2010, intended to expand health insurance and thus health care access to millions of nonelderly adults. Cardiovascular hospitalizations represent an important measure of effective CVD prevention because many life-changing CVD events do not result in death, especially in nonelderly adult populations.

The highest CVD mortality rates among southern US states[1,8–11] and among Black populations are examples of well-documented disparate geographic, racial, and ethnic CVD outcomes.[1,12] Despite improvements in many of the national cardiovascular health objectives in the past decade set by federal initiatives such as Healthy People 2020, geographic, racial, and ethnic disparities nevertheless have persisted.[13,14] It is also of concern that recent data have suggested that CVD prevalence may be increasing in younger and middle-aged populations.[1,4,15,16] Indeed, CVD mortality rates appeared to decelerate in the first half of the past decade,[17] with increases in total CVD deaths by the end of the decade.[1] These factors have led recent national CVD prevention initiatives to identify nonelderly adults and certain groups based on race and ethnicity as "priority" populations in which to improve CVD outcomes.[6,18] Despite this focus and substantial geographic variation in outcomes, there is currently a dearth of data on whether there are divergent hospitalization trends within race and ethnicity groups residing in different states. Geographic differences in hospitalization trends for populations with disproportionate CVD burdens may be masked within national-level data. Such information is imperative to understanding the possible impact of CVD preventive initiatives on disparities. In this study, we investigated whether state of residence was associated with disparate CVD hospitalization trends both within and between non-Hispanic Black, Hispanic, and non-Hispanic White populations.

METHODS

All data used in this study are publicly available and can either be accessed freely directly from the organizations online (Census Bureau, Behavioral Risk Factor Surveillance System [BRFSS]) or by request to the organization (State Inpatient Databases).

Data Sources

We utilized hospitalization data for January 1, 2009 to December 31, 2018 from the Agency for Healthcare Research and Quality Healthcare Cost and Utilization Project State Inpatient Databases, which provides a census of inpatient hospitalizations for each state.[19] The study was approved by the Rutgers University Institutional Review Board. Because the data are publicly available, informed consent was not applicable. We obtained data from 4 states, which represent diverse populations with variation in CVD mortality and burden, insured population rates, and state health policy (eg, Medicaid expansion): New Jersey, Kentucky, North Carolina, and Florida. New Jersey and Kentucky participated in the Affordable Care Act Medicaid Expansion

on January 1, 2014. Race and ethnicity information in the databases is provided by Healthcare Cost and Utilization Project State Partners based on data from hospitals. The Joint Commission, which accredits US hospitals, set an official standard in 2011 that hospitals should collect race and ethnicity data and do so by patient self-report (allowing for patients to decline to provide this information). However, there is no standardized fashion in which hospitals collect this information.[20]

We defined hospitalizations for CVD causes, using *International Classification of Diseases, Ninth Revision (ICD-9)* and *Tenth Revision (ICD-10)* diagnosis codes. We identified all CVD hospitalizations with *ICD-9* diagnosis codes 390–459 or *ICD-10* diagnosis codes I00-I99 listed as the principal (position 1) discharge diagnosis. These *ICD* codes are commonly utilized as a group to represent all CVD diagnoses.[1] The transition from *ICD-9* to *ICD-10* diagnostic codes occurred in October 2015.

We determined the overall sex, race, and ethnicity based adult populations for each calendar year within each state using publicly available population data from the Census Bureau.[21] We calculated the mean age for the overall population and aforementioned subpopulations within each state. Census data also provided education (percent of population with a bachelor's degree or higher) for each state population as well as state-level household income data.[22,23] These sociodemographic data from the decennial census and other periodic surveys conducted by the Census Bureau are self-reported. We obtained population-level prevalence of chronic diseases in each state from the Centers for Disease Control and Prevention BRFSS. These data are a well-established source of state-level prevalence data for chronic health conditions and health behaviors in the United States, based on yearly self-reported survey data collected by telephone interview of US residents that is weighted to be representative of each state population.[24] We also used the BRFSS data to collect the estimated proportions of each subpopulation with low income and residence in rural areas (defined as not living in a Metropolitan Statistical Area per the Federal Office of Management and Budget definition)[25] because these data are more limited by sex, race, and ethnicity in Census Bureau data. Because of the change in weighting methodology for BRFSS starting in 2011, which does not allow for direct comparison of yearly prevalence data before (pre-2011) and after (2011-onwards) this change, we used linear regression-based imputation to estimate values for 2009 and 2010 BRFSS variables. We also imputed data for variables not included in even years of the survey (hypertension and cholesterol awareness questions were not included in the survey in even years) along with education data for 2009 that were not publicly available from the Census Bureau. These data were not available at all for these aforementioned years from these data sources and thus were imputed via the aforementioned methodology. We determined based on review of the available data points that the assumption of a linear relationship between missing data and year (time) that is made in this imputation method would be acceptable.[26]

Cardiovascular Disease Hospitalization Rates

Using the state-specific data from the Census Bureau as the denominator, we first calculated yearly CVD hospitalization rates for the overall population and subpopulations defined by sex, race, and ethnicity for each state. We plotted yearly hospitalization rates by 18 to 44 years ("younger") and 45 to 64 years ("middle-aged") groups to illustrate the crude yearly trends in overall populations and subpopulations in each age group.

Statistical Analysis

We used negative binomial regression to model time trend for CVD hospitalizations. The dependent variable was quarterly hospitalization rate calculated as number of hospitalizations per quarter divided by the base population in each study year, assuming a stable base population within the year. The model initially included terms for state (New Jersey as a referent), calendar year, state–year trend interaction, and mean age of the base population. We selected New Jersey as the referent based on the observed crude trends showing New Jersey having the lowest CVD hospitalization rates. We repeated models for each subpopulation defined by sex, race, and ethnicity groups. Kentucky was not included in the models for Hispanic populations because the Hispanic population in Kentucky was too small for accurate model estimates.

In sensitivity analyses to investigate whether any observed differences among states or subgroups in the yearly trends were robust to changes in population characteristics over time, we fit multivariable models incorporating sex, race, and ethnicity-specific adult population demographic and comorbidity prevalence data from the Census Bureau and BRFSS. The following additional sociodemographic variables were considered for inclusion: percent of adult population with a bachelor's degree or greater, percent of population in a rural residence and percent with income <$35 000. Comorbid variables including prevalence of obesity, high cholesterol, hypertension, chronic obstructive pulmonary disease, asthma, diabetes, malignancy, chronic kidney disease, depression, and smoking were also considered.

Two-sided P values <0.05 were deemed statistically significant. All statistical analyses were performed with SAS Enterprise Guide version 8.3 (SAS Institute Inc., Cary, NC).

RESULTS

Population Demographics

Basic demographics for the overall base population in each state are presented in Table 1. Mean age (40–42 years) and female proportion (50%–51%) of the 18-to-64-year-old populations for each state were similar. Race and ethnicity compositions expectedly differed by state. There was a higher proportion of Hispanic persons in most states at the end of the study period. Cardiovascular risk factors including diabetes, obesity, high cholesterol, and hypertension were common in all states. Diabetes prevalence was higher in each state at the end of the study period. Obesity prevalence was higher in the end of the study period for most states. State population characteristics by sex, race, and ethnicity are presented in Table S1. Mean ages for the non-Hispanic Black (39–40 years) and Hispanic (35–37 years for North Carolina, otherwise 38–40 for other states) populations during the study period were lower than for the White (41–43 years) populations for each state. A greater proportion of the non-Hispanic Black and Hispanic populations in each state had a low income (Table S1). Within each state, proportions of populations with obesity, or a diagnosis of hypertension or diabetes were generally highest among Black populations. However, there was significant variability between states in the prevalence of most comorbid characteristics by sex, race, and ethnicity (Table S1). Among major CVD risk health factors (diabetes, hypertension, high cholesterol, and obesity) and health behaviors included in the study (smoking),[1,27] Kentucky had the highest proportions of populations for each sex, race, and ethnicity group with at least 1 or more CVD risk factors (Table S2). For each state, the highest proportions of persons with multiple CVD risk factors were among the non-Hispanic Black and White populations (Table S2). Basic demographics of the population hospitalized for CVD in each state can be found in Table S3. There were 314 973 and 288 843 total CVD hospitalizations among the 4 states in 2009 and 2018, respectively. The proportion of the hospitalized population with Medicaid increased most significantly in New Jersey and Kentucky, with the uninsured proportion declining in these states during the study period, whereas the uninsured proportion did not decline in Florida and North Carolina.

Yearly Cardiovascular Hospitalization Rates

Yearly trends in crude CVD hospitalization rate for overall populations and subpopulations defined by sex, race, and ethnicity within the 45-to 64-year-old age group are presented in Figure 1. For the overall population for each state, Kentucky had the highest yearly CVD hospitalization rates throughout the study period. Cardiovascular hospitalization rates declined in all states. Decline in hospitalization rates appeared to decelerate later in the study period in all states, most apparently in Kentucky, Florida, and North Carolina. Hospitalization rates were higher among men compared with women for each state; however, trends over time appeared grossly similar to the overall population patterns.

By contrast, whereas for the non-Hispanic White middle-aged populations in each state, yearly trends in CVD hospitalization rates grossly mirrored overall declining trends over the time period, CVD hospitalization rates for non-Hispanic Black populations were actually higher in Kentucky and North Carolina at the end of the study period (Figure 1). Non-Hispanic Black populations had higher CVD hospitalization rates in every state compared with non-Hispanic White populations. Among Hispanic populations, CVD hospitalization rates declined in New Jersey, whereas rates were higher at the end of the time period in Florida and North Carolina. Of interest, hospitalization rates for non-Hispanic Black populations in New Jersey were among the highest at the beginning of the time period but were the lowest at the end.

Yearly trends in crude CVD hospitalization rate overall, and by sex, race, and ethnicity within the 18-to-44-year-old age group are presented in Figure 2. Overall CVD hospitalization rates were lower than those in the 45-to-64-year-old population. However, similar patterns as in the middle-aged population were present with non-Hispanic White populations in all states experiencing declines in hospitalization rates, but comparable declines were only present among non-Hispanic Black and Hispanic populations in New Jersey.

Negative Binomial Regression Analyses

In the age-adjusted regression models (Table 2) for overall populations, the mean yearly change in hospitalization rate in New Jersey was –2.5%/y (95% CI, –2.9 to –2.1) and in Kentucky –1.6%/y (95% CI, –1.9 to –1.2) with no significant decreasing trend in Florida and North Carolina for the overall study period. Similar patterns in trends were observed by sex. Among non-Hispanic White populations, there was a significant yearly decline in hospitalization rate in all states except Florida, with the greatest mean yearly decline in New Jersey (–3.8%/y [95% CI, –4.4 to –3.2]) Notably, among the non-Hispanic White population in North Carolina there was a significant mean yearly decline despite this not being the case for the overall population. By contrast, a significant decline was present for non-Hispanic Black and Hispanic populations only in New Jersey. For the non-Hispanic Black population in

Table 1. Nonelderly Adult Demographic and Comorbidity Characteristics by State and Year*

Year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Mean age, y										
New Jersey	41.0	41.2	41.3	41.3	41.3	41.4	41.4	41.5	41.5	41.5
Kentucky	40.6	40.9	41.0	41.0	40.9	41.0	41.0	41.0	41.0	41.0
Florida	40.8	41.1	41.2	41.2	41.2	41.2	41.3	41.3	41.3	41.4
North Carolina	40.3	40.5	40.6	40.6	40.7	40.7	40.8	40.7	40.8	40.8
Age ≥45 y, %										
New Jersey	43.2	43.9	44.2	44.3	44.4	44.6	44.8	44.9	44.8	44.6
Kentucky	42.2	43.2	43.4	43.3	43.2	43.2	43.3	43.4	43.2	43.1
Florida	42.8	44.1	44.3	44.1	44.0	44.0	44.1	44.2	44.2	44.1
North Carolina	40.9	41.6	42.0	42.0	42.0	42.2	42.5	42.6	42.7	42.5
Female, %										
New Jersey	50.2	50.7	50.7	50.6	50.6	50.5	50.5	50.5	50.5	50.4
Kentucky	50.2	50.2	50.3	50.2	50.2	50.2	50.2	50.2	50.1	50.1
Florida	50.0	50.7	50.6	50.6	50.6	50.6	50.6	50.6	50.6	50.5
North Carolina	50.5	50.8	50.9	50.9	50.9	50.9	50.9	50.9	50.9	50.9
Non-Hispanic Black, %										
New Jersey	13.3	13.1	13.2	13.3	13.3	13.4	13.4	13.4	13.5	13.5
Kentucky	7.6	7.8	8.0	8.1	8.2	8.3	8.3	8.4	8.5	8.5
Florida	15.6	15.7	15.9	16.1	16.2	16.3	16.4	16.4	16.4	16.4
North Carolina	21.5	21.5	21.7	21.8	22.0	22.1	22.1	22.1	22.1	22.1
Non-Hispanic White, %										
New Jersey	60.7	58.6	58.0	57.3	56.7	56.2	55.6	55.0	54.4	53.8
Kentucky	87.8	86.9	86.6	86.3	86.0	85.7	85.5	85.2	84.9	84.6
Florida	58.3	56.7	56.0	55.1	54.3	53.6	52.9	52.2	51.5	50.8
North Carolina	67.5	65.9	65.6	65.2	64.8	64.4	64.1	63.7	63.3	62.8
Hispanic, %										
New Jersey	16.7	18.1	18.5	18.8	19.2	19.5	19.8	20.2	20.5	20.9
Kentucky	2.4	2.9	3.0	3.1	3.2	3.2	3.2	3.3	3.5	3.6
Florida	22.2	23.4	23.8	24.4	25.0	25.5	26.1	26.7	27.3	27.9
North Carolina	6.8	7.9	7.9	8.0	8.1	8.2	8.4	8.5	8.7	9.0
Bachelor's degree or greater, %										
New Jersey	34.8	35.4	35.3	36.2	36.6	37.4	37.6	38.6	39.7	40.8
Kentucky	20.5	20.5	21.1	21.8	22.6	22.2	23.3	23.4	24.0	24.8
Florida	25.2	25.8	25.8	26.8	27.2	27.3	28.4	28.6	29.7	30.4
North Carolina	26.3	26.5	26.9	27.4	28.4	28.7	29.4	30.4	31.3	31.9
Median income, $										
New Jersey	77 375	73 993	71 014	74 399	70 083	70 525	73 764	72 943	74 299	75 520
Kentucky	50 961	48 301	45 403	45 834	49 334	46 250	45 740	48 335	51 805	55 543
Florida	54 505	51 782	51 383	51 395	53 350	49 876	52 687	54 521	55 365	55 634
North Carolina	50 056	51 504	51 498	46 355	50 937	50 572	54 815	57 278	51 674	54 336
Income <$35 000										
New Jersey	30.9	30.1	29.0	28.2	27.5	27.3	25.0	25.5	25.4	21.8
Kentucky	37.1	36.2	30.9	41.9	28.5	39.2	25.8	32.7	25.8	31.7
Florida	43.9	42.8	41.5	40.6	41.1	38.3	35.8	34.5	37.4	33.9
North Carolina	42.5	41.2	38.8	39.3	37.5	36.0	34.5	33.7	33.1	29.3
Rural residence classification, %										
New Jersey	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kentucky	37.8	35.4	33.2	29.7	28.1	28.2	22.1	19.5	17.6	17.4
Florida	8.6	7.6	7.2	5.9	4.8	3.6	1.6	1.2	1.0	1.2
North Carolina	31.0	27.9	26.1	21.3	19.7	15.4	9.9	7.3	5.9	6.0
Hypertension, %										
New Jersey	29.6	29.9	30.5	30.6	31.0	31.3	30.8	32.0	32.9	32.7
Kentucky	37.7	37.9	37.9	38.3	39.0	38.8	38.9	39.2	39.3	39.6
Florida	34.1	34.1	34.1	34.1	34.5	34.1	33.3	34.1	34.4	34.0
North Carolina	32.6	33.0	32.3	33.7	35.4	34.4	35.1	35.1	34.7	35.7
High cholesterol, %										
New Jersey	38.9	38.4	36.7	37.3	38.9	36.3	35.0	35.3	34.6	34.2

(*Continued*)

Table 1. Continued

Year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Kentucky	43.4	42.8	41.0	41.7	42.9	40.6	40.4	39.5	38.1	38.3
Florida	43.6	42.7	41.6	40.7	40.0	38.8	37.7	36.8	35.9	34.9
North Carolina	40.8	40.2	38.2	39.0	40.6	37.8	36.8	36.6	35.5	35.4
Diabetes, %										
New Jersey	8.2	8.4	8.8	9.3	9.2	9.6	9.0	9.2	11.0	10.7
Kentucky	9.6	10.0	10.7	10.7	10.6	12.4	13.4	13.1	12.8	13.7
Florida	10.4	10.5	10.3	11.3	11.1	11.2	11.3	11.7	10.5	12.6
North Carolina	10.1	10.3	10.8	10.4	11.4	10.8	10.7	11.2	11.3	12.5
Asthma, %										
New Jersey	8.9	8.8	8.9	8.6	9.0	8.2	7.2	8.2	8.6	8.4
Kentucky	10.2	10.3	10.3	11.0	9.4	11.8	11.8	11.5	10.7	11.4
Florida	7.8	7.8	7.5	8.1	8.2	8.0	7.4	6.7	7.4	8.7
North Carolina	7.7	7.8	8.8	7.6	8.4	7.7	8.1	8.0	9.1	9.3
COPD, %										
New Jersey	5.2	5.3	5.1	5.5	5.9	5.6	5.0	6.2	6.1	5.5
Kentucky	10.0	10.3	9.8	11.2	10.9	12.2	12.0	11.4	12.1	12.1
Florida	7.4	7.4	7.9	7.6	7.3	7.6	6.9	7.1	7.8	8.3
North Carolina	6.6	6.7	6.8	6.8	7.4	7.8	7.4	7.3	7.7	8.1
Smoking, %										
New Jersey	17.7	17.1	16.7	16.6	14.8	14.2	12.9	13.3	13.1	12.3
Kentucky	29.6	28.8	28.8	27.5	25.3	25.1	25.1	23.8	23.8	22.7
Florida	19.5	18.9	19.2	17.3	16.1	16.4	14.9	14.5	15.3	13.8
North Carolina	22.8	22.1	21.7	20.6	19.9	18.3	18.4	17.3	16.5	16.7
Obesity, %										
New Jersey	22.9	23.0	21.9	22.5	24.0	24.6	22.6	24.0	23.6	22.1
Kentucky	27.5	28.1	28.4	29.6	31.2	29.6	32.2	31.9	31.7	34.1
Florida	23.8	24.0	25.2	23.8	25.0	24.3	24.7	24.5	25.0	27.0
North Carolina	26.1	26.4	27.2	27.7	27.3	26.9	26.9	29.0	29.0	29.7
Chronic kidney disease, %										
New Jersey	1.8	1.9	2.0	2.3	2.4	2.4	2.0	2.6	2.7	3.1
Kentucky	2.0	2.3	2.5	3.0	2.7	3.4	3.0	3.6	4.0	4.2
Florida	3.5	3.5	3.2	3.5	3.4	3.8	3.0	3.2	2.8	3.4
North Carolina	1.8	2.0	2.2	2.6	2.5	2.6	2.8	3.2	4.2	3.2
Malignancy, %										
New Jersey	5.2	5.3	5.5	5.7	6.2	6.0	5.8	6.1	6.4	7.1
Kentucky	6.7	6.9	7.0	7.0	7.3	8.1	7.8	7.2	8.4	8.1
Florida	7.1	7.1	7.4	7.1	7.5	7.2	7.4	7.5	7.6	7.9
North Carolina	6.2	6.3	6.5	6.4	6.3	6.2	7.2	6.2	6.7	7.0
Depression, %										
New Jersey	12.3	12.4	11.0	13.0	13.8	13.3	12.6	12.1	14.7	11.7
Kentucky	19.6	20.0	19.6	23.4	20.1	23.8	18.7	23.2	24.2	23.9
Florida	16.9	16.7	16.3	16.8	16.6	16.1	16.4	14.2	17.0	15.5
North Carolina	16.9	17.2	17.4	17.5	18.6	18.9	18.7	18.2	19.9	19.7

*Age, sex, race, and ethnicity are specific to the age 18-to-64-years population. Bachelor's degree or higher data are for adults 25 years or older. All other data are for the entire adult population (≥18 years). Income <$35 000, rural residence, and all comorbidity data come from the Behavioral Risk Factor Surveillance System (BRFSS). All other data are from the Census Bureau. COPD indicates chronic obstructive pulmonary disease.

Kentucky, there was a significant mean yearly increase in hospitalization rate (+1.6%/y [95% CI, 0.8–2.4]). The differences in yearly trends between states for overall populations, by sex, race, and ethnicity were statistically significant (Table 2, *P* value for state–year interaction with New Jersey as referent is <0.0001 for all except *P*=0.0008 for North Carolina compared with New Jersey for Hispanic populations) consistent with a greater decline in hospitalization rates in New Jersey relative to the other states for each subpopulation over the study period as observed graphically (Figures 1 and 2).

In sensitivity analyses with multivariable models for each subpopulation additionally adjusted for yearly subpopulation specific state demographic and comorbid characteristics, non-Hispanic White populations had significant yearly declines in hospitalization rate in all states, with the greatest declines in New Jersey, similar to the age-adjusted models (*P* value for state–year interaction all <0.002 with New Jersey as the referent,

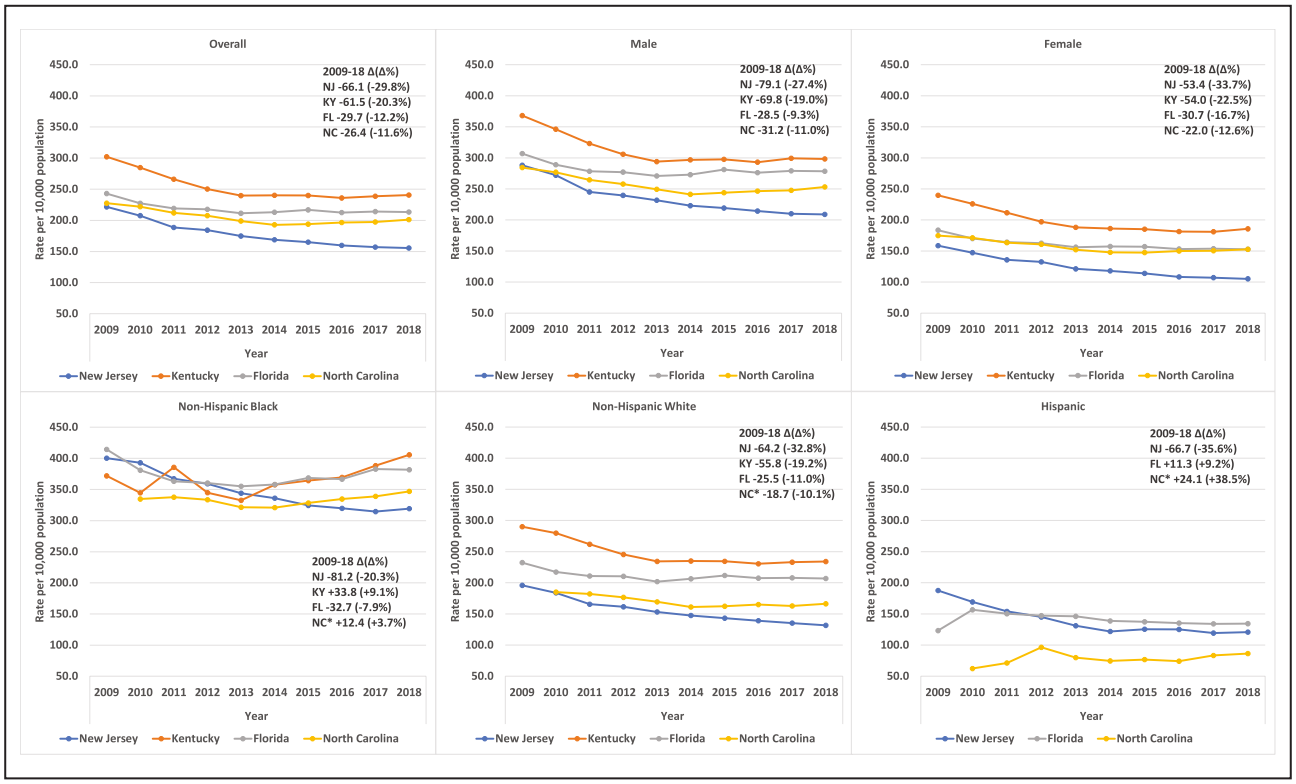

Figure 1. State yearly cardiovascular hospitalization rate overall, by sex and race and ethnicity for 45-to-64-years age group, 2009 to 2018.
*No race and ethnicity data were available for North Carolina in 2009.

see Table S4). Findings for non-Hispanic Black and Hispanic populations were similar to the age-adjusted models. Given the presence of multiple modest to high-level correlations, some population characteristic covariates were excluded from final models. Final models included mean age, income, high cholesterol, diabetes, chronic kidney disease, and obesity based on univariate analysis, bivariate correlations along with inspection of variance inflation factors to aid in assessing for multicollinearity.

DISCUSSION

In this study, we investigated whether there were disparate trends in CVD hospitalizations within different race and ethnicity populations based on state of residence. We found that observed declines in overall CVD hospitalization rates in the past decade among young and middle-aged adults appeared to be driven primarily by improvements in rates within the non-Hispanic White population with regard to race and ethnicity. Furthermore, for non-Hispanic Black and Hispanic populations, only in New Jersey did these populations experience a significant improvement in CVD hospitalization rates during the study period whereas in other states, rates either did not improve as significantly or even potentially worsened. Within every sex, racial, and ethnic subpopulation, the greatest declines in CVD hospitalization rates appeared to occur in New Jersey regardless of whether the rates were among the highest or lowest at the start of the study period.

Our findings represent not only disparate trends *within* race and ethnicity populations *between* states but also worsening of disparate CVD hospitalization rates *between* race and ethnicity populations *within* states. A previous study of adults ≥35 years in a large commercially insured cohort in California noted significant declines in hospitalizations for acute myocardial infarction occurring between 2000 and 2014 for all race and ethnicity groups during the study period.[28] A study of Medicare beneficiaries ≥65 years suggested greater increases in hospitalization rates for acute hypertension from 1999 to 2019 among non-Hispanic Black, Asian, Hispanic, and Native Americans compared with White beneficiaries with significant differences in cross-sectional rates by US county but no comparison of trends over time between counties.[29] A study of hospitalization data in 2016 found marked variation in fatal and nonfatal CVD events among adults by state with the highest overall rates among non-Hispanic Black patients, but no comparison between states or multiyear trend analysis.[4] Despite race, ethnicity, and geographic disparities in CVD prevalence and outcomes being well documented,[1] there is a dearth of data comparing

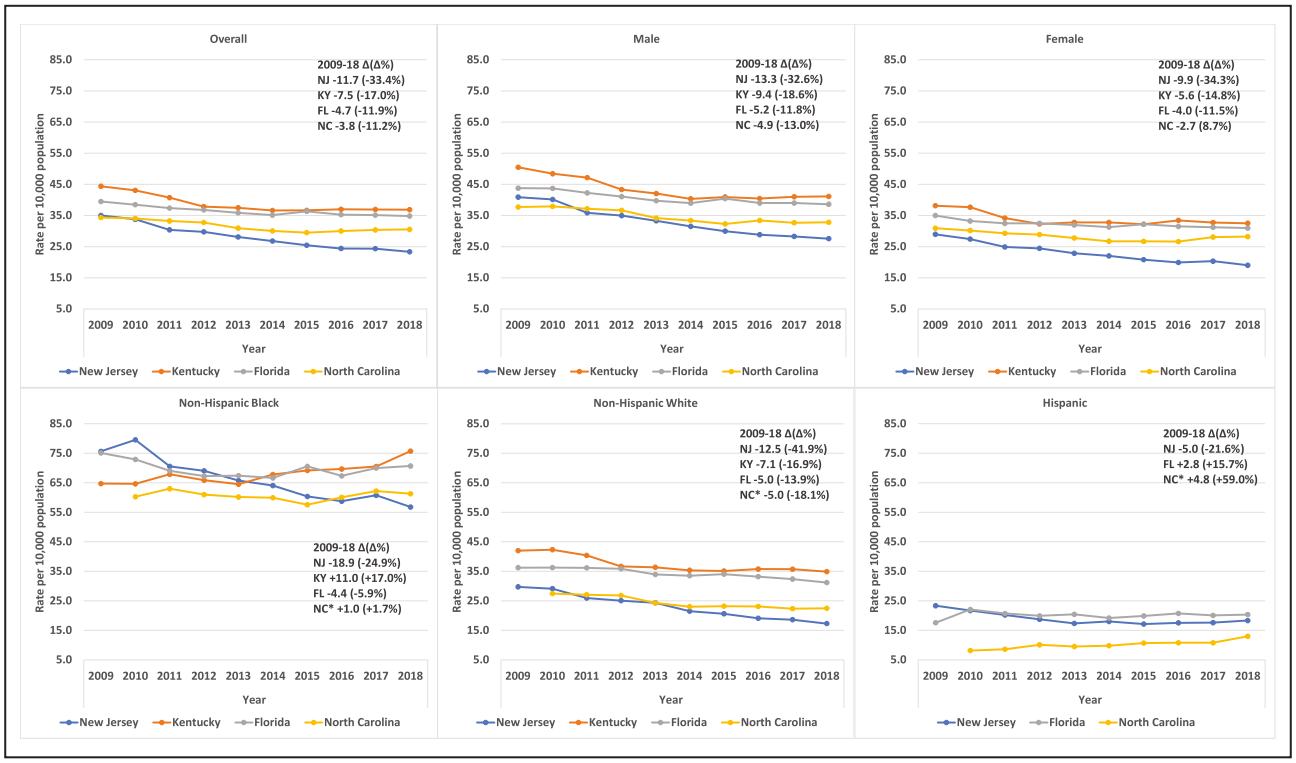

Figure 2. State yearly cardiovascular hospitalization rate overall, by sex, race, and ethnicity for 18-to-44-years age group, 2009 to 2018.
*No race and ethnicity data were available for North Carolina in 2009.

hospitalization trends over time between states for subpopulations that share a disproportionate burden of CVD. The National Academy of Medicine (formerly the Institute of Medicine) has stated that greater understanding and surveillance of CVD disparities at the state and local level are essential to eliminating disparities.[30] Our study adds to the current literature in 3 significant ways. First, we demonstrate that overall improvements in CVD hospitalizations did not necessarily extend to non-Hispanic Black and Hispanic populations and may have even masked worsened trends in some cases. Second, the degree of improvement, if any, in CVD hospitalization rate within these subpopulations varied widely among states. Lastly, we demonstrate these findings in young and middle-aged adults, a population of special concern in CVD preventive efforts in light of recent data suggesting possible worsening of CVD prevalence in these populations. These findings have potential implications for both national and state level initiatives past and present to improve CVD outcomes in all populations, especially given recent deceleration in declines in CVD mortality.[17]

Present Study in Context

The past decade saw major public health initiatives. The federal government's Healthy People 2020 set multiple public health objectives in 2010, including improving cardiovascular health over the decade.[5] There was also the Million Hearts Initiative launched in 2011 with the goal to prevent 1 million strokes and myocardial infarctions within 5 years.[7] The Affordable Care Act was signed into law in 2010 with implementation of many major provisions in early 2014, which data suggest led to expansion of health insurance access and narrowing of race and ethnicity differences in coverage.[31] In major national initiatives such as Healthy People 2020 (and now Healthy People 2030) which many states and local agencies use as a guide for their initiatives,[32] there is a clear recognition and emphasis on the need to reduce socioeconomic, sex, racial, and ethnic disparities in CVD risk factors and outcomes.[33,34] There were significant improvements in multiple Healthy People 2020 cardiovascular health objectives during the past decade, including achievement of a 20% reduction in coronary artery disease and stroke mortality on a national level and among most subpopulations; however, socioeconomic, geographic, racial, and ethnic disparities have persisted.[13,14]

We demonstrated that non-Hispanic Black and Hispanic populations experienced significant improvements in CVD hospitalization rates in New Jersey but not in the other states under study. Our analyses suggest that these within-race and ethnicity population and between-state differences were not necessarily

Table 2. Estimated Mean Percent Change in Yearly Cardiovascular Hospitalization Rate from Age-Adjusted Negative Binomial Regression Models and State–Year Interaction

State	Mean percent change in hospitalization rate per year (95% CI)	*P* value for state–year interaction
Overall		
New Jersey	−2.5% (−2.9 to −2.1)	Referent
Kentucky	−1.6% (−1.9 to −1.2)	<0.0001
Florida	+0.2% (−0.2 to 0.5)	<0.0001
North Carolina	−0.2% (−0.6 to 0.2)	<0.0001
Male		
New Jersey	−2.5% (−2.9 to −2.2)	Referent
Kentucky	−1.7% (−2.1 to −1.5)	<0.0001
Florida	+0.1% (−0.2 to 0.4)	<0.0001
North Carolina	−0.5% (−0.8 to −0.2)	<0.0001
Female		
New Jersey	−2.5% (−2.9 to −2.2)	Referent
Kentucky	−1.2% (−1.5 to −0.9)	<0.0001
Florida	+0.2% (−0.1 to 0.6)	<0.0001
North Carolina	+0.2% (−0.1 to 0.5)	<0.0001
Non-Hispanic Black		
New Jersey	−1.7% (−2.7 to −0.8)	Referent
Kentucky	+1.6% (0.8 to 2.4)	<0.0001
Florida	+0.7% (−0.4 to 1.7)	<0.0001
North Carolina	+0.5% (−0.2 to 1.3)	<0.0001
Non-Hispanic White		
New Jersey	−3.8% (−4.4 to −3.2)	Referent
Kentucky	−1.8% (−2.4 to −1.3)	<0.0001
Florida	−0.5% (−1.0 to 0.1)	<0.0001
North Carolina	−1.4% (−2.0 to −0.8)	<0.0001
Hispanic		
New Jersey	−6.2% (−9.4 to −2.8)	Referent
Florida	−2.3% (−5.3 to 0.8)	<0.0001
North Carolina	−0.2% (−6.3 to 6.4)	0.0008

driven by changes in major state-level socioeconomic factors or comorbidities over time. It is notable that the CVD hospitalization rates in New Jersey for these groups started among the highest at the beginning of the study period compared with the other states under study. Because many CVD events are considered preventable, especially in younger and middle-aged adults,[3] reductions in CVD hospitalization rates represent an important marker of successful preventive efforts, which reliance on mortality as an indicator alone may not fully capture. While causality cannot be established in this observational study, it is reasonable to consider that state-level health or other policy directives may have contributed to these differential outcomes within sex, race, and ethnicity populations between states.

While it is important to recognize that state and local policies must be tailored to their underlying populations, this study and future studies investigating differences in how populations with disparate CVD burdens fare over time based on residence should prompt consideration about whether successes in 1 state could help guide effectuation of more impactful policy interventions in others. Interventions that not only reduce disparate health outcomes between groups but also within these populations will contribute most to improvements in overall population health and to achieving the elimination of health disparities.

Our findings should be viewed with some important limitations in mind. Although the BRFSS is a trusted source of state-level prevalence data, the data are self-reported and thus can be subject to response and other forms of bias, which in turn could have affected our sensitivity analyses attempting to account for population characteristics over time. Race and ethnicity data in the State Inpatient Databases are provided by states based on data from hospitals. Although collection of self-reported race and ethnicity data by hospitals is a widely accepted standard, there is no formal standardized manner in which hospitals collect this information. Thus, we cannot exclude the possibility that differences between or within states could have affected calculated hospitalization rates. We defined CVD hospitalizations based on the *ICD* diagnosis codes for any CVD disorder listed as the principal discharge diagnosis. Although use of these codes is a common method for identifying CVD hospitalizations,[1] there is the inherent possibility of inaccurate identification of hospitalizations when relying on administrative data. *ICD-9* codes transitioned to *ICD-10* diagnosis codes in the United States in October 2015, which could have affected observed trends in hospitalization rates. Although any potential bias introduced into the data would not be expected to manifest differentially between subpopulations, this transition should nevertheless be kept in mind when interpreting trends across the study period. Because of limitations related to population size, we focused on analyses in non-Hispanic Black, non-Hispanic White, and Hispanic populations. Therefore, our findings may not be generalizable to other race and ethnicity-based populations and do not address potential heterogeneity within these race and ethnicity populations. Finally, our findings cannot be presumed to be applicable to other states.

CONCLUSIONS

Decreases in CVD hospitalization rates in the past decade among nonelderly adults varied considerably by state and appeared to be largely driven by declines among non-Hispanic White populations. Overall

declines did not represent divergent trends between states within non-Hispanic Black and Hispanic populations. Recognition of differences not just between but also within race and ethnicity groups should inform national and local policy initiatives aimed at reducing disparities in CVD outcomes.

ARTICLE INFORMATION

Received June 28, 2022; accepted October 17, 2022.

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Acknowledgments

This study examined hospitalizations using discharge data from the State Inpatient Databases of the following states: Florida, Kentucky, New Jersey, and North Carolina. We thank these states and the Agency for Healthcare Research and Quality Healthcare Cost and Utilization Project for making these data publicly available.

Sources of Funding

None.

Disclosures

The authors have no disclosures relevant to the content of this manuscript.

Supplemental Material

Table S1–S4

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SUPPLEMENTAL MATERIAL

Table S1. Non-Elderly Adult State Population Demographic and Comorbidity Characteristics by Sex, Race and Ethnicity Group for Select Study Years

	New Jersey			Kentucky‡			Florida			North Carolina		
Year	**2009**	**2013**	**2018**	**2009**	**2013**	**2018**	**2009**	**2013**	**2018**	**2009**	**2013**	**2018**
Mean Age (years)*												
Non-Hispanic Black	39.2	39.9	40.4	38.2	39.0	39.1	38.2	38.8	39.3	39.1	39.8	40.0
Hispanic	38.0	38.1	39.0	---	---	---	38.6	39.1	39.8	35.2	35.6	36.8
Non-Hispanic White	42.5	43.0	43.0	41.0	41.5	41.5	42.5	43.0	43.1	41.3	41.8	41.9
Male	40.7	41.0	41.2	40.3	40.7	40.7	40.4	40.8	41.0	39.9	40.3	40.4
Female	41.3	41.6	41.8	40.9	41.2	41.3	41.3	41.5	41.8	40.7	41.0	41.1
Female*, %												
Non-Hispanic Black	52.6	53.0	52.3	50.3	49.6	49.3	52.0	52.2	51.9	53.4	53.5	53.3
Hispanic	47.9	49.2	49.3	---	---	---	47.7	50.0	49.8	41.1	46.0	47.3
Non-Hispanic White	50.2	50.3	50.1	50.5	50.4	50.4	50.2	50.2	50.2	50.4	50.5	50.4
Bachelor's degree or greater*, %												
Non-Hispanic Black	19.4	20.8	25.6	14.0	15.5	17.1	14.4	17.4	20.1	14.7	18.9	21.7
Hispanic	13.6	16.7	20.9	---	---	---	20.3	21.5	25.5	10.5	12.8	15.7
Non-Hispanic White	36.2	40.1	45.0	21.6	22.8	25.2	28.7	30.5	32.0	29.5	32.0	35.7
Male	34.5	37.2	40.4	19.5	22.2	23.7	26.2	27.9	30.2	26.1	27.9	30.5
Female	33.5	36.0	41.1	20.4	22.9	25.8	23.4	26.6	30.5	26.4	28.8	33.1
Income <$35,000, %												
Non-Hispanic Black	49.4	38.2	28.8	50.1	31.5	39.1	55.2	51.5	44.6	61.1	52.1	36.0
Hispanic	60.6	54.3	39.2	---	---	---	60.4	55.6	43.9	71.8	62.4	52.3
Non-Hispanic White	21.0	18.4	16.0	35.2	27.7	30.6	35.7	32.8	27.4	33.7	30.0	24.7
Male	28.9	25.6	21.1	35.7	27.1	29.1	42.7	39.2	32.2	42.0	36.1	25.6
Female	32.8	29.2	22.5	38.4	29.9	34.2	45.0	42.9	35.6	43.1	38.8	32.7
Rural Residence Classification, %												
Non-Hispanic Black	0.0	0.0	0.0	12.7	9.1	3.2	4.8	3.9	0.8	25.4	17.8	6.1
Hispanic	0.0	0.0	0.0	---	---	---	3.0	1.6	0.2	18.3	11.8	1.2
Non-Hispanic White	0.0	0.0	0.0	40.4	30.5	19.6	11.7	6.7	1.7	34.3	21.4	6.4
Male	0.0	0.0	0.0	35.5	24.8	14.4	8.1	4.8	1.0	28.4	17.9	5.6
Female	0.0	0.0	0.0	40.1	31.2	20.3	9.0	4.8	1.3	33.4	21.3	6.3
Hypertension†, %												
Non-Hispanic Black	38.1	41.5	41.7	37.9	44.1	48.5	34.5	33.7	38.2	39.8	44.7	44.8

	Hispanic	25.2	26.7	26.7	---	---	---	28.8	28.1	25.6	13.0	16.2	19.1
	Non-Hispanic White	30.5	31.7	34.1	38.1	39.4	40.4	35.8	38.3	38.3	32.9	35.5	35.9
	Male	28.3	32.5	34.9	38.4	40.2	43.1	35.8	37.1	35.7	32.6	41.1	36.7
	Female	29.7	29.5	30.0	37.1	37.9	36.2	32.5	32.1	32.5	32.7	34.7	34.9
High Cholesterol†, %													
	Non-Hispanic Black	33.6	39.9	32.8	43.6	38.6	27.1	34.0	32.1	30.8	35.3	37.1	36.3
	Hispanic	39.5	38.7	33.1	---	---	---	38.3	35.8	32.1	36.3	34.0	27.1
	Non-Hispanic White	40.1	39.7	36.1	43.5	43.6	40.1	47.0	44.0	38.4	42.9	42.5	36.3
	Male	41.1	42.1	36.4	43.7	43.1	39.6	45.7	41.9	35.4	40.6	41.1	37.3
	Female	36.9	36.1	32.3	43.2	42.7	37.2	41.9	38.5	34.4	40.9	40.2	33.6
Diabetes, %													
	Non-Hispanic Black	10.2	11.9	14.8	13.2	10.1	14.5	12.4	12.3	15.4	13.3	15.4	15.9
	Hispanic	9.4	8.8	9.3	---	---	---	10.7	10.8	11.8	5.8	6.0	7.7
	Non-Hispanic White	7.6	8.8	10.4	9.3	11.0	13.9	10.1	11.4	12.2	9.6	11.0	12.2
	Male	8.1	7.5	7.6	9.2	10.7	13.8	11.2	12.2	13.6	10.2	11.4	13.1
	Female	7.2	8.3	11.0	10.0	10.6	13.5	9.7	10.1	11.7	10.0	11.3	12.0
Asthma, %													
	Non-Hispanic Black	11.9	11.5	12.4	10.8	9.0	13.9	7.7	8.8	10.2	9.1	11.0	9.6
	Hispanic	9.7	8.6	7.9	---	---	---	7.7	8.3	8.0	3.0	3.9	5.1
	Non-Hispanic White	8.7	9.2	7.8	11.0	9.3	11.1	7.9	8.3	8.7	7.9	8.0	9.0
	Male	7.1	6.3	4.9	7.1	6.6	8.8	5.7	5.6	5.0	5.5	5.6	5.5
	Female	10.6	11.4	11.7	13.1	12.0	13.9	9.8	10.7	12.2	9.7	11.0	12.9
Chronic Obstructive Pulmonary Disease, %													
	Non-Hispanic Black	5.9	7.1	4.3	9.4	8.1	9.0	5.5	5.1	5.3	5.5	6.3	6.0
	Hispanic	4.8	4.7	3.3	---	---	---	4.4	4.6	6.4	2.3	2.7	2.2
	Non-Hispanic White	5.5	6.4	6.9	9.9	11.1	12.6	9.0	9.2	9.9	7.3	8.2	9.1
	Male	4.1	5.1	5.4	8.9	9.6	11.9	6.3	6.4	6.7	5.9	6.7	6.3
	Female	6.2	6.6	5.7	11.0	12.0	12.2	8.5	8.2	9.7	7.2	8.0	9.7
Smoking, %													
	Non-Hispanic Black	23.6	16.5	11.8	33.3	22.5	23.8	17.1	13.9	10.7	25.3	20.9	16.5
	Hispanic	14.8	12.8	12.2	---	---	---	14.8	13.1	11.9	16.3	11.0	10.0
	Non-Hispanic White	18.4	15.9	13.7	29.2	25.8	22.7	21.5	17.9	15.3	22.7	21.0	17.6
	Male	20.6	16.6	13.7	32.4	27.3	22.5	21.9	18.7	15.4	25.4	23.0	19.2
	Female	15.1	13.1	11.1	27.0	23.4	22.6	17.3	13.8	12.3	20.4	17.0	14.4
Obesity, %													

	Non-Hispanic Black	32.5	32.6	29.2	41.3	37.8	37.6	33.2	32.3	33.3	36.5	37.7	40.5
	Hispanic	25.1	24.0	19.7	---	---	---	23.5	24.6	27.0	23.3	17.1	22.5
	Non-Hispanic White	22.3	24.5	23.5	26.5	30.9	34.7	22.6	24.1	25.8	23.6	25.8	27.3
	Male	26.1	26.6	23.0	28.2	32.4	35.3	25.5	26.8	28.2	26.8	27.5	29.9
	Female	20.0	21.7	21.2	26.8	30.0	33.1	22.2	23.3	25.7	25.4	27.1	29.6
Chronic Kidney Disease, %													
	Non-Hispanic Black	1.8	1.9	1.8	3.3	5.3	3.7	2.2	2.4	3.1	0.9	2.7	4.2
	Hispanic	2.6	3.7	4.3	---	---	---	4.1	4.2	3.0	1.4	3.1	1.8
	Non-Hispanic White	1.5	2.3	3.7	1.9	2.6	4.3	3.6	3.5	3.6	2.2	2.5	2.9
	Male	1.6	2.4	3.4	1.6	2.2	4.0	3.2	3.2	3.3	1.5	2.5	3.6
	Female	1.9	2.4	2.8	2.4	3.2	4.4	3.8	3.6	3.6	2.1	2.5	2.8
Malignancy, %													
	Non-Hispanic Black	3.4	6.2	5.6	4.1	6.0	7.9	2.9	4.3	5.1	5.1	6.4	4.1
	Hispanic	2.1	3.5	4.6	8.2	5.7	2.7	3.0	4.2	6.0	0.8	0.9	2.9
	Non-Hispanic White	6.5	7.5	9.0	6.8	7.4	8.5	9.4	9.9	9.7	7.0	7.1	8.4
	Male	4.3	5.1	6.2	5.1	4.8	6.2	5.5	6.7	7.4	5.1	4.9	5.3
	Female	6.0	7.2	7.9	8.3	9.7	9.9	8.6	8.3	8.4	7.2	7.6	8.5
Depression, %													
	Non-Hispanic Black	9.1	12.0	10.0	17.1	14.6	21.6	12.8	13.8	10.8	11.6	14.4	18.0
	Hispanic	14.9	14.4	11.4	---	---	---	16.7	13.6	14.1	12.7	12.4	12.7
	Non-Hispanic White	13.1	15.3	13.8	19.4	20.6	24.4	17.5	18.5	17.5	18.7	20.7	20.7
	Male	10.3	10.5	8.0	15.1	14.4	17.7	13.4	11.9	10.7	12.7	12.7	14.4
	Female	14.2	16.9	15.1	23.8	25.6	29.9	20.2	21.0	20.1	20.7	24.0	24.6
Coronary Artery Disease, %													
	Non-Hispanic Black	6.2	5.3	3.5	7.0	7.1	7.8	5.2	6.7	5.6	6.4	7.6	6.3
	Hispanic	5.7	6.6	4.8	---	---	---	5.4	5.5	7.4	4.1	2.6	2.1
	Non-Hispanic White	7.1	6.4	7.6	8.7	9.4	10.4	10.1	9.7	9.8	7.4	7.5	9.4
	Male	8.1	7.5	7.6	10.3	10.9	11.4	9.3	9.9	11.1	8.0	8.3	10.5
	Female	4.9	5.1	4.6	7.3	7.4	8.8	7.2	6.2	6.1	5.9	6.0	6.0
Stroke, %													
	Non-Hispanic Black	3.6	4.1	5.6	4.0	4.1	6.0	2.4	4.6	5.1	3.5	4.8	4.4
	Hispanic	0.4	2.1	4.9	---	---	---	2.5	2.0	3.0	1.1	1.8	1.0
	Non-Hispanic White	2.3	2.5	2.3	3.8	4.3	4.4	3.8	4.2	4.3	3.1	3.5	3.8
	Male	1.8	2.4	2.6	3.7	4.0	4.5	2.8	3.7	4.7	2.9	3.3	4.2
	Female	2.3	2.7	3.4	3.8	4.4	4.6	3.8	3.7	3.4	3.2	4.0	3.4

*From Census Bureau data. All other data are from the Behavioral Risk Factor Surveillance System.
†Survey questions regarding hypertension and hyperlipidemia were not part of the Behavioral Risk Factor Surveillance System survey in even years and different sampling weights were used prior to 2011. Therefore, data were imputed for hypertension and hyperlipidemia for 2009 and even years as described in the article.
‡Data not reported for Hispanic population in Kentucky due to small sample size.

Table S2. Proportion of State Non-Elderly Adult Population with One of More Cardiovascular Risk Factors and Mean Number of Cardiovascular Risk Factors by Sex, Race and Ethnicity for Select Study Years

	New Jersey				Kentucky†				Florida				North Carolina			
Year*	**2011**	**2013**	**2015**	**2017**	**2011**	**2013**	**2015**	**2017**	**2011**	**2013**	**2015**	**2017**	**2011**	**2013**	**2015**	**2017**
≥1 Risk Factors, %																
NH Black	67.1	66.4	68.0	68.2	77.0	72.8	74.0	71.8	65.0	62.0	63.1	65.4	71.5	74.2	70.7	71.2
Hispanic	58.9	58.2	55.5	58.5	---	---	---	---	59.8	60.1	57.0	60.0	53.2	47.9	42.7	45.8
NH White	64.9	65.7	62.0	64.0	73.4	74.3	73.8	71.2	71.2	70.0	67.0	67.9	68.2	68.5	65.1	67.1
Male	65.5	66.2	63.5	66.6	75.3	74.3	74.6	72.7	70.2	68.8	66.5	67.3	70.1	69.7	65.8	67.3
Female	59.9	58.9	56.9	57.5	71.5	72.5	71.1	68.6	64.9	62.6	60.1	62.4	64.9	65.4	62.5	63.3
≥2 Risk Factors, %																
NH Black	35.4	40.5	37.5	37.8	46.3	41.4	38.7	43.4	37.1	33.1	34.7	33.3	41.5	44.8	43.9	42.9
Hispanic	28.3	27.4	25.9	29.4	---	---	---	---	29.8	27.9	27.0	28.6	18.3	15.4	15.5	20.9
NH White	32.7	33.7	31.1	34.5	40.0	42.5	42.9	42.9	38.0	38.5	37.3	37.4	35.2	38.8	36.4	36.1
Male	33.4	34.5	33.4	35.5	40.8	43.0	43.6	44.7	37.2	37.2	35.1	35.8	35.7	38.5	35.6	36.9
Female	28.9	29.9	26.3	30.0	39.3	40.1	39.3	39.2	34.4	32.1	32.5	32.0	34.5	36.7	35.5	35.0
≥3 Risk Factors, %																
NH Black	14.9	19.1	16.2	16.2	21.6	20.8	20.3	19.2	16.0	15.0	17.9	15.1	20.2	21.1	20.6	22.9
Hispanic	9.9	9.7	9.6	11.6	---	---	---	---	11.6	11.9	9.9	10.2	6.7	5.0	2.5	9.1
NH White	11.6	13.0	12.0	13.8	17.6	19.2	19.7	20.6	15.1	16.4	14.9	15.2	14.5	15.9	15.8	14.5
Male	12.1	14.4	12.8	14.5	18.4	19.4	21.2	23.2	15.4	16.1	14.6	14.8	15.1	16.2	15.6	16.5
Female	10.4	10.9	10.0	11.8	17.2	18.4	17.3	16.8	13.3	13.5	13.1	12.9	15.0	15.5	15.4	14.7
≥4 Risk Factors, %																
NH Black	4.0	6.8	5.8	5.3	11.1	6.4	8.1	2.8	5.6	5.5	6.5	3.7	7.1	6.9	8.1	7.7
Hispanic	1.9	2.3	2.5	3.4	---	---	---	---	2.9	3.2	3.3	2.8	0.8	0.9	0.9	1.4
NH White	2.9	3.0	2.5	3.4	5.5	5.4	6.5	6.8	4.5	4.6	4.1	3.9	4.1	4.8	5.0	4.0
Male	3.3	3.9	3.5	3.7	5.8	5.8	7.2	7.0	4.6	5.1	4.5	4.0	3.9	4.8	4.8	4.5
Female	2.2	2.8	2.3	3.1	5.8	4.9	5.6	5.8	4.0	3.2	3.8	3.2	4.9	5.0	5.5	4.6
Mean Number of Risk Factors (SD)																
NH Black	1.2 (0.04)	1.3 (0.05)	1.3 (0.05)	1.3 (0.05)	1.6 (0.09)	1.4 (0.08)	1.4 (0.09)	1.4 (0.09)	1.2 (0.05)	1.2 (0.04)	1.2 (0.05)	1.2 (0.05)	1.4 (0.04)	1.5 (0.04)	1.4 (0.04)	1.5 (0.06)
Hispanic	1.0 (0.03)	1.0 (0.03)	0.9 (0.04)	1.0 (0.04)	---	---	---	---	1.0 (0.04)	1.0 (0.04)	1.0 (0.04)	1.0 (0.04)	0.8 (0.06)	0.7 (0.04)	0.6 (0.04)	0.8 (0.07)

NH White	1.1	1.2	1.1	1.2	1.4	1.4	1.4	1.4	1.3	1.3	1.2	1.2	1.2	1.3	1.2	1.2
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)
Male	1.1	1.2	1.1	1.2	1.4	1.4	1.5	1.5	1.3	1.3	1.2	1.2	1.3	1.3	1.2	1.3
	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)	(0.02)	(0.03)	(0.03)
Female	1.0	1.0	1.0	1.0	1.3	1.4	1.3	1.3	1.2	1.1	1.1	1.1	1.2	1.2	1.2	1.2
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)

Weighted percentages of number of risk factors based on survey responses from the Behavioral Risk Factor Surveillance System. Risk factors included major cardiovascular health factors: Hypertension, High Cholesterol, Diabetes, Obesity in addition to Smoking, which were the same major cardiovascular health factors and health behaviors considered in the study models.

*These years are presented since the relevant survey questions from the Behavioral Risk Factor Surveillance System regarding hypertension and hyperlipidemia were not part of the survey in even years and different sampling weights were used prior to 2011.

†Data not reported for Hispanic population in Kentucky due to small sample size.

NH, Non-Hispanic; SD, Standard Deviation

Table S3. Demographic Characteristics of Population Hospitalized for Any Cardiovascular Reason by State and Year

	New Jersey			Kentucky			Florida			North Carolina*		
	2009	**2013**	**2018**	**2009**	**2013**	**2018**	**2009**	**2013**	**2018**	**2009***	**2013**	**2018**
Total Cardiovascular Hospitalizations	63,424	51,853	45,192	41,768	34,388	33,952	142,833	134,379	143,804	66,948	62,573	65,895
Age, years												
18-44	10,919 (17.2)	8,676 (16.7)	7,098 (15.7)	7,007 (16.8)	5,859 (17.0)	5,717 (16.8)	25,495 (17.9)	23,873 (17.8)	24,659 (17.2)	12,003 (17.9)	11,048 (17.7)	11,203 (17.0)
45-64	52,505 (82.8)	43,177 (83.3)	38,094 (84.3)	34,761 (83.2)	28,529 (83.0)	28,235 (83.2)	117,338 (82.2)	110,506 (82.2)	119,145 (82.9)	54,945 (82.1)	51,525 (82.3)	54,692 (83.0)
Sex												
Male	39,697 (62.6)	32,867 (63.3)	29,057 (64.3)	24,614 (58.9)	20,408 (59.3)	20,298 (59.8)	85,936 (60.2)	81,455 (60.6)	88,702 (61.7)	39,689 (59.3)	37,115 (59.3)	39,130 (59.4)
Female	23,727 (37.4)	18,986 (36.6)	16,134 (35.7)	17,154 (41.1)	13,979 (40.7)	13,653 (40.2)	56,896 (39.8)	52,924 (39.4)	55,102 (38.3)	27,259 (40.7)	25,454 (40.7)	26,760 (40.6)
Missing	0	0	1 (<0.1)	0	1 (<0.1)	1 (<0.1)	1 (<0.1)	0	0	0	4 (<0.1)	5 (<0.1)
Race*												
White	36,908 (59.0)	28,360 (54.7)	22,138 (49.8)	35,920 (86.0)	29,630 (86.2)	28,633 (84.3)	86,836 (61.2)	76,441 (56.9)	76,795 (53.8)	39,649 (61.4)	36,266 (58.0)	35,828 (55.0)
Black	14,443 (23.1)	13,210 (25.5)	12,278 (27.6)	3,657 (8.8)	3,750 (10.9)	4,631 (13.6)	34,095 (24.1)	33,569 (25.0)	38,907 (27.3)	22,021 (34.1)	22,381 (35.8)	24,979 (38.3)
Hispanic	6,857 (11.0)	5,812 (11.2)	6,274 (14.1)	119 (0.3)	695 (2.0)	341 (1.0)	13,305 (9.4)	19,551 (14.5)	22,597 (15.8)	881 (1.4)	1,271 (2.0)	1,944 (3.0)
Asian/PI	1,786 (2.9)	1,428 (2.8)	1,583 (3.6)	63 (0.2)	84 (0.2)	106 (0.3)	1,014 (0.7)	960 (0.7)	1,275 (0.9)	387 (0.6)	297 (0.5)	529 (0.8)
Native American	176 (0.3)	108 (0.2)	82 (0.2)	13 (0.03)	28 (0.1)	43 (0.1)	197 (0.1)	210 (0.2)	147 (0.1)	998 (1.6)	947 (1.5)	1,065 (1.6)
Other	2,343 (3.8)	2,032 (3.9)	2,087 (4.7)	1,996 (4.8)	201 (0.6)	198 (0.6)	6,348 (4.5)	2,297 (1.7)	2,908 (2.0)	633 (1.0)	684 (1.1)	805 (1.2)
Missing	911 (1.4)	903 (1.7)	750 (1.6)	0	0	0	1,038 (0.7)	1,351 (1.0)	1,175 (0.8)	3,353 (5.0)	727 (1.1)	745 (1.1)

Location												
Urban	63,192 (99.7)	51,676 (99.7)	45,110 (99.9)	20,928 (50.2)	18,335 (53.3)	18,774 (55.3)	129,636 (91.6)	121,647 (90.5)	134,310 (94.7)	41,958 (63.2)	39,905 (63.8)	47,878 (72.7)
Rural	193 (0.3)	139 (0.3)	55 (0.1)	20,798 (49.8)	16,026 (46.6)	15,171 (44.7)	11,927 (8.4)	11,139 (8.3)	7,545 (5.3)	24,488 (36.9)	21,392 (34.2)	17,991 (27.3)
Missing	39 (<0.1)	38 (<0.1)	27 (<0.1)	42 (0.1)	27 (<0.1)	7 (<0.1)	1,270 (0.9)	1,593 (1.2)	1,949 (1.4)	502 (0.7)	1,276 (2.0)	26 (<0.1)
Primary Payer												
Medicare	10,483 (16.5)	9,721 (18.7)	8,440 (18.7)	11,335 (27.1)	9,759 (28.4)	9,672 (28.5)	29,432 (20.6)	31,450 (23.4)	33,907 (23.6)	16,437 (24.7)	15,089 (24.1)	13,871 (21.2)
Medicaid	4,132 (6.5)	5,038 (9.7)	9,862 (21.8)	6,450 (15.4)	5,742 (16.7)	11,133 (32.8)	22,112 (15.5)	25,930 (19.3)	25,773 (17.9)	10,767 (16.2)	11,478 (18.3)	12,331 (18.8)
Private	38,184 (60.2)	26,239 (50.6)	21,734 (48.1)	16,798 (40.2)	12,777 (37.2)	11,298 (33.3)	59,748 (41.8)	45,235 (33.7)	53,800 (37.4)	28,564 (42.8)	24,616 (39.3)	28,021 (42.8)
Uninsured	9,864 (15.6)	10,096 (19.5)	2,104 (4.7)	5,576 (13.4)	5,071 (14.7)	1,001 (3.0)	23,377 (16.4)	24,555 (18.3)	23477 (16.3)	8,554 (12.8)	9,045 (14.5)	9,188 (14.0)
Other	761 (1.2)	759 (1.5)	3,052 (6.8)	1,609 (3.9)	705 (2.1)	848 (2.5)	8,164 (5.7)	7,209 (5.4)	6,847 (4.8)	2,366 (3.6)	2,209 (3.5)	2,029 (3.1)
Missing	0	0	0	0	334 (0.1)	0	0	0	0	260 (0.4)	136 (0.2)	455 (0.7)
Median household income												
Quartile 1	9,646 (15.4)	6,535 (12.6)	8,990 (20.0)	24,720 (60.9)	19,232 (55.9)	18,924 (56.7)	45,355 (32.7)	59,606 (44.3)	56,922 (40.8)	29,357 (45.1)	29,281 (46.8)	31,969 (49.4)
Quartile 2	9,947 (15.9)	6,663 (12.8)	7,292 (16.3)	9,143 (22.5)	9,400 (27.3)	9,010 (27.0)	46,055 (33.3)	41,415 (30.8)	49,561 (35.5)	24,016 (36.9)	20,391 (32.6)	20,778 (32.1)
Quartile 3	14,621 (23.4)	12,757 (24.6)	10,434 (23.3)	4,950 (12.2)	4,143 (12.0)	4,200 (12.6)	33,789 (24.4)	22,622 (16.8)	24,806 (17.8)	7,927 (12.2)	7,169 (11.5)	8,109 (12.5)
Quartile 4	28,359 (45.3)	25,370 (48.9)	18,153 (40.5)	1,769 (4.4)	880 (2.6)	1,224 (3.7)	13,316 (9.6)	6,827 (5.1)	8,363 (6.0)	3,770 (5.8)	3,000 (4.8)	3,855 (6.0)
Missing	851 (1.3)	528 (1.0)	323 (0.7)	1,186 (2.8)	733 (2.1)	594 (1.7)	4,318 (3.0)	3,909 (2.9)	4,152 (2.9)	1,878 (2.8)	2,732 (4.4)	1,184 (1.7)

All data reported as n (%) unless otherwise specified.

*For North Carolina, no race and ethnicity data were available for 2009, therefore 2010 race and ethnicity data are shown in the table. N for Total hospitalizations for 2010 was 67922. All other sub-cohorts are based on 2009 total hospitalization N as listed in table. PI, Pacific Islander

Table S4. Estimated Mean Percent Change in Yearly Cardiovascular Hospitalization Rate from Multivariable Negative Binomial Regression Models

State	Mean Percent Change in Hospitalization Rate Per Year (95% CI)	P value for State-Year interaction
Male		
New Jersey	-3.6% (-4.1, -3.1)	Referent
Kentucky	-3.4% (-4.1, -2.7)	0.4883
Florida	-1.2% (-1.8, -0.6)	<.0001
North Carolina	-2.0% (-2.6, -1.3)	<.0001
Female		
New Jersey	-3.7% (-4.0, -3.3)	Referent
Kentucky	-2.4% (-2.8, -2.0)	<.0001
Florida	-1.4% (-1.8, -1.0)	<.0001
North Carolina	-1.1% (-1.5, -0.6)	<.0001
Non-Hispanic Black		
New Jersey	-1.8% (-3.2, -0.3)	Referent
Kentucky	+0.7% (-1.2, 2.7)	0.0063
Florida	+0.5% (-0.8, 1.9)	<.0001
North Carolina	+0.8% (-0.6, 2.2)	0.0002
Non-Hispanic White		
New Jersey	-4.7% (-5.5, -3.9)	Referent
Kentucky	-3.2% (-4.5, -1.8)	0.0013
Florida	-2.4% (-3.7, -1.2)	<.0001
North Carolina	-3.0% (-4.2, -1.9)	0.0001
Hispanic		
New Jersey	-6.3% (-10.3, -2.0)	Referent
Florida	-2.4% (-7.3, 1.6)	0.0005
North Carolina	+0.0% (-8.8, 8.4)	0.0059