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Secular Trends in Risk Profiles Among Adults With Cardiovascular Disease in the United States

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Associated Data

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Abstract

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BACKGROUND

Documenting trends in risk factors among individuals with cardiovascular disease (CVD) may inform policy and secondary prevention initiatives.

OBJECTIVES

This study aimed to examine 20-year trends in risk profiles among U.S. adults with CVD and any racial/ethnic disparities.

METHODS

In this serial cross-sectional analysis of 6,335 adults with self-reported CVD participating in the National Health and Nutrition Examination Survey from 1999 through 2018, we calculated age- and sex-adjusted proportions with ideal risk factor attainment.

RESULTS

The proportions with ideal hemoglobin A1c (<7% if diabetes or <5.7% if not) and body mass index (<25 kg/m^2) worsened from 58.7% (95% CI: 55.2%-62.1%) to 52.4% (95% CI: 48.2%-56.6%) and 23.9% (95% CI: 21.5%-26.4%) to 18.2% (95% CI: 15.6%-21.2%) from 1999-2002 to 2015-2018, respectively. After initial improvement, the proportion with blood pressure <130/80 mm Hg declined from 52.1% (95% CI: 48.9%-55.4%) in 2007-2010 to 48.6% (95% CI: 44.2%-52.7%) in 2015-2018. The proportion with non-high-density lipoprotein cholesterol levels <100 mg/dL increased from 7.3% (95% CI: 5.6%-9.5%) in 1999-2002 to 30.3% (95% CI: 25.7%-35.5%) in 2015-2018. The proportions with ideal smoking, physical activity, and diet profiles were unchanged over time, and in 2015-2018 were 77.8% (95% CI: 73.6%-81.4%), 22.4% (95% CI: 19.3%-25.9%), and 1.3% (95% CI: 0.7%-2.6%). Worsening trends were observed in Hispanic adults for cholesterol, and in Black adults for smoking (both $P < 0.05$ for nonlinear and linear trends). Persistently lower ideal risk factor attainment was observed for blood pressure in Black adults and for hemoglobin A1c levels in Asian adults compared with White adults (all $P < 0.05$ for differences).

CONCLUSIONS

Trends in cardiovascular risk factor profiles in U.S. adults with CVD were suboptimal from 1999 through 2018, with persistent racial/ethnic disparities.

Keywords: cardiovascular disease, health equity, risk factor profiles, secondary prevention, U.S. trends

The past 2 decades brought major advances in treatments for secondary prevention of cardiovascular disease (CVD).[1,2] During this time period, professional societies, including the American College of Cardiology and the American Heart Association, have recommended increasingly intensive control of cardiovascular risk factors, including type 2 diabetes mellitus, uncontrolled blood pressure, hyperlipidemia, excess weight, smoking, physical inactivity, and unhealthy eating, to reduce the risk of recurrent cardiovascular events and death among individuals with a history of CVD.[3-5] The professional society guidelines incorporate greater understanding with respect to lifestyle changes and an increased armamentarium of safe and effective pharmaceutical options for individuals with CVD.

It is important to assess secular trends in CVD risk factor control to understand to what extent new treatments and guidelines are being translated to practice and identify areas that may require more clinical and public health attention. Prior publications have assessed risk factor control for primary prevention in the general U.S. population and raise concern for insufficient implementation of guidelines.[6,7] In the secondary prevention setting, where intensive risk factor modification is especially emphasized, trends in risk factor control have recently been described in patients with peripheral artery disease.[8,9] However, many patients with other types of CVD, including coronary heart disease and stroke, have been missed. In addition, prior analyses in secondary risk factor management reported nationally representative data nearly 2 decades ago.[10] Furthermore, there is a need for greater understanding of trends in health inequities in CVD risk factor control.

Therefore, using nearly 2 decades of data (1999-2018) from the National Health and Nutrition Examination Survey (NHANES), we evaluated the trends in cardiovascular risk factor profiles and a summary metric of secondary prevention of CVD in U.S. adults with a history of CVD.

METHODS

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STUDY POPULATION.

The NHANES is a cross-sectional survey that uses a stratified and multistage probability cluster sampling scheme to represent the U.S. noninstitutionalized, civilian population.[11] In 6,338 participants aged ≥20 years from NHANES 1999-2018 with a self-reported history of coronary heart disease, myocardial infarction, stroke, angina, or congestive heart failure, 3 participants were excluded because of missing data on all risk factors of interest (described in the following section), leaving 6,335 for the current analysis. We included those with at least 1 risk factor available, and thus the sample size varied for each individual risk factor (additional details are given in the Supplemental Methods). The comparison of the baseline characteristics between the included population and the excluded population because of missing any cardiovascular risk factors is shown in Supplemental Table 1. The study protocols were approved by the Institutional Review Board of the National Center for Health Statistics, and all study participants provided written informed consent.

CARDIOVASCULAR RISK FACTORS.

Blood glucose level was assessed by using hemoglobin A1c (HbA_{1c}) levels because fasting plasma glucose was only available in a subsample of NHANES participants.[12] Different methods were used to measure HbA_{1c} levels over time; we therefore used a previously validated equi-percentile equating approach to calibrate HbA_{1c} values between NHANES survey cycles, with 2015-2018 as the reference survey years.[13] Blood pressure was measured 3 times consecutively with a mercury sphygmomanometer after each participant was seated for 5 minutes. Mean systolic and diastolic blood pressures were calculated by averaging the second and third readings. Due to low-density lipoprotein cholesterol data being only available in a subsample of fasting NHANES participants, we focused on non-high-density lipoprotein cholesterol (non-HDL-C),[14] calculated by subtracting HDL-C levels from total cholesterol levels. Total and HDL-C were measured using standardized enzymatic assays.[15] Body mass index was calculated as weight in kilograms divided by height in meters squared. Smoking status and duration of smoking abstinence were self-reported via survey questionnaires. Frequency, duration, and types of physical activity were also self-reported. Similar to prior NHANES risk factor studies,[7,16] we used the Healthy Eating Index-2015 (HEI-2015) to assess diet quality.[17] Each of 13 dietary components is assigned to a per 1000 kcal standard for achieving a maximum score, and scores from all components sum to a maximum of 100 points, with higher scores indicating better diet quality.

SECONDARY PREVENTION METRIC.

Consistent with risk factors identified in secondary prevention guidelines and the framework of the American Heart Association Life's Simple 7,[3-5,16,18,19] we constructed a 14-point secondary prevention metric based on the levels (2 points for ideal, 1 point for intermediate, and 0 points for poor) of each of 7 factors (HbA_{1c}, blood pressure, non-HDL-C, body mass index, smoking status, physical activity, and HEI-2015). However, we modified the definitions of ideal, intermediate, and poor levels according to secondary prevention guidelines and cutoffs used in previous publications,[3-5,16] as Life's Simple 7 was developed for primordial prevention of CVD. The modified secondary prevention metric ensured that we did not preclude individuals from being categorized as an ideal level based on medication use status. For example, ideal blood pressure was defined as <130/80 mm Hg and ideal cholesterol profile as non-HDL-C <100 mg/dL regardless of medication use, consistent with blood pressure and cholesterol guidelines.[4,5] After excluding those with missing values on any cardiovascular risk factors (data missingness listed in Supplemental Table 2), the current analysis of the secondary prevention metric included 4,747 participants. To address data missingness, we subsequently conducted a sensitivity analysis using multiple imputations. The secondary prevention metric was created to serve as a summary statistic, not to infer prognosis. The detailed definitions for our secondary prevention metric and the American Heart Association Life's Simple 7 are summarized in Supplemental Table 3.

STATISTICAL ANALYSIS.

All statistical analyses followed the recommended analytic guidelines and accounted for the complex NHANES sampling design, oversampling, and survey nonresponse.[11] To improve the precision of estimates, we pooled survey data in 4-year intervals from 1999 through 2018 (ie, 1999-2002, 2003-2006, 2007-2010, 2011-2014, 2015-2018). The survey weights were rescaled to provide reliable estimates to represent the U.S. adult population with self-reported CVD.[20] Baseline characteristics were compared across 4-year survey periods from 1999 through 2018. Data on race and ethnicity for non-Hispanic Asian participants became available in NHANES after 2009-2010.[21]

To facilitate interpretations in the clinical context, we examined the age- and sex-adjusted proportions of ideal cardiovascular risk factors as our main results. We also assessed the age- and sex-adjusted population-level means of risk factors for comparability with prior publications.[22,23] For the trends analysis, the midpoint of each 4-year survey period was used as a continuous variable to test for linear trends in measures of our interest using logistic or linear regression models. If the overall model fit improved after adding a quadratic term of time (the midpoint of each 4-year survey period) based on the likelihood ratio test, the nonlinear trends were then modeled by using piece-wise spline models to facilitate the interpretations of a nonlinear relationship between time and outcome measures in a clinical context. Before fitting piece-wise spline models, the flexible and informed Bayesian regression analysis with multiple change points (the R package [mcp]) was performed to compare the predictive accuracy of models with 1 vs 2 inflection points.[24] In general, the 2 inflection point models were not favored; thus, we fit the data using 2-piece spline regression with an inflection point for nonlinear trends. Moderate or vigorous physical activity levels were log-transformed when modeling to account for the positively skewed distribution. Age- and sex-adjusted means of the secondary prevention metric were also calculated.

We evaluated interactions of the age- and sex-adjusted trends with race/ethnicity (non-Hispanic White, non-Hispanic Black, and Hispanic) and CVD subtypes (coronary heart disease/myocardial infarction/stroke/angina vs congestive heart failure). The homogeneity of temporal trends by subgroups was tested by using multiplicative interaction terms with time (linear and/or quadratic) in age and sex-adjusted regression models. In a sensitivity analysis, we used multiple multivariate imputation of variables with five imputed datasets to replace missing values on the secondary prevention metric, amounting to 25.1% of total values. All analyses were performed by using Stata version 15.1 (StataCorp), and a 2-sided P value <0.05 was considered statistically significant.

RESULTS

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The distribution of age and sex in U.S. adults with CVD remained stable from 1999 through 2018 (Table 1). The mean age of the study population ranged from 63.8 to 65.4 years, and the proportion of men from 49.9% to 55.7%. Proportions of non-Hispanic Black and Hispanic participants with CVD increased from 11.3% and 7.8% in 1999-2002 to 13.0% and 9.5% in 2015-2018, respectively. The top 3 CVD subtypes in terms of relative percentages were coronary heart disease, myocardial infarction, and angina in 1999-2002 and changed to coronary heart disease, myocardial infarction, and stroke in 2015-2018.

TABLE 1

Characteristics of U.S. Adults With CVD, NHANES 1999 to 2018

	1999-2002 (n = 1,202)	2003-2006 (n = 1,249)	2007-2010 (n = 1,385)	2011-2014 (n = 1,176)	2015-2018 (n = 1,326)
Age, y	63.8 ± 0.85	65.4 ± 0.69	64.7 ± 0.45	64.8 ± 0.62	65.3 ± 0.45
Male	53.9 ± 2.1	49.9 ± 2.0	54.9 ± 1.9	52.1 ± 2.1	55.7 ± 2.0
Race/ethnicity	(n = 1,171)	(n = 1,206)	(n = 1,335)	(n = 1,144)	(n = 1,254)
Non-Hispanic White	80.9 ± 2.1	83.2 ± 2.3	78.9 ± 2.5	75.6 ± 2.5	74.5 ± 2.0
Non-Hispanic Black	11.3 ± 1.7	11.5 ± 1.5	13.2 ± 1.5	12.2 ± 1.6	13.0 ± 1.6
Hispanic	7.8 ± 2.0	5.3 ± 1.1	8.0 ± 1.7	9.3 ± 1.6	9.5 ± 1.3
Non-Hispanic Asian	–	–	–	2.9 ± 0.4	3.0 ± 0.6
Education	(n = 1,189)	(n = 1,243)	(n = 1,383)	(n = 1,173)	(n = 1,323)
Less than high school	36.7 ± 2.1	29.7 ± 2.0	29.9 ± 1.7	24.3 ± 2.0	17.5 ± 1.8
High school graduate	27.1 ± 2.0	26.4 ± 2.0	27.6 ± 1.7	26.7 ± 2.1	28.3 ± 1.8
Some college	22.9 ± 1.6	28.7 ± 2.0	24.6 ± 1.9	28.7 ± 1.6	32.7 ± 2.0
College graduate or higher	13.3 ± 1.3	15.2 ± 1.7	17.9 ± 1.7	20.2 ± 1.7	21.5 ± 2.4
Family income-to-poverty ratio	(n = 1,046)	(n = 1,163)	(n = 1,252)	(n = 1,077)	(n = 1,163)
≤100%	19.0 ± 1.7	14.7 ± 1.3	17.4 ± 1.5	18.8 ± 2.1	16.8 ± 1.6
>100%-299%	43.9 ± 2.1	50.0 ± 2.2	44.6 ± 1.7	49.4 ± 2.6	44.2 ± 2.4
>300%-499%	18.1 ± 1.9	21.3 ± 2.7	18.4 ± 1.4	18.2 ± 1.7	19.4 ± 2.0
≥500%	19.0 ± 2.4	13.9 ± 1.6	19.6 ± 1.9	13.5 ± 1.7	19.6 ± 2.3

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Values are mean ± SE. All estimates were weighted and accounted for National Health and Nutrition Examination Survey (NHANES) sampling design.
CVD = cardiovascular disease.

CARDIOVASCULAR RISK FACTOR PROFILES FROM 1999 THROUGH 2018.

Figure 1 summarizes the age- and sex-adjusted proportions of different levels of risk profiles in U.S. adults with CVD. The proportion with ideal HbA_{1c} values (<7% with a self-reported diagnosis of diabetes or <5.7% without) decreased from 58.7% (95% CI: 55.2%-62.1%) in 1999-2002 to 52.4% (95% CI: 48.2%-56.6%) in 2015-2018 ($P = 0.001$ for linear trend) (Figure 1, Supplemental Figure 1). Trends in proportions with ideal blood pressure and cholesterol profiles were nonlinear, with an inflection point around 2007-2010. The proportion with ideal blood pressure (systolic blood pressure <130 mm Hg and diastolic blood pressure <80 mm Hg) improved from 44.0% (95% CI: 39.4%-48.6%) in 1999-2002 to 52.1% (95% CI: 48.9%-55.4%) in 2007-2010, and then plateaued at 48.6% (95% CI: 44.2%-52.7%) in 2015-2018 ($P < 0.001$ for nonlinear trend). The proportion with ideal cholesterol levels (non-HDL-C <100 mg/dL) increased from 7.3% (95% CI: 5.6%-9.5%) in 1999-2002 to 30.3% (95% CI: 25.7%-35.5%) in 2015-2018 ($P = 0.002$ for nonlinear trend). The proportion with ideal body mass index (<25 kg/m^2) worsened from 23.9% (95% CI: 21.5%-26.4%) in 1999-2002 to 18.2% (95% CI: 15.6%-21.2%) in 2015-2018 ($P = 0.008$ for linear trend). The proportion with an ideal smoking profile (never smoked or quit smoking >1 year) remained unchanged from 81.4% (95% CI: 77.4%-84.9%) in 1999-2002 to 77.8% (95% CI: 73.6%-81.4%) in 2015-2018 ($P = 0.17$ for linear trend). The proportion with ideal physical activity levels (≥150 minutes per week in moderate, ≥75 minutes per week in vigorous, or ≥150 minutes per week in combined physical activity) was 25.3% (95% CI: 21.6%-29.4%) in 1999-2002 and 22.4% (95% CI: 19.3%-25.9%) in 2015-2018 ($P = 0.23$ for linear trend). The proportion with an ideal diet (HEI-2015 score ≥80) was 1.2% (95% CI: 0.6%-2.4%) in 1999-2002 and 1.3% (95% CI: 0.7%-2.6%) in 2015-2018 ($P = 0.49$ for linear trend). Temporal trends in proportions of ideal risk profiles between 1999-2002 and 2015-2018 according to CVD subtypes were largely similar to those in the overall population (Supplemental Figure 2).

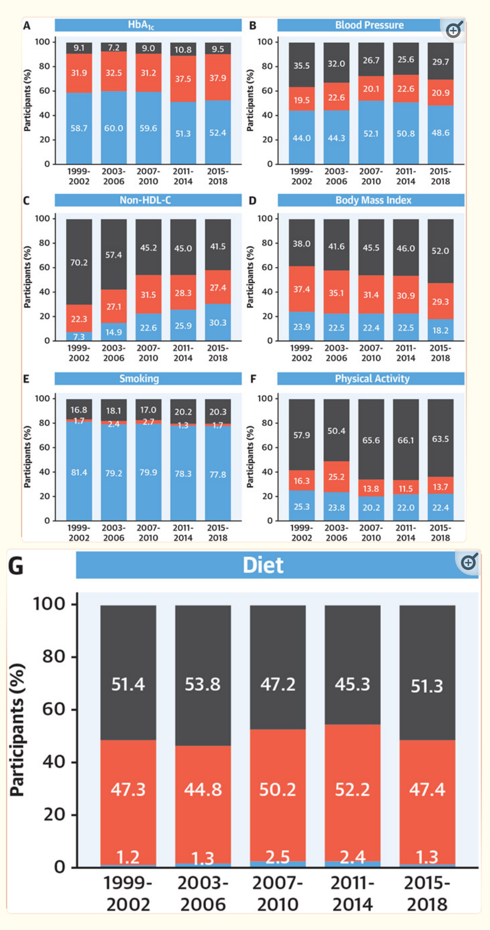

FIGURE 1

Cardiovascular Risk Profiles Among U.S. Adults With CVD, NHANES 1999-2018

Poor **(black)**, intermediate **(red)**, and ideal **(blue)** levels of cardiovascular risk profiles are defined in Supplemental Table 3. All estimates were adjusted for age and sex. **(A)** HbA_{1c}, **(B)** blood pressure, **(C)** non-HDL-C, **(D)** body mass index, **(E)** smoking, **(F)** physical activity, and **(G)** diet. CVD = cardiovascular disease; HbA_{1c} = hemoglobin A_{1c}; NHANES = National Health and Nutrition Examination Survey; non–HDL-C = non-high-density lipoprotein cholesterol.

Consistent with risk factor attainment proportions, the age- and sex-adjusted population means of cardiovascular risk factors are presented in Supplemental Figure 3. For example, mean HbA_{1c} increased from 6.0% (95% CI: 5.9%-6.1%) in 1999-2002 to 6.2% (95% CI: 6.1%-6.3%) in 2015-2018 ($P < 0.001$ for linear trend) in U.S. adults with CVD. Mean systolic blood pressure decreased from 132.9 mm Hg (95% CI: 131.0-134.8) in 1999-2002 to 127.3 mm Hg (95% CI: 126.1-128.5) in 2007-2010, then increased to 131.1 mm Hg (95% CI: 129.0-133.2) in 2015-2018 ($P < 0.001$ for nonlinear trend). Mean non-HDL-C levels decreased from 153.3 mg/dL (95% CI: 147.8-158.8) in 1999-2002 to 133.9 mg/dL (95% CI: 131.0-136.8) in 2007-2010, then continued to decrease, yet at a slower rate, to 125.2 mg/dL (95% CI: 120.7-129.6) in 2015-2018 ($P < 0.001$ for nonlinear trend). In our study, the population-level distribution of non-HDL-C values shifted lower, and we observed a significant decline in U.S. adults with CVD who had non-HDL-C levels ≥200 mg/dL from 1999 through 2018 (Supplemental Figure 4).

CARDIOVASCULAR RISK FACTOR PROFILES ACCORDING TO RACE AND ETHNICITY.

Different trends in proportions of ideal risk profiles according to race and ethnicity were observed in non-HDL-C, smoking, and physical activity (all $P < 0.05$ for subgroup homogeneity) (Figure 2). The proportion with ideal cholesterol increased from 6.6% (95% CI: 4.6%-9.2%) in 1999-2002 to 31.3% (95% CI: 25.9%-37.3%) in 2015-2018 in non-Hispanic White adults ($P = 0.003$ for nonlinear trend), and from 15.4% (95% CI: 9.7%-23.5%) in 1999-2002 to 31.0% (95% CI: 26.3%-36.2%) in 2015-2018 in non-Hispanic Black adults ($P < 0.001$ for linear trend). Among Hispanic adults, the proportion with ideal cholesterol improved at a declining rate ($P = 0.002$ for nonlinear trend), with a widening Hispanic-White difference ($P = 0.12$ in 1999-2002 and $P = 0.048$ in 2015-2018). The proportion with an ideal smoking profile decreased from 70.4% (95% CI: 62.7%-77.0%) in 1999-2002 to 64.2% (95% CI: 55.6%-72.0%) in 2015-2018 in non-Hispanic Black adults ($P = 0.049$ for linear trend) but did not change in other racial and ethnic subgroups (all $P > 0.05$ for linear trend). The proportion with ideal physical activity levels improved from 10.8% (95% CI: 6.6%-17.3%) in 1999-2002 to 22.3% (95% CI: 15.3%-31.4%) in 2015-2018 in Hispanic adults ($P = 0.008$ for linear trend) but remained unchanged in non-Hispanic White and Black adults (all $P > 0.05$ for linear trend).

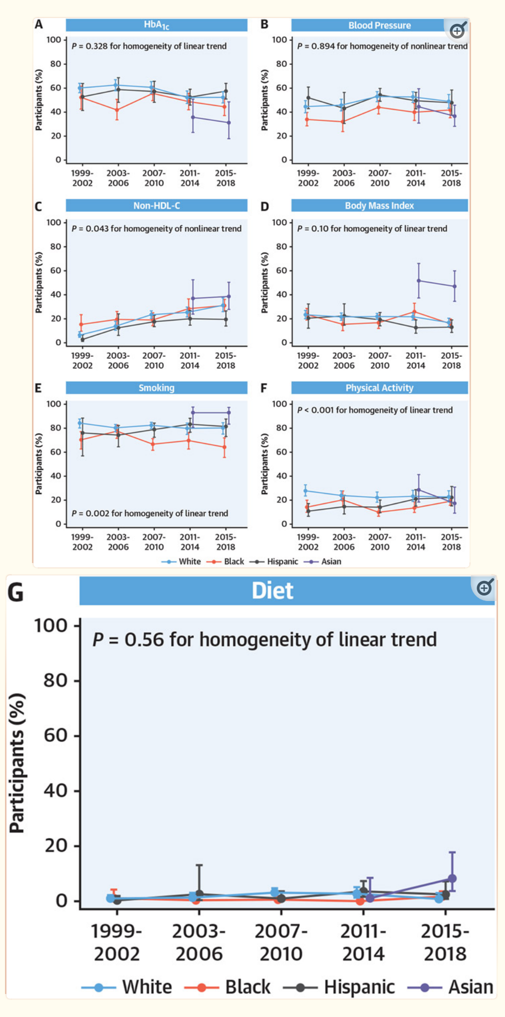

FIGURE 2

Trends in Ideal Risk Profiles According to Race/Ethnicity, NHANES 1999-2018

All estimates were adjusted for age and sex. Trends in non–HDL-C <100 mg/dL ($P = 0.003$ and $P = 0.002$ for nonlinear trend in White and Hispanic adults, respectively; $P < 0.001$ for linear trend in Black adults); never smoked or quit smoking >1 year ($P = 0.22$, $P = 0.049$, and $P = 0.28$ for linear trend in White, Black, and Hispanic adults); and physical activity ($P = 0.17$, $P = 0.55$, and $P = 0.008$ for linear trend White, Black, and Hispanic adults). **(A)** HbA_{1c}, **(B)** blood pressure, **(C)** non-HDL-C, **(D)** body mass index, **(E)** smoking, **(F)** physical activity, and **(G)** diet. **Error bars** indicate 95% CIs. Abbreviations as in Figure 1.

In addition, non-Hispanic Black adults with CVD had a consistently lower proportion of ideal blood pressure (all $P < 0.05$ for group differences) compared with non-Hispanic White adults. Non-Hispanic Asian adults with CVD had a consistently lower proportion of an ideal HbA_{1c} profile (all $P < 0.05$ for group differences) but higher proportions of an ideal body mass index (all $P < 0.001$ for group differences) and smoking profile (all $P < 0.05$ for group differences) compared with non-Hispanic White adults.

SECONDARY PREVENTION METRIC.

The 14-point secondary prevention metric was persistently suboptimal from 1999-2002 through 2015-2018. The age- and sex-adjusted mean metric increased from 6.6 (95% CI: 6.4-6.9) in 1999-2002 to 7.0 (95% CI: 6.8-7.2) in 2007-2010, before leveling off at 6.8 (95% CI: 6.6-7.1) in 2015-2018 (Figure 3). The overall metric was consistently and significantly lower in non-Hispanic Black adults with CVD (all $P < 0.01$ for group differences) and higher in non-Hispanic Asian adults (all $P < 0.001$ for group differences) compared with non-Hispanic White adults. Trends did not differ by CVD subtypes (Supplemental Figure 5). In addition, the overall nonlinear trends in the secondary prevention metric remained consistent after modeling using multiple imputations (P for nonlinear trend = 0.038 in multiple imputations vs P for nonlinear trend = 0.04 in the main analysis).

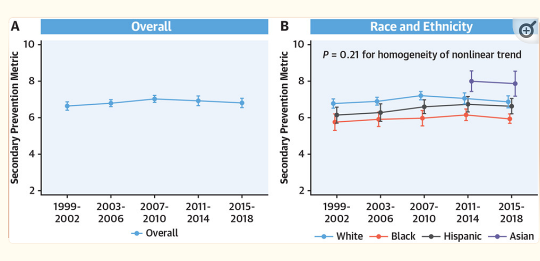

FIGURE 3

Trends in Mean Secondary Prevention Metric, NHANES 1999-2018

(A) Overall and **(B)** by race and ethnicity. All estimates were adjusted for age and sex. **Error bars** indicate 95% confidence intervals. Abbreviations as in Figure 1.

DISCUSSION

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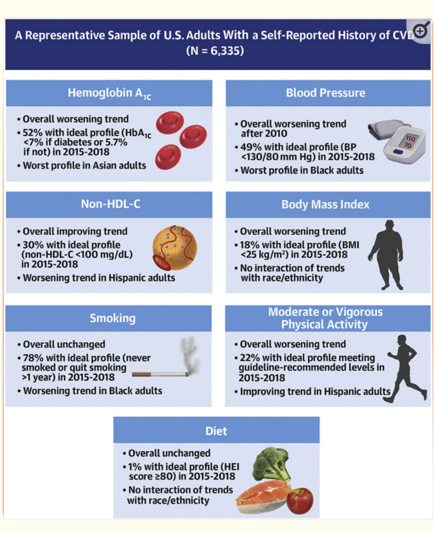
Building on previous studies from more than a decade ago and reports in CVD subtypes,[8-10] our study found suboptimal secular trends in risk factor profiles in U.S. adults with self-reported CVD from 1999 through 2018 (Central Illustration). Despite an improvement in non-HDL-C profiles since 1999, gaps remain in ideal cholesterol attainment, and profiles in HbA_{1c} and body mass index have worsened. Blood pressure profiles improved from 1999 through 2010 and worsened afterward. There were few changes in the profiles of smoking, moderate/vigorous physical activity, and diet in U.S. adults with CVD. In addition, consistent with individual risk factor analysis, our composite secondary prevention metric showed a lack of progress, with persistent racial/ethnic disparities shown in non-Hispanic Black adults with CVD. The extent of racial/ethnic inequities in secondary prevention has remained relatively unchanged over time. This observation is in contrast with the trends in the general U.S. population, in which racial/ethnic disparities in cardiovascular health have shown signs of improvement from 2000 to 2012.[25]



CENTRAL ILLUSTRATION

Trends in Risk Profiles in U.S. Adults With Cardiovascular Disease, 1999 to 2018

Each **light blue box** summarizes the overall trend, proportion with an ideal risk profile in 2015-2018, and any racial/ethnic disparities for the following individual risk factors: hemoglobin A_{1c}, blood pressure, non–high-density lipoprotein cholesterol, body mass index, smoking control, self-reported moderate or vigorous physical activity, and diet. All estimates were adjusted for age and sex and accounted for the sampling design of the National Health and Nutrition Examination Survey. HbA_{1c} = hemoglobin A_{1c}; HEI = Healthy Eating Index; non-HDL-C = non-high-density lipoprotein cholesterol.

Glucose profiles worsened over time in U.S. adults with CVD, with only about one-half of the individuals having ideal HbA_{1c} in the most recent, 2015-2018 cycle (ie, <7% with a self-reported diagnosis of diabetes or <5.7% without). Our finding is consistent with the declining trend in HbA_{1c} control reported in the primary prevention population.[22] The persistently lower proportion with ideal HbA_{1c} values in Asian adults with CVD in our study might be attributed to inconsistent public health efforts directed toward ending disparities in the diagnosis and management of diabetes.[26,27]

Blood pressure in U.S. adults with CVD improved after 1999, and then worsened beyond 2010, which was similar to trends in U.S. adults with hypertension.[28] Public health efforts to promote hypertension awareness might have contributed to the initial improvement in blood pressure control from 1999 through 2010.[29] Because we analyzed data up to 2018, the impact from the latest blood pressure recommendations might not yet be reflected. However, in re-analysis using the previous goal of <140/90 mm Hg, ~30% of U.S. adults with CVD still had blood pressure above goal levels in 2015-2018. Disparities in blood pressure profiles in Black individuals have been reported in the general U.S. population, and we now document this in adults with CVD.[30] Observed disparities may be attributed to similar reasons described for individuals without CVD, which include a lack of adequate hypertension management for women and worse medication adherence for Black adults.[30-32]

Non-HDL-C levels improved over the last 2 decades. This is consistent with prior reports that non-HDL-C and low-density lipoprotein cholesterol improved among patients with atherosclerotic CVD from 1999 to 2016.[33] This is likely due to an increase in lipid-lowering medication use seen in our study and reported in other publications.[33] The disparities in non-HDL-C between Hispanic and non-Hispanic White adults may be due to racial/ethnic differences in awareness and treatment of dyslipidemia.[34]

Ideal profiles of all 4 behavioral risk factors (smoking profile, body mass index, physical activity, and diet) either worsened or remained unchanged from 1999-2002 through 2015-2018. We found that 1 in 5 individuals with CVD still currently smoke. A worsening trend in smoking status was observed in non-

Hispanic Black adults with CVD, which may reflect the previously reported finding that non-Hispanic Black adults have more difficulty quitting smoking compared with other racial/ethnic groups.[32] Body mass index also worsened from 1999 through 2018 in U.S. adults with CVD. Our findings parallel the increasing obesity trends seen in the general U.S. population, with Black adults having a significantly higher body mass index than White adults.[20] Around 22% of U.S. adults with CVD met the guideline-recommended levels of physical activity in 2015-2018, which is lower than the 25% reported in 1999-2002, and likely due to an increase in sedentary behaviors over time.[33] About 1% of adults with CVD had an ideal diet profile in 2015-2018, and the 20-year trend remained unchanged, which is similar to the previous estimates in U.S. adults with stroke.[18]

To examine risk factors simultaneously, we created the secondary prevention metric, in accordance with the guideline emphasis on comprehensive risk factor management for patients with CVD.[1] Our metric may be used as a monitoring instrument to closely track progress in secondary prevention but is not proposed as a prognostic algorithm. Although the 10-year risk of atherosclerotic CVD improved from 1999-2000 through 2011-2012, then plateaued in the general U.S. population,[34] our secondary prevention metric showed little positive changes from 1999 through 2018. Per secondary prevention guidelines, one evidence-based approach to comprehensively modifying these risk factors for individuals with CVD is through cardiovascular rehabilitation.[35] However, cardiovascular rehabilitation is currently underutilized, with only ~20% of eligible patients participating in in-center rehabilitation programs and even lower participation rates for older adults, women, and underserved minority groups. Systematic and innovative approaches to ensure uptake of guideline recommendations at scale are important for the future of CVD prevention.

STUDY LIMITATIONS.

First, the diagnosis of CVD in our study was self-reported, which may be subject to misclassification. Prior studies have shown that self-reported information has low sensitivity but high specificity to identify CVD.[36] Second, although survey weights have been incorporated in our modeling to account for participant nonresponse, response bias could have affected the composite metric estimates, with 25% of values missing. Nevertheless, analyses on the imputed datasets yielded results similar to those reported in the main analysis. Third, our secondary prevention metric was not validated to infer clinical prognosis based on its numeric scale. Fourth, despite calibrating HbA_{1c} measured by different methods across survey cycles, residual bias in HbA_{1c} levels over time is difficult to eliminate. Fifth, the time since CVD diagnosis and duration of medication use were not available in NHANES, precluding investigation into the impact of initiation or termination of cardiovascular medications on risk factor management in patients with CVD. Sixth, because racial/ethnic information regarding non-Hispanic Asian adults was only reported starting in 2011-2012, we were unable to conduct a trends analysis in this subgroup.

CONCLUSIONS

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We observed persistently suboptimal cardiovascular risk factor profiles among U.S. adults with CVD from 1999 through 2018. These data highlight a major gap in translating secondary prevention guideline recommendations into practice. Non-Hispanic Black adults with CVD had worse overall risk profiles compared with non-Hispanic White adults with CVD, with little improvement in disparities over time. These findings serve as an urgent call for innovative and comprehensive solutions to improve cardiovascular risk factors, promote secondary prevention of CVD, and advance health equity in U.S. adults with CVD.

PERSPECTIVES

COMPETENCY IN SYSTEMS-BASED PRACTICE:

Between 1999 and 2018, adults in the United States with self-reported CVD exhibited lower blood cholesterol levels; higher HbA_{1c}, blood pressure, and body mass index; less physical activity; and little change in diet or smoking control. Over this period, racial and ethnic disparities in risk factor profiles persisted.

TRANSLATIONAL OUTLOOK:

Fresh approaches to health care delivery and public health education are needed to eliminate racial and ethnic disparities and improve implementation of secondary prevention guideline recommendations.

Supplementary Material

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Supplementary Material

Click here to view.(1.3M, docx)

FUNDING SUPPORT AND AUTHOR DISCLOSURES

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Dr Martin is a founder of and holds equity in Corrie Health; has received material support from Apple and iHealth; received funding from the Maryland Innovation Initiative, Wallace H. Coulter Translational Research Partnership, Louis B. Thalheimer Fund, the Johns Hopkins Individualized Health Initiative, the American Heart Association (20SFRN35380046, 20SFRN35490003, COVID19-811000, #878924, and #882415), the Patient-Centered Outcomes Research Institute (ME-2019CI-15328), the National Institutes of Health (P01 HL108800 and R01AG071032), the David and June Trone Family Foundation, the Pollin Digital Innovation Fund, the PJ Schafer Cardiovascular Research Fund, Sandra and Larry Small, CASCADE FH, Google, and Amgen; has received personal fees for serving on scientific advisory boards for Amgen, AstraZeneca, Dalcor, Esperion, Kaneka, Novartis, Novo Nordisk, Sanofi, and 89bio; and is a coinventor on a system for low-density lipoprotein cholesterol estimation. All other authors have reported that they have no relationships relevant to the contents of this paper to disclose.

ABBREVIATIONS AND ACRONYMS

Go to: ›

CVD	cardiovascular disease
HbA_{1c}	hemoglobin A_{1c}
HEI-2015	Healthy Eating Index-2015
NHANES	National Health and Nutrition Examination Survey
Non-HDL-C	non-high-density lipoprotein cholesterol

Footnotes

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The authors attest they are in compliance with human studies committees and animal welfare regulations of the authors' institutions and Food and Drug Administration guidelines, including patient consent where appropriate. For more information, visit the Author Center.

APPENDIX For supplemental figures and tables, please see the online version of this paper.

REFERENCES

Go to: ›

1. Cholesterol Treatment Trialists Collaboration, Baigent C, Blackwell L, et al. Efficacy and safety of more intensive lowering of LDL cholesterol: a meta-analysis of data from 170,000 participants in 26 randomised trials. *Lancet*. 2010;376:1670–1681. [PMC free article] [PubMed] [Google Scholar]

2. Zelniker TA, Wiviott SD, Raz I, et al. SGLT2 inhibitors for primary and secondary prevention of cardiovascular and renal outcomes in type 2 diabetes: a systematic review and meta-analysis of cardiovascular outcome trials. *Lancet*. 2019;393:31–39. [PubMed] [Google Scholar]

3. Smith SC Jr, Benjamin EJ, Bonow RO, et al. AHA/ACCF secondary prevention and risk reduction therapy for patients with coronary and other atherosclerotic vascular disease: 2011 update: a guideline from the American Heart Association and American College of Cardiology Foundation endorsed by the World Heart Federation and the Preventive Cardiovascular Nurses Association. *J Am Coll Cardiol*. 2011;58:2432–2446. [PubMed] [Google Scholar]

4. Grundy SM, Stone NJ, Bailey AL, et al. 2018 AHA/ACC/AACVPR/AAPA/ABC/ACPM/ADA/AGS/APhA/ASPC/NLA/PCNA guideline on the management of blood cholesterol: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *J Am Coll Cardiol*. 2019;73:e285–e350. [PubMed] [Google Scholar]

5. Whelton PK, Carey RM, Aronow WS, et al. 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA guideline for the prevention, detection, evaluation, and management of high blood pressure in adults: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *J Am Coll Cardiol*. 2018;71:2199–2269. [PubMed] [Google Scholar]

6. Yang Q, Cogswell ME, Flanders WD, et al. Trends in cardiovascular health metrics and associations with all-cause and CVD mortality among US adults. *JAMA*. 2012;307:1273–1283. [PMC free article] [PubMed] [Google Scholar]

7. Han L, You D, Ma W, et al. National trends in American Heart Association revised Life's Simple 7 metrics associated with risk of mortality among US adults. *JAMA Netw Open*. 2019;2:e193131. [PMC free article] [PubMed] [Google Scholar]

8. Criqui MH, Matsushita K, Aboyans V, et al. Lower extremity peripheral artery disease: contemporary epidemiology, management gaps, and future directions: a scientific statement from the American Heart Association. *Circulation*. 2021;144:e171–e191. [PMC free article] [PubMed] [Google Scholar]

9. Erasso LH, Fukaya E, Mohler ER 3rd, Xie D, Sha D, Berger JS. Peripheral arterial disease, prevalence and cumulative risk factor profile analysis. *Eur J Prev Cardiol*. 2014;21:704–711. [PMC free article] [PubMed] [Google Scholar]

10. Muntner P, DeSalvo KB, Wildman RP, Raggi P, He J, Whelton PK. Trends in the prevalence, awareness, treatment, and control of cardiovascular disease risk factors among noninstitutionalized patients with a history of myocardial infarction and stroke. *Am J Epidemiol*. 2006;163:913–920. [PubMed] [Google Scholar]

11. Johnson CL, Paulose-Ram R, Ogden CL, et al. National Health and Nutrition Examination Survey: analytic guidelines, 1999-2010. *Vital Health Stat*; 2013:1–24. [PubMed] [Google Scholar]

12. American Diabetes Association. 2. Classification and diagnosis of diabetes: standards of medical care in diabetes-2021. *Diabetes Care*. 2021;44:S15–S33. [PubMed] [Google Scholar]

13. Selvin E, Parrinello CM, Sacks DB, Coresh J. Trends in prevalence and control of diabetes in the United States, 1988-1994 and 1999-2010. *Ann Intern Med*. 2014;160:517–525. [PMC free article] [PubMed] [Google Scholar]

14. Sabatine MS, Giugliano RP, Keech AC, et al. Evolocumab and clinical outcomes in patients with cardiovascular disease. *N Engl J Med*. 2017;376:1713–1722. [PubMed] [Google Scholar]

15. National Center for Health Statistics. *2017-2018 data documentation, codebook, and frequencies (cholesterol)*. Published February 2020. Accessed February 25, 2022: https://wwwn.cdc.gov/Nchs/Nhanes/2017-2018/TCHOL_J.htm

16. Lin MP, Ovbiagele B, Markovic D, Towfighi A. "Life's Simple 7" and long-term mortality after stroke. *J Am Heart Assoc*. 2015;4:e001470. [PMC free article] [PubMed] [Google Scholar]

17. Reedy J, Lerman JL, Krebs-Smith SM, et al. Evaluation of the Healthy Eating Index-2015. *J Acad Nutr Diet*. 2018;118:1622–1633. [PMC free article] [PubMed] [Google Scholar]

18. Lloyd-Jones DM, Hong Y, Labarthe D, et al. Defining and setting national goals for cardiovascular health promotion and disease reduction: the American Heart Association's Strategic Impact Goal through 2020 and beyond. *Circulation*. 2010;121:586–613. [PubMed] [Google Scholar]

19. American Diabetes Association. 10. Cardiovascular disease and risk management: standards of medical care in diabetes-2021. *Diabetes Care*. 2021;44:S125–S150. [PubMed] [Google Scholar]

20. Heerings S, West BT, Berglund PA. *Applied survey data analysis*. Second ed. Boca Raton, FL: CRC Press, Taylor & Francis Group; 2017. [Google Scholar]

21. Paulose-Ram R, Burt V, Broitman L, Ahluwalia N. Overview of Asian American data collection, release, and analysis: National Health and Nutrition Examination Survey 2011-2018. *Am J Public Health*. 2017;107:916–921. [PMC free article] [PubMed] [Google Scholar]

22. He J, Zhu Z, Bundy JD, Dorans KS, Chen J, Hamm LL. Trends in cardiovascular risk factors in US adults by race and ethnicity and socioeconomic status, 1999-2018. *JAMA*. 2021;326:1286–1298. [PMC free article] [PubMed] [Google Scholar]

23. Patel N, Bhargava A, Kalra R, et al. Trends in lipid, lipoproteins, and statin use among U.S. adults: impact of 2013 cholesterol guidelines. *J Am Coll Cardiol*. 2019;74:2525–2528. [PubMed] [Google Scholar]

24. Lindelas JK. *mcp: An R Package for Regression With Multiple Change Points*. Published January 2020. Accessed February 25, 2022. 10.31219/osf.io/fzqxv. [CrossRef] [Google Scholar]

25. Mitchell UA, Ailshire JA, Kim JK, Crimmins EM. Black-White differences in 20-year trends in cardiovascular risk in the United States, 1990-2010. *Ethn Dis*. 2019;29:587–598. [PMC free article] [PubMed] [Google Scholar]

26. Ely EK, Gruss SM, Luman ET, et al. A national effort to prevent type 2 diabetes: participant-level evaluation of CDC's National Diabetes Prevention Program. *Diabetes Care*. 2017;40:1331–1341. [PMC free article] [PubMed] [Google Scholar]

27. Barker L, Crespo R, Gerzoff RB, Denham S, Shrewsberry M, Cornelius-Averhart D. Residence in a distressed county in Appalachia as a risk factor for diabetes, Behavioral Risk Factor Surveillance System, 2006-2007. *Prev Chronic Dis*. 2010;7:A104. [PMC free article] [PubMed] [Google Scholar]

28. Muntner P, Hardy ST, Fine LJ, et al. Trends in blood pressure control among U.S. adults with hypertension, 1999-2000 to 2017-2018. *JAMA*. 2020;324:1190–1200. [PMC free article] [PubMed] [Google Scholar]

29. Gao F, He D, Zhang W, Walton RG. Trends in prevalence, awareness, management, and control of hypertension among United States adults, 1999 to 2010. *J Am Coll Cardiol*. 2012;60:599–606. [PubMed] [Google Scholar]

30. Kressin NR, Orner MB, Manze M, Glickman ME, Berlowitz D. Understanding contributors to racial disparities in blood pressure control. *Circ Cardiovasc Qual Outcomes*. 2010;3:173–180. [PMC free article] [PubMed] [Google Scholar]

31. Chou AF, Scholle SH, Weisman CS, Bierman AS, Correa-de-Araujo R, Mosca L. Gender disparities in the quality of cardiovascular disease care in private managed care plans. *Womens Health Issues*. 2007;17:120–130. [PubMed] [Google Scholar]

32. Keyhani S, Scobie JV, Hebert PL, McLaughlin MA. Gender disparities in blood pressure control and cardiovascular care in a national sample of ambulatory care visits. *Hypertension*. 2008;51:1149–1155. [PubMed] [Google Scholar]

33. Vega GL, Grundy SM. Current trends in non-HDL cholesterol and LDL cholesterol levels in adults with atherosclerotic cardiovascular disease. *J Clin Lipidol*. 2019;13:563–567. [PubMed] [Google Scholar]

34. Rodriguez CJ, Cai J, Swett K, et al. High cholesterol awareness, treatment, and control among Hispanic/Latinos: results from the Hispanic Community Health Study/Study of Latinos. *J Am Heart Assoc*. 2015;4:e001867. [PMC free article] [PubMed] [Google Scholar]

35. Gandhi KK, Foulds J, Steinberg MB, Lu SE, Williams JM. Lower quit rates among African American and Latino menthol cigarette smokers at a tobacco treatment clinic. *Int J Clin Pract*. 2009;63:360–367. [PubMed] [Google Scholar]

36. Petersen R, Pan L, Blanck HM. Racial and ethnic disparities in adult obesity in the United States: CDC's tracking to inform state and local action. *Prev Chronic Dis*. 2019;16:E46. [PMC free article] [PubMed] [Google Scholar]

37. Piercy KL, Troiano RP, Ballard RM, et al. The Physical Activity Guidelines for Americans. *JAMA*. 2018;320:2020–2028. [PMC free article] [PubMed] [Google Scholar]

38. Lin AM, Lin MP, Markovic D, Ovbiagele B, Sanossian N, Towfighi A. Less than ideal: trends in cardiovascular health among U.S. stroke survivors. *Stroke*. 2019;50:5–12. [Google Scholar]

39. Ritchey MD, Maresh S, McNeely J, et al. Tracking cardiac rehabilitation participation and completion among Medicare beneficiaries to inform the efforts of a national initiative. *Circ Cardiovasc Qual Outcomes*. 2020;13:e005902. [PMC free article] [PubMed] [Google Scholar]

40. Barr EL, Tonkin AM, Welborn TA, Shaw JE. Validity of self-reported cardiovascular disease events in comparison to medical record adjudication and a statewide hospital morbidity database: the AusDiab study. *Intern Med J*. 2009;39:49–53. [PubMed] [Google Scholar]

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