

RESEARCH ARTICLE

Health Insurance Status as a Barrier to Ideal Cardiovascular Health for U.S. Adults: Data from the National Health and Nutrition Examination Survey (NHANES)

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Abstract

Background

Little is known about the association between cardiovascular (CV) health and health insurance status. We hypothesized that U.S. adults without health insurance coverage would have a lower likelihood of ideal cardiovascular health.

Methods and Results

Using National Health and Nutrition Examination Survey (NHANES) data from 2007–2010, we examined the relationship between health insurance status and ideal CV health in U.S. adults aged ≥ 19 years and < 65 ($N = 3304$). Ideal CV health was defined by the American Heart Association (AHA) as the absence of clinically manifested CV disease and the simultaneous presence of 6–7 “ideal” CV health factors and behaviors. Logistic regression modeling was used to determine the relationship between health insurance status and the odds of ideal CV health. Of the U.S. adult population, 5.4% attained ideal CV health, and 23.5% were without health insurance coverage. Those without health insurance coverage were more likely to be young ($p < 0.0001$), male ($p < 0.0001$), non-white ($p < 0.0001$), with less than a high school degree ($p < 0.0001$), have a poverty-to-income ratio less than 1

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($p < 0.0001$) and unemployed ($p < 0.0001$) compared to those with coverage. Lack of health insurance coverage was associated with a lower likelihood of ideal CV health; however, this relationship was attenuated by socioeconomic status.

Conclusions

U.S. adults without health insurance coverage are less likely to have ideal CV health. Population-based strategies and interventions directed at the community-level may be one way to improve overall CV health and reach this at-risk group.

Introduction

Cardiovascular disease (CVD) is the leading cause of morbidity and mortality in the United States [1]. Recent data suggest that having a greater number of ideal cardiovascular (CV) health factors and behaviors (i.e. optimal body-mass-index (BMI), blood pressure, fasting blood glucose, and blood lipid levels; adequate physical activity (PA), a healthy diet pattern, and non-smoking) is inversely associated with lower CVD morbidity and mortality [2–4]. Therefore, population-level interventions that shift CV health behaviors and factors from poor toward ideal are essential.

Unfortunately, ideal CV health is rare in U.S. adults. Less than 5% of U.S. adults achieve ideal CV status, with African Americans disproportionately less likely to have six or seven ideal cardiovascular health factors compared to all other US racial/ethnic groups [1]. Consequently, public health agencies, including the U.S. Department of Health and Human Services through the Healthy People 2020 Guidelines, and organizations such as the American Heart Association (AHA) have outlined initiatives and prioritized strategies to improve CV health and shift CV health factors towards ideal for the U.S. population [5, 6].

Inadequate access to health care services likely poses a challenge to improving the CV health of the U.S. population. Studies have shown that uninsured U.S. adults are less likely to receive medical care, particularly preventive services including routine testing and screening for CVD risk factors [7, 8]. In 2013, 42 million Americans lacked health insurance coverage [9]. Despite expanded and improved access through the Patient Protection and Affordable Care Act in 2014, lack of health insurance coverage remains common among U.S. adults, with gross disparities across racial/ethnic groups and age [10]. Multiple studies have found an association between lack of health insurance and all-cause mortality [11–13]. However, no study to date has looked at the relationship between health insurance coverage and ideal cardiovascular health, a clear precursor to reduced cardiovascular morbidity and mortality [2, 3].

Thus, we sought to understand the relationship between health insurance coverage and CV health in a nationally representative U.S. adult population using National Health and Nutrition Examination Survey (NHANES) data from 2007–2010. We hypothesized that those U.S. adults without health insurance coverage would have a lower likelihood of ideal CV health.

Methods

National Health and Nutrition Examination Overview

The National Health and Nutrition Examination Survey (NHANES) is a series of cross-sectional surveys designed by the Centers for Disease Control's National Center for Health Statistics (NCHS). The survey is conducted using a multistage, stratified sampling design to assess

the health and nutritional status of a nationally representative sample of the civilian, non-institutionalized U.S. population. In-home medical history interviews were conducted to gather demographic, socio-economic and health-related information. Participants also underwent a standardized physical examination and completed a 24-hour dietary recall and a dietary behavior questionnaire at mobile examination centers (MEC). The first 24-hour recall for each participant was conducted in-person with English- or Spanish-speaking dietary interviewers. Detailed information regarding NHANES data collection has been previously reported [14]. NHANES data from 2007–2010 were merged for this analysis. Earlier cycles were not included because the physical activity questionnaire changed between the 05–06 and 07–08 cycles.

Ethics Statement

The study was conducted according to the guidelines in the Declaration of Helsinki and all procedures involving human subjects were approved by the National Center for Health Statistics Institutional Review Board. Written informed consent was obtained from all participants 18 years of age and older.

Sample Demographics

Age, sex, race and ethnicity, education, poverty-to-income ratio (PIR) and employment categories were defined using self-reported demographic data from 2007–2010 NHANES. Four distinct age groups were included in our analysis: 19–29 years, 30–39 years, 40–49 years, and 50–64 years. Racial and ethnic groups were characterized based on responses to questions about race and Hispanic origin. We included non-Hispanic White, non-Hispanic Black, and Mexican American persons who reported a single racial identity because the group sample sizes were adequate for separate evaluation and estimates [15]. Level of education was categorized as less than high school, completed high school/equivalent, some college, and completed college. The PIR is a ratio of family income to the Health and Human Services (HHS) federal poverty threshold that accounts for inflation and family size. A PIR below 1 indicates that the family income is less than 130% of the poverty threshold, a PIR of 1–3 corresponds to 131%–185% of the poverty threshold, and a PIR of greater than 3 corresponds to income greater than 185% of the poverty threshold. Employment was defined as unemployed, employed (working at a job or business), or employed, but not working (with a job or business, but not at work).

Cardiovascular Health Factors

Four CV health factors were measured during the physical examination (blood pressure, body mass index, cholesterol, fasting blood glucose), and three CV factors were determined by self-report (smoking status, physical activity, and dietary intake). Three separate blood pressure measurements were taken during the physical exam and averaged to calculate each individual's blood pressure [16]. Ideal blood pressure was defined as systolic <120 mm Hg and diastolic <80 mm Hg, intermediate was defined as systolic 120–139 mm Hg, diastolic 80–90 mm Hg, or treated to goal, and poor was defined as systolic \geq 140 mm Hg or diastolic \geq 90 mm Hg. Weight and height were measured during NHANES physical examinations at the MEC. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared and rounded to the nearest tenth. Consistent with standard weight ranges of normal, overweight and obese, BMI was categorized as ideal, intermediate and poor. Ideal was defined as BMI 18.5–24.9 kg/m², intermediate was defined as BMI 25–29.9 kg/m², and poor was defined as BMI \geq 30 kg/m². Blood samples were collected from NHANES participants during their physical examination. Further procedures for blood processing are described elsewhere [14]. Total blood cholesterol and fasting blood glucose measurements for NHANES participants were

determined from their blood sample. Ideal total blood cholesterol was defined as <200 mg/dl untreated, intermediate total blood cholesterol was defined as 200–239 mg/dl or treated to goal, and poor total blood cholesterol was defined as ≥ 240 mg/dl. Ideal fasting blood glucose was defined as <100 mg/dl with no history of diabetes mellitus. Intermediate fasting blood glucose was defined as 100–125 mg/dl or treated to goal. Poor fasting blood glucose was defined as ≥ 126 mg/dl.

Ideal smoking status was defined as never smoker, intermediate was defined as former smoker, and poor was defined as current smoker. Ideal physical activity (PA) was defined as ≥ 150 minutes per week of moderate activity or ≥ 75 minutes per week of vigorous activity or ≥ 150 minutes per week of combined moderate and vigorous activity; intermediate was defined as 1–149 minutes per week of moderate activity or 1–74 minutes per week of vigorous activity or 1–149 minutes per week of combined moderate and vigorous activity; and poor was defined as no reported physical activity.

Dietary Intake. The dietary portion of NHANES is conducted as a partnership between the U.S. Department of Agriculture (USDA) and HHS to estimate the types and amounts of foods and beverages consumed by respondents during the 24-hour period prior to the interview. Two 24-hour dietary recalls were collected by trained dietary interviewers: an in-person interview on Day 1 at the MEC and a telephone interview collected 3–10 days after Day 1. All participants who had reliable 24-hour recall data from Day 1 were included in our study population. Day 1 of the 24-hour recall data was used because the majority of participants completed Day 1 testing during the MEC examination, and the setting was consistent for all participants.

Each food or beverage reported during the 24-hour recall was coded with a specific food code from the US Department of Agriculture Food and Nutrient Database for Dietary Studies (FNDDS), a database of foods and beverages, nutrient values and weights for portions. NHANES 2007–2008 and NHANES 2009–2010 data were coded with FNDDS 4.1 and FNDDS 5.0, respectively [17, 18]. The USDA's Food Patterns Equivalents Database (FPED) was used to translate single and multi-ingredient foods into cup, ounce (oz.) or teaspoon equivalents and to convert reported foods into nutritionally meaningful groupings. The database disaggregates reported foods into ingredients and classifies the ingredients into one of 37 predefined groupings ("components"), such as whole grains or dark green vegetables [19, 20]. FPED 07–08 and FPED 09–10 correspond with NHANES 07–08 and NHANES 09–10.

Fruit and vegetable servings were measured in cup equivalents. Fruits included whole, dried, and canned fruit, mixed fruit dishes and fruit juice. Vegetables included dark green vegetables, red and orange vegetables, starchy vegetables, and excluded beans and legumes. The sum of the total fruits and vegetables for each respondent represented total fruit and vegetable intake measured in cups. Fish servings were measured in cup equivalents and included fish high and low in n-3 fatty acids. Fiber-rich whole grains were measured in ounce equivalents and included those whole grains that contain the entire grain kernel – the bran, germ, and endosperm. Dietary sodium intake in milligrams per day was measured using the Total Nutrient Intake File [21, 22]. Estimated sodium intake does not include salt added at the table. Consistent with other studies [23, 24], sugar-sweetened beverages (SSBs) were defined as any non-diet, non-alcoholic beverage items and beverage concentrates with added sugars. SSBs included soda, fruit drinks, energy and sports drinks, sweetened coffee, sweetened tea, liquid and dry beverage concentrates and sweetened bottled waters, all with added sugars. Those beverages that were sweetened after purchase were not considered a SSB. SSBs were measured in kilocalories per week. Because FPED values for added sugars are measured in teaspoons per day, a standard 16.8 kcal/teaspoon of added sugars was used as a conversion factor for calculating kilocalories from added sugars in SSBs. Total kilocalories was multiplied by seven to represent weekly caloric intake from added sugars in SSBs.

To evaluate the dietary intake of US adults, we computed a healthy diet score, previously described by Lloyd-Jones *et al* [5] and consistent with the current Dietary Guidelines for Americans [25] and AHA recommendations [26, 27]. The healthy diet score sets ideal criteria for five constituents of dietary intake: fruits and vegetables [≥ 4.5 cups per day], fish [\geq two 3.5-oz servings per week (preferably oily fish)], fiber-rich whole grains [\geq three 1-oz-equivalent servings per day], sodium [< 1500 mg per day], and SSBs [≤ 450 kcal (36 oz.) per week]. Ideal dietary intake was defined as meeting 4 to 5 components of the healthy diet criteria. Intermediate was defined as meeting 2 to 3 components. Poor was defined as meeting 0 to 1 components.

Overall, ideal CV health was defined as meeting ideal across 6–7 CV health factors, intermediate CV health was defined as meeting ideal across 3–5 CV health factors, and poor CV health was defined as meeting ideal across 0–2 ideal CV health factors.

Study Population

For our analysis, we included data on those US adults aged 19–64 who had a non-missing sample weight and a non-missing questionnaire response to the health insurance coverage question. We excluded those aged 65 and older, as an overwhelming majority of these individuals have health insurance through Medicare. In agreement with previous studies [11, 28, 29], we also excluded individuals covered under the Department of Veterans Affairs/Civilian Health and Medical Program of the Uniformed Services military insurance and non-elderly Medicare due to poor health being a prerequisite for coverage for most individuals under these plans. Of the 3576 individuals with a non-missing insurance status, non-missing sample weight and within the age range of 19–64 years, 272 (7.6%) had incomplete information for one or more of the 7 CV health factors, resulting in a final study population of 3304 NHANES participants. Of the 272 participants excluded, 105 had incomplete BP data, 0 had incomplete blood glucose data, 19 had incomplete cholesterol data, 1 had incomplete PA measurement data, 0 had incomplete dietary data, 124 had incomplete smoking data, and 33 had incomplete BMI data. Some participants had incomplete data for multiple CV factors.

Statistical Analysis

A multistage, probability sampling design was used to make our cohort representative of the civilian, non-institutionalized U.S. population. The sample-weighted chi-square test was used to compare the percentage of uninsured across socio-demographic categories. An age-adjusted, sample-weighted linear regression model was used to compare the percentage of uninsured across CV health factor categories. Sample-weighted logistic regression models were developed to assess the relationship between health insurance coverage and the likelihood of ideal cardiovascular health. Results from logistic models are shown as unadjusted, adjusted for age, race and sex (Model 1), and adjusted for age, race, sex and socioeconomic status (SES) (Model 2). All analyses were performed using SAS, version 9.2, in 2014–2015.

Results

The sample-weighted percentages of uninsured U.S. adults for the 2007–2010 NHANES population across socio-demographic categories are shown in [Table 1](#). Of the U.S. adult population, 76.5% ($n = 2225$) were with health insurance coverage, while 23.5% ($n = 1079$) were without coverage. U.S. adults without health insurance were more likely to be young ($p < 0.0001$), male ($p < 0.0001$), non-white ($p < 0.0001$), have less than a high school level education ($p < 0.0001$), have a PIR less than 1 ($p < 0.0001$) and unemployed ($p < 0.0001$) compared to those with health insurance ([Table 1](#)).

Table 1. Sample-weighted Baseline Characteristics of 2007–2010 NHANES Population (N = 3304) by Health Insurance Status.

| Baseline Characteristics | | N ^a | % Uninsured (SE) | p-value |
|--------------------------------|------------------------------------|----------------|------------------|---------|
| Age | 19–29 | 681 | 37.8 (2.3) | < .0001 |
| | 30–39 | 701 | 24.0 (2.3) | |
| | 40–49 | 768 | 20.0 (1.6) | |
| | 50–64 | 1154 | 15.3 (1.4) | |
| Sex | Female | 1714 | 20.3 (1.2) | < .0001 |
| | Male | 1590 | 26.7 (1.3) | |
| Race | Non-Hispanic White | 1488 | 16.6 (1.3) | < .0001 |
| | Non-Hispanic Black | 647 | 29.5 (2.1) | |
| | Mexican American | 1169 | 49.7 (2.1) | |
| Education | <High school | 896 | 52.7 (2.0) | < .0001 |
| | High school/equivalent | 775 | 29.3 (2.5) | |
| | Some college | 932 | 20.5 (1.5) | |
| | College graduate | 698 | 7.4 (1.2) | |
| Poverty-to-Income Ratio | <1 | 672 | 52.6 (2.8) | < .0001 |
| | 1–3 | 1214 | 32.9 (1.9) | |
| | >3 | 1122 | 7.3 (1.1) | |
| Employment | Unemployed | 1015 | 30.1 (1.7) | < .0001 |
| | Employed, working ^b | 2208 | 21.4 (1.1) | |
| | Employed, not working ^c | 81 | 11.9 (3.7) | |

SE = Standard Error

^a Sample size (N) for each group represents total unweighted N for individuals in each group.

^b Employed, working, includes those working at a job or business

^c Employed, not working, includes those with a job or business, but not working

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Of U.S. adults included in this analysis, 5.4% (n = 141) had ideal CV health (6–7 ideal CV health factors), 58.3% (n = 1839) had intermediate CV health (3–5 ideal CV health factors), and 36.3% (n = 1324) had poor CV health (0–2 ideal CV health factors). Only 0.02% of the population had ideal status for all 7 CV health factors. Among the individuals with ideal, intermediate, and poor CV health, the age-adjusted percent distribution with standard errors for those without health insurance coverage was 6.3%±3.1% (n = 31), 23.6%±1.1% (n = 650), and 24.9%±1.5% (n = 398), respectively (p < .0001).

Table 2 displays the sample-weighted, age-adjusted percentage of uninsured U.S. adults for the 2007–2010 NHANES population across ideal, intermediate or poor categories for each of the seven CV health factors and behaviors. With regard to health factors, U.S. adults with poor fasting blood glucose (uncontrolled diabetes), and poor blood pressure levels (uncontrolled hypertension) were more likely to be uninsured. Those with poor status for BMI (BMI ≥ 30 kg/m²) and blood cholesterol were less likely to be uninsured. For the health behaviors, those with poor smoking status (current smokers) and with a poor level of physical activity (none reported per week) were also more likely to be uninsured. There was no statistically significant relationship between dietary intake and insurance status.

Fig 1 displays the odds of ideal CV health of the NHANES 2007–2010 adult population by health insurance status. U.S. adults without health insurance were 51% less likely to have ideal CV health compared to U.S. adults with health insurance coverage (OR = 0.49, CI = 0.30–0.80), a relationship that remained significant after adjustment for age, race and sex (OR = 0.38, 95% CI = 0.23–0.62). This relationship no longer remained significant after

Table 2. Sample-weighted, Age-Adjusted Cardiovascular Health Factors of 2007–2010 NHANES Population (N = 3304) by Health Insurance Status.

| Baseline Characteristics | | N ^d | % Uninsured (SE) | p-value |
|---|---|----------------|------------------|---------|
| Body Mass Index | Ideal (Normal: 18.5–24.9 kg/m ²) | 853 | 23.7 (1.8) | < .0001 |
| | Intermediate (Overweight: 25–29.9 kg/m ²) | 1144 | 23.3 (1.4) | |
| | Poor (Obese: ≥30 kg/m ²) | 1307 | 22.6 (1.7) | |
| Dietary Intake^e | Ideal (4–5 Healthy Diet components) | 5 | 42.4 (24.7) | 0.0953 |
| | Intermediate (2–3 Healthy Diet components) | 564 | 21.3 (1.8) | |
| | Poor (0–1 Healthy Diet components) | 2735 | 23.5 (1.0) | |
| Cholesterol | Ideal (<200 mg/dL untreated) | 1620 | 24.7 (1.4) | < .0001 |
| | Intermediate (200–239 mg/dl or treated to goal) | 1234 | 21.4 (1.4) | |
| | Poor (≥240 mg/dL) | 450 | 22.6 (2.3) | |
| Smoking Status | Ideal (Never smoker) | 1820 | 18.8 (1.2) | < .0001 |
| | Intermediate (Former Smoker) | 672 | 20.5 (1.6) | |
| | Poor (Current Smoker) | 811 | 36.0 (2.0) | |
| Fasting Blood Glucose | Ideal (<100 mg/dL w/o Hx of DM) | 1687 | 22.2 (1.3) | < .0001 |
| | Intermediate (100–125 mg/dL or treated to goal) | 1310 | 23.4 (1.4) | |
| | Poor (≥126 mg/dL) | 307 | 30.4 (2.5) | |
| Blood Pressure | Ideal (SBP < 120 mmHg, DBP < 80 mm Hg) | 1615 | 21.7 (1.4) | < .0001 |
| | Intermediate (SBP 120–139 mmHg, DBP 80–90 mmHg) | 1295 | 21.9 (1.6) | |
| | Poor (SBP ≥ 140 mm Hg or DBP ≥ 90 mm Hg) | 394 | 36.8 (3.0) | |
| Physical Activity (minutes/week) | Ideal (≥150 mod/ ≥75 vig/ ≥150 mod/vig) | 2132 | 22.1 (1.0) | < .0001 |
| | Intermediate (≤149 mod/ ≤74 vig/ ≤149 mod/vig) | 444 | 19.5 (2.5) | |
| | Poor (None) | 728 | 30.2 (2.2) | |

Hx, history; DM, Diabetes Mellitus; SBP, systolic blood pressure; DBP, indicates diastolic blood pressure; mod, moderate; vig, vigorous

^d Sample size (N) for each group represents total unweighted N for individuals in each group.

^e Healthy Diet components: Fruits and vegetables: >4.5 cups per day; Fish: >two 3.5-oz servings per week (preferably oily fish); Fiber-rich whole grains (>1.1 g of fiber per 10 g of carbohydrate): > three 1-oz-equivalent servings per day; Sodium: <1500 mg per day; Sugar-sweetened beverages: <450 kcal (36 oz. per week) per week

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adjusting for SES (OR = 0.64, 95% CI = 0.37–1.11). For both models 1 and 2, there was neither a sex (p = 0.76 and p = 0.76, respectively) nor race (p = 0.13 and p = 0.26, respectively) interaction. Post hoc analyses revealed that education was the most dominant explanatory SES variable associated with ideal CV health based on c-statistics (data not shown). However, the combined model adjusting for insurance status, education, and income provided a significantly better fit than the models considering individual SES variables only.

Discussion

In our logistic regression analysis of an ethnically diverse cohort of U.S. adults, we found that those without health insurance coverage were less likely to have ideal cardiovascular health, independent of age, sex, and race. Adjusting for individual-level SES attenuated this relationship. With regard to CV health factors, U.S. adults with poor fasting blood glucose and poor blood pressure levels were more likely to be uninsured. Those with poor status for BMI were less likely to be uninsured. Those with ideal total cholesterol levels were more likely to be uninsured than those with poor total cholesterol levels. With regards to CV health behaviors, those with poor smoking status and with a poor level of physical activity were also more likely to be uninsured. Thus, targeting policy efforts that aim to increase healthcare coverage may aid in

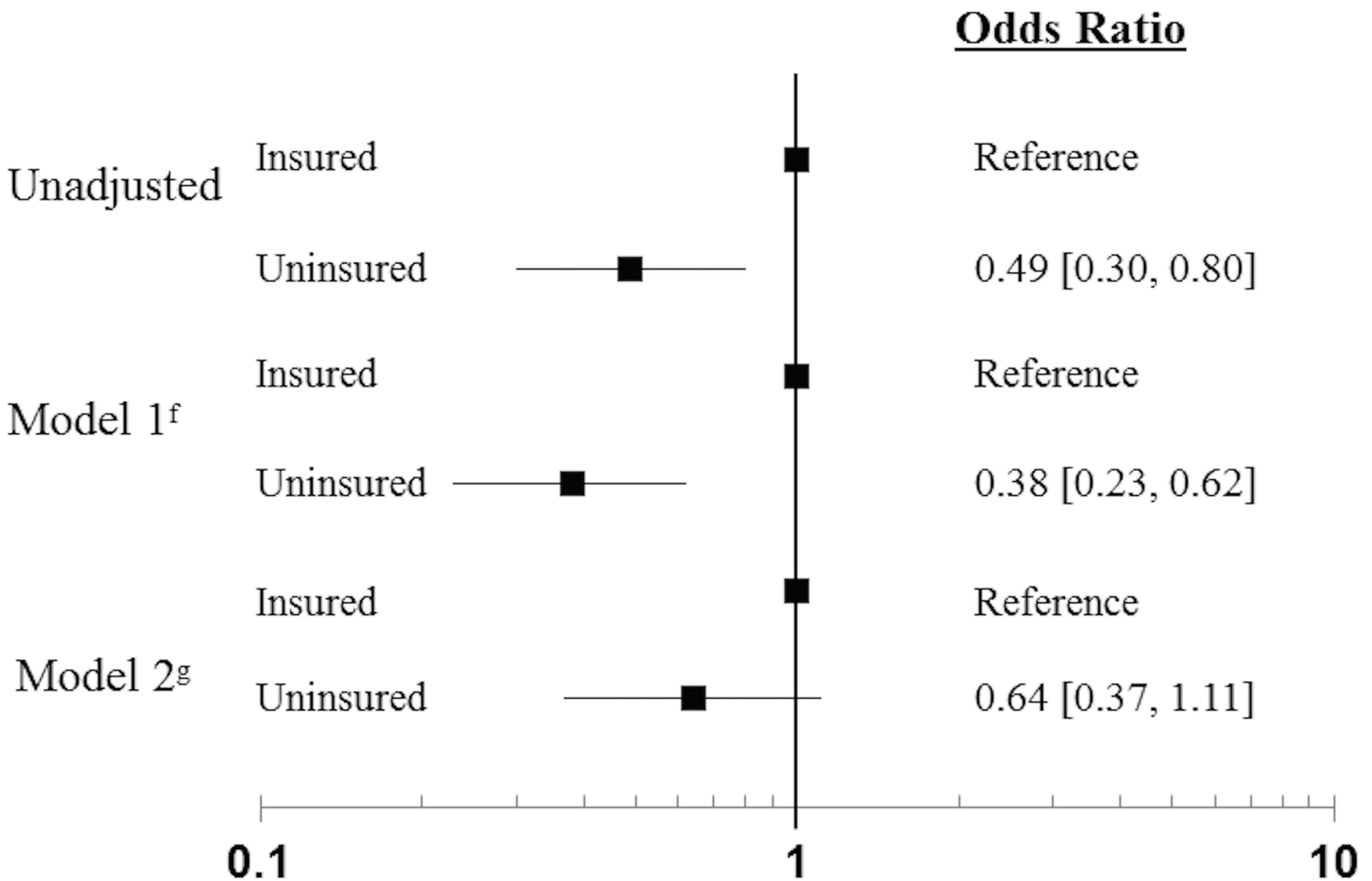


Fig 1. Odds of Ideal Cardiovascular Health of NHANES 2007–2010 Population (N = 3304) by Health Insurance Status. ^fModel 1: Adjusted for age, sex, race; ^gModel 2: Adjusted for age, sex, race, SES.

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improving and sustaining certain individual level CV health factors and behaviors, thus improving the overall CV health of adults in the United States.

This is one of the first studies to assess the relationship between health insurance coverage and prevalence of ideal CV health. Our findings suggest that the lack of health insurance coverage may be a barrier to achieving ideal cardiovascular health for U.S. adults. Consistent with previous work, our findings also suggest that uncontrolled hypertension and uncontrolled diabetes mellitus (designated by AHA-defined “poor” status for blood pressure: SBP ≥ 140 mmHg or DBP ≥ 90 mmHg, and fasting blood glucose: ≥ 126 mg/dl) are conditions associated with a lack of health insurance coverage [30–32]. Prior data in a similar NHANES adult population demonstrate that uninsured hypertensive adults were more likely to be uncontrolled than their insured peers, and uninsured diabetics were twice as likely to be previously undiagnosed than insured diabetics, but these data do not explain how the lack of health insurance coverage impacts individual CV health factors’ contribution to overall ideal CV health [30, 32]. Analyses of health insurance coverage and chronic conditions typically show that adults without health insurance are less likely to be aware of personal diagnoses, less likely to receive screening for and achieve control of chronic medical conditions, such as hypercholesterolemia and hypertension [7, 8, 31–33] and less likely to receive preventive care including routine check-ups, hypertension screening, cholesterol screening, weight loss counseling, and smoking cessation [34].

This disparity may put uninsured individuals at increased risk of having undiagnosed or uncontrolled conditions, including hypertension, hypercholesterolemia, and diabetes mellitus. Observations in the present study suggest that by expanding health insurance coverage, cases of uncontrolled hypertension and uncontrolled diabetes mellitus may decrease, thus shifting the overall CV health of U.S. adults closer to ideal.

While a lack of health insurance coverage appears to be associated with uncontrolled hypertension and diabetes mellitus, our results show an inverse association between a lack of health insurance coverage and both obesity (designated by the AHA-defined poor status for BMI: $\text{BMI} \geq 30 \text{ kg/m}^2$) and hypercholesterolemia. These findings may be attributed to an uninsured population in the United States that is disproportionately younger [35] and our inability to adjust for additional age-related confounders, including metabolic rate [36] that likely affect BMI and blood cholesterol. Our findings differ from previous studies in which uninsured individuals were observed to have a higher BMI and a higher prevalence of obesity than and similar or lower total blood cholesterol levels as their insured peers [33, 34, 37, 38]. For instance, in a study of a predominantly white adult population in the Framingham Heart Study, uninsured women had significantly higher mean BMI (28.0 kg/m^2 versus 26.5 kg/m^2 ; $p = 0.02$), a higher prevalence of obesity (34% versus 23%; $p = 0.01$), and comparable total blood cholesterol levels ($193 \pm 36 \text{ mg/dL}$ versus $195 \pm 40 \text{ mg/dL}$; $p = 0.67$) [33]. While our inability to adjust for additional confounders may explain some variation in findings, it is also possible that our results differed from previous studies due to differences in the composition of the study populations. NHANES data are representative of the general U.S. population and possess geographic variability and racial/ethnic diversity that most other population-based cohorts do not.

Consistent with our observations, other data suggest that there may, in fact, be no association between poor BMI levels and lack of health insurance coverage. For example, a 2010 state-by-state analysis of insurance coverage for obesity treatments found that if an obese patient obtained individual health insurance, there was no guarantee that obesity-related treatment would be covered under his or her health plan [39]. Furthermore, at the time the NHANES cycles analyzed in this study were conducted, states were not insuring recommended screening and treatment of adults for obesity through public or private insurance [39]. Further research is needed to see the impact on CV health of more recent insurance coverage for obesity and hypercholesterolemia screening, diagnosis, and treatment.

Regarding CV health behaviors, we observed an association between a lack of health insurance coverage and those with poor smoking status (current smokers), a finding consistent with prior studies [7, 28, 33, 37]. Reduced access to preventive care, particularly smoking cessation, may explain the poor smoking status of uninsured individuals, as insurance coverage of evidence-based smoking cessation treatments has been shown to lead to increases in quit attempts, use of cessation treatments, and successful smoking cessation [40]. Increasing health insurance coverage may be one way to expand the reach of cessation efforts; however, increasing coverage appears to be only one part of the solution [41]. For insured patients to take full advantage of cessation coverage, it should also be promoted within health plans adequately [41]. Smoking cessation appears to require a multi-faceted approach, and our findings show that expanding health insurance coverage may play a role.

Consistent with previous work [12], engaging in physical activity appears to be an additional CV health behavior that is linked to health insurance status, while dietary intake appears to be unrelated. Data from the National Health Interview Survey has shown that uninsured adults are more likely to be inactive than adults insured by private insurance, Medicaid or other forms of health insurance [42–45]. Though this association could be explained by overall SES, health insurance coverage may be a primary contributor, as lacking coverage is one marker of lower SES. Adults with a lower SES often experience greater barriers to exercise than their

higher SES peers, particularly with respect to transportation and costs [46]. Health insurance coverage may aid in the reduction of costs for physical activity programs and facilities for individuals, thus alleviating one of the often cited barriers to physical activity by low SES adults.

Interventions that shift at-risk individuals, particularly those without health insurance, from poor toward ideal cardiovascular health are essential. During the first quarter of 2015, the uninsured rate among Americans dropped to 11.9%, its lowest point in seven years, with success largely credited to the roll out of the Affordable Care Act during the last quarter of 2013 [47]. Despite the steady improvement, U.S. adults continue to live without health insurance and are likely not receiving the preventive care and disease management necessary for ideal CV health. Our study suggests that interventions designed to target those CV health factors and behaviors associated with a lack of health insurance coverage (i.e. poor blood glucose control, poor blood pressure control, poor levels of PA, smoking) can potentially facilitate this shift towards ideal cardiovascular health for uninsured populations. To reach at-risk populations, community-based interventions may offer an effective population approach to target prevalent obesity and shift cardiovascular health towards ideal [48–50]. Community-based interventions can address disparities in cardiovascular health across racial/ethnic groups, particularly among those with limited access to care in clinical settings [51]. Uninsured adults are one sub-population with limited access to care in clinical settings, so expanding community-based interventions to reach this at-risk group may contribute to improved CV health and reduce health disparities.

Strengths of this study include the use of the National Health and Nutrition Examination Survey, a nationally representative sample, for our analysis, and the ability to gather data on all seven measures of CV health. However, limitations of this analysis must be acknowledged. We have documented an association between health insurance coverage and ideal cardiovascular health, but the possibility of unmeasured confounding requires further investigation. Our analysis focused specifically on health insurance coverage and did not take into consideration the usual source of care of survey respondents. In previous studies, those individuals (both uninsured and insured) who reported a regular, ongoing relationship with a health service facility or provider were more likely than those without a usual source of care to access health services [52, 53], suggesting that health care seeking behaviors are multi-factorial and not solely dependent on health insurance coverage. Additionally, out-of-pocket expenses (cost sharing) and setting of care are unknown. In the RAND Health Insurance Experiment, cost sharing reduced the use of nearly all health services, worsened blood pressure control, was associated with a decrease in use of essential medications and was associated with an increase in adverse events among the poor and elderly [54, 55]. Also, the cross-sectional design of NHANES, limited our ability to measure continuity of coverage, duration of insurance coverage and temporal changes in the health care system which would likely impact our findings, as irregular insurance coverage has been associated with poor health among middle-aged persons and the near-elderly [56, 57]. Lastly, although measurements are based on validated survey instruments, the CV health behaviors (e.g. PA, dietary intake, smoking status) are subject to self-reported measurement error.

Our results suggest that public policy initiatives that focus on improving access to health insurance may play a role in improving individual cardiovascular health factors and behaviors and overall cardiovascular health for the U.S. population. Additionally, community-level interventions targeting blood glucose and blood pressure control, smoking and physical inactivity may be most effective at improving CV health for uninsured populations. Future studies should aim to further examine the relationship between health insurance coverage and CV health and further explore community-based strategies for reaching this at-risk population in the United States.

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Author Contributions

Conceived and designed the experiments: TP MM DB CA. Analyzed the data: MM LY VS RC CA AN DB TP. Contributed reagents/materials/analysis tools: CA AN. Wrote the paper: MM LY TP.

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