ORIGINAL RESEARCH

Educational Attainment, Race, and Ethnicity as Predictors for Ideal Cardiovascular Health: From the National Health and Nutrition Examination Survey

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BACKGROUND: Educational attainment is protective for cardiovascular health (CVH), but the benefits of education may not persist across racial and ethnic groups. Our objective was to determine whether the association between educational attainment and ideal CVH differs by race and ethnicity in a nationally representative sample.

METHODS AND RESULTS: Using the National Health and Nutrition Examination Survey, we determined the distribution of ideal CVH, measured by Life's Simple 7, across levels of educational attainment. We used multivariable ordinal logistic regression to assess the association between educational attainment (less than high school, high school graduate, some college, college graduate) and Life's Simple 7 category (ideal, intermediate, poor), by race and ethnicity (Asian, Black, Hispanic, White). Covariates were age, sex, history of cardiovascular disease, health insurance, access to health care, and income–poverty ratio. Of 7771 National Health and Nutrition Examination Survey participants with complete data, as level of educational attainment increased, the criteria for ideal health were more often met for most metrics. After adjustment for covariates, effect of education was attenuated but remained significant ($P<0.01$). Those with at least a college degree had 4.12 times the odds of having an ideal Life's Simple 7 compared with less than high school (95% CI, 2.70–5.08). Among all racial and ethnic groups, as level of educational attainment increased, so did Life's Simple 7. The magnitude of the association between education and CVH varied by race and ethnicity (interaction $P<0.01$).

CONCLUSIONS: Our findings demonstrate that educational attainment has distinct associations with ideal CVH that differs by race and ethnicity. This work demonstrates the need to elucidate barriers preventing individuals from racial and ethnic minority groups from achieving equitable CVH.

Key Words: cardiovascular health ■ educational status ■ race and ethnicity

In the United States, sociodemographic factors, particularly race, ethnicity, educational attainment, and income, strongly affect health outcomes.[1] Individuals with predominantly European ancestry (that is, those of White race) commonly comprise the referent group to which other race groups are compared. Individuals from racial and ethnic minority groups and those with lower levels of educational attainment have worse risk factor profiles and die at younger ages compared with referent groups, and race and educational attainment are independently associated with burden of cardiovascular disease (CVD).[2] Higher levels of educational attainment have been associated with better cardiovascular health (CVH).[3–5] In some studies, education

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CLINICAL PERSPECTIVE

What Is New?

- The lifestyle and wellness goals that comprise ideal cardiovascular health may not be equitably obtained across sociodemographic groups, and we sought to determine the relation between race, ethnicity, and level of education with cardiovascular health.
- We analyzed a nationally representative sample to assess the intersecting sociodemographic factors affecting the American Heart Association's Life's Simple 7 metric to determine whether the association between educational attainment and ideal cardiovascular health differs by race and ethnicity.

What Are the Clinical Implications?

- We found that educational attainment is associated with ideal cardiovascular health, and that the association differs by race and ethnicity, thus demonstrating the need for health care strategies to overcome the structural barriers that are impeding the equitable achievement of heart-healthy lifestyles.

Nonstandard Abbreviations and Acronyms

AA	associate of arts
CVH	cardiovascular health
LS7	Life's Simple 7
NHANES	National Health and Nutrition Examination Survey

level has been shown to have a greater effect on life expectancy than does race.[6] Past literature has advocated for education as a means to overcome race-based differences.[1] Proponents have suggested that implementing public policies that encourage post–secondary school attendance and life-long learning across sociodemographic groups would help to overcome health disparities.[1,7]

In studying disparities in cardiovascular outcomes, researchers are now directing increased attention to the differences in achievement of cardiovascular wellness rather than focusing solely on adverse outcomes. The American Heart Association's Life's Simple 7 (LS7) metric is useful in studying factors that promote health. Four health behaviors and 3 physiologic measures operationalize CVH as either ideal, intermediate, or poor.[8] Higher LS7 scores correspond to more ideal CVH. Measuring CVH across sociodemographic groups can provide valuable insight into mechanisms

and strategies to promote CVH. There have been few studies of factors that promote CVH for racial minorities. A better understanding of intersecting sociodemographic factors among racially diverse individuals may reveal novel insights into strategies to improve the CVH of at-risk populations.

Although prior studies have reported the relations of race and education with incident CVD,[9] few have focused on measures of cardiovascular wellness. Large cohort studies have shown that LS7 scores vary by sociodemographic factors,[10–12] yet the extent to which education and race interact in their contributions to cardiovascular outcomes remain understudied, and the disaggregation of race from socioeconomic factors is challenging.[3,13,14] A recent cross-sectional analysis showed that Black race and Hispanic ethnicity moderated the relationship between education and prevalent CVD, but the study did not adjust for sociodemographic factors such as insurance and access to care.[9] The adjusted effect of a possible race–education interaction for the achievement of cardiovascular wellness has not been established. We therefore conducted an effect modification analysis to determine the combined effect of race and education on CVH. We hypothesized that the interaction between race and educational attainment would be a significant contributor to achievement of ideal CVH in a nationally representative cohort of adults.

METHODS

Study Sample

The data that support the findings of this study are available from the corresponding author upon reasonable request. The National Health and Nutrition Examination Survey (NHANES) is conducted by the National Center for Health Statistics of the Centers for Disease Control and Prevention. The survey is conducted in 2-year cycles and is designed as a cross-sectional, stratified, and clustered sample of the noninstitutionalized US population to assess health and nutrition status. Survey materials, methods, and data for NHANES are publicly available on the National Center for Health Statistics website.[15] No individual-level identifiers are accessible. Informed consent was obtained for all survey participants, and the National Center for Health Statistics Research Ethics Review Board approved administration of the surveys. NHANES has a written survey to assess demographic and lifestyle data, and an in-person examination portion that consists of an interview, physical examination, and laboratory measurements. In this study, we combined the 2013 to 2014 and 2015 to 2016 NHANES cycles. Participants were included in this analysis if they completed both the interview and medical examination components, were at least 25 years of

age, were free of CVD history (congestive heart failure, coronary heart disease, myocardial infarction, stroke) at the time of examination, and had complete LS7, education, and race and ethnicity data (n=7771).

Definitions of Independent Variables

Participants reported demographic and lifestyle information via a household questionnaire. The primary independent variables of interest were race and ethnicity and educational attainment. Race and ethnicity were self-reported and categorized as non-Hispanic White, non-Hispanic Black, Asian, and Hispanic. Hispanic and non-Hispanic Black respondents were oversampled to allow stable estimates for these groups. Highest grade or level of school completed was self-reported and categorized as (1) less than high school/general equivalency degree, (2) completion of high school/general equivalency degree, (3) some college or associate of arts degree, and (4) college graduate or above.

Covariates were age at the time of survey completion, binary sex category, health insurance, access to health care, and income–poverty ratio. Medical conditions and health insurance status were self-reported by participants with yes/no/refused/don't know response options. To assess for health care access, participants were asked, "Is there a place you usually go when you are sick or need advice about your health?" Response options were yes/there is no place/there is more than 1 place/refused/don't know. The response option "there is more than 1 place" was defined the same as the response option "yes." For all survey questions, responses of "refused" or "don't know" were defined as missing. We found no evidence of multicollinearity between study covariates as determined by calculating their correlation coefficients.

Life's Simple 7

Participants reported frequency and duration of physical activity over the 7 days before the interview, and time of moderate and vigorous activity was summed. NHANES reports each food item with a United States Department of Agriculture food code.[15] Food descriptions and portion sizes were obtained from the United States Department of Agriculture Food and Nutrient Database for Dietary Studies to convert the quantity of food reported in grams to portion sizes.[16] For liquids, reported grams were converted to fluid ounces, with the assumption 30 g were equal to 1 fluid ounce across all beverage types. Two dietary recall questionnaires asking about 24-hour intake of fruits, vegetables, whole grains, sugar-sweetened beverages, and sodium were administered, and means were calculated. Fish intake was recalled over the course of 30 days and adjusted to reflect weekly intake. To obtain blood pressure measurements, participants rested quietly for

5 minutes in a seated position then had 3 consecutive blood pressure readings taken. If a measure was incomplete or interrupted, a fourth measurement was taken. Blood pressure measurements were averaged over all available measurements for a participant.

The 7 metrics (smoking, body mass index, physical activity, diet, total cholesterol, blood pressure, and blood glucose) that define the LS7 were each scored as 0 points (poor), 1 point (intermediate), or 2 points (ideal). The 2010 American Heart Association definitions for ideal, intermediate, and poor health were used to score blood pressure, cholesterol, and body mass index and are shown in Table S1. We followed published American Heart Association parameters in assigning total CVH scores, which ranged from 0 to 14 and were categorized into poor (0–4), intermediate (5–9), and ideal (10–14) CVH groups.[8] Participants missing data for any of the LS7 metrics were excluded from analyses. In comparison with the LS7 metrics defined by the American Heart Association, fasting plasma glucose was not used in this analysis because only a subset of NHANES participants had fasting plasma glucose data available. Consistent with other studies,[17] glycohemoglobin was used in place of fasting plasma glucose, and the categorization of glycohemoglobin is defined in Table S1.

Statistical Analysis

Descriptive statistics were obtained for all participants with complete data and were stratified by educational attainment. Continuous variables are shown as medians with the associated interquartile range or 95% CI. Distributions of categorical LS7 scores were assessed across educational attainment. Overall and component LS7 scores are shown by mean and standard deviation, and χ^2 tests were used to identify significant differences across education groups. We separately determined the influence of incomplete LS7 data by comparing demographics across participants without a complete LS7 score to those with a complete LS7 score.

We used multivariable ordinal logistic regression to assess the association between race and ethnicity, educational attainment, and LS7 category. We created an interaction term between race and ethnicity and educational attainment for modeling. Categorical variables highly associated with the outcome were assessed by percent agreement and changes in regression coefficients and C-statistics after inclusion. The proportional odds assumption was checked with the Brant test ($P>0.05$). Probabilities were modeled across the higher-ordered values (ideal and intermediate categories). Multivariable models consisted of Model 1: race and ethnicity, education, race and ethnicity*education, age, and sex; and Model 2: Model 1+health insurance status, access to health care, and income–poverty

ratio. C-statistics were calculated for each model to assess goodness of fit. We incorporated missing data for covariates into each model by including the Not Missing Completely at Random ('NOMCAR') option in SAS 9.4 (SAS Institute, Cary, NC). We used this option to treat missing values in the variance computation as not missing completely at random, thus analyzing the entire cohort irrespective of missingness.

To estimate the effect modification of race and ethnicity on the relationship between educational attainment and CVH, the differences of the interaction term's least square means were calculated using Model 1. This was performed by adding an LSMEANS statement to the PROC SURVEYLOGISTIC command in SAS. We performed the Brant test using Stata 16.1 (StataCorp, College Station, TX). We used GraphPad

(La Jolla, CA) Prism 8.4.3 to create Figures 1 and 2. For all analyses, a 2-tailed *P* value of ≤0.05 was considered significant. All frequencies reported are crude frequencies with weighted proportions. All analyses used complex survey procedures where medical examination component weights, strata, and clusters were used in all calculations. Because we combined 2 survey cycles, we divided each participant's weight by 2 per NHANES analytics guidelines.[15]

RESULTS

Sample Characteristics

Among 9300 NHANES participants that were ≥25 years of age with valid race and education responses, 7771
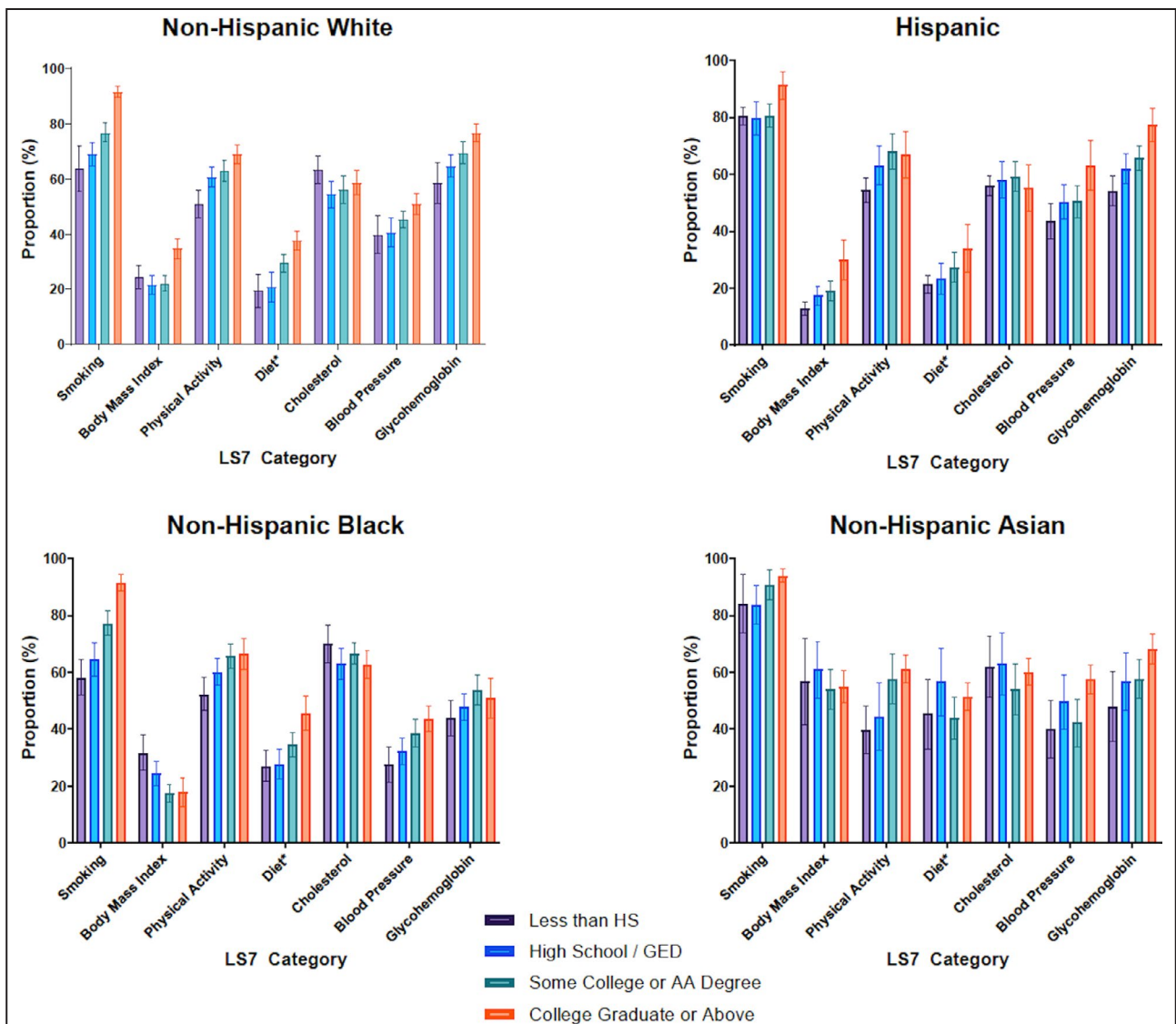

Figure 1.   Achievement of ideal cardiovascular health metrics by level of educational attainment and race and ethnicity.
*Diet data include intermediate category because almost none in any category achieved ideal diet. AA indicates associate of arts; GED, general equivalency degree; HS, high school; and LS7, Life's Simple 7.
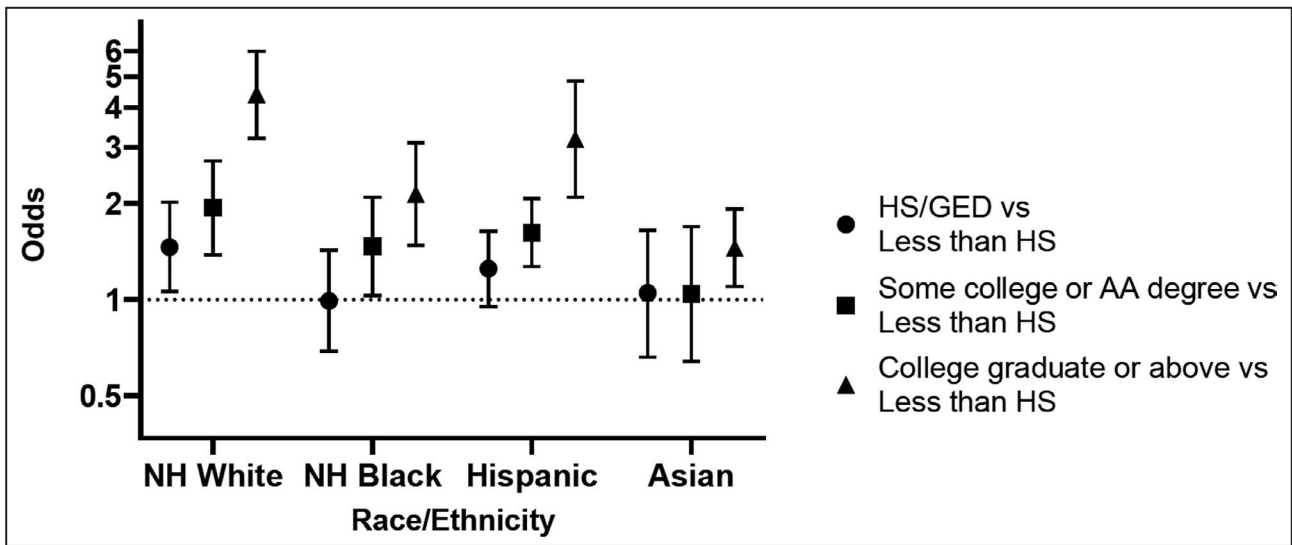
Figure 2. Association between race and ethnicity and ideal cardiovascular health stratified by level of educational attainment.
Increased educational attainment increases odds of having better cardiovascular health within each racial and ethnic group but with significant differences in the strength of association between racial and ethnic groups. The dotted line represents odds of 1, which is no significant difference in Life's Simple 7 (LS7) at that level of educational attainment as compared with the less than high school (HS) group for each race. Bars that cross the dotted line mean that the group does not have a significant difference in LS7 when compared with the lowest educational attainment group (ie, no significant benefit of education on LS7). AA indicates associate of arts; GED, general equivalency degree; and NH, non-Hispanic.

Table 1. Descriptive Statistics by Level of Educational Attainment of the National Health and Nutrition Examination Survey Cohort

	All participants, n=7771	Less than HS, n=1692	HS or GED, n=1697	Some college or AA degree, n=2248	College graduate or above, n=2134
Age, y, median (IQR)	48.4 (36.2-60.7)	49.1 (36.5-61.7)	49.8	48.4 (36.2-60.7)	47.6 (35.4-59.8)
Sex, men, n (%)	3661 (47.5)	829 (50.4)	855 (50.0)	958 (43.4)	1019 (48.5)
Race and ethnicity, n (%)					
Non-Hispanic White	3160 (69.3)	374 (40.0)	712 (69.1)	1054 (73.0)	1020 (77.9)
Hispanic	2162 (15.0)	923 (42.8)	448 (15.0)	512 (12.3)	279 (6.2)
Non-Hispanic Black	1580 (10.5)	297 (13.2)	429 (13.0)	531 (12.0)	323 (6.7)
Non-Hispanic Asian	869 (5.2)	98 (4.0)	712 (2.9)	151 (2.8)	512 (9.2)
Health insurance, yes, n (%)	6274 (85.1)	1128 (65.4)	1288 (79.8)	1883 (86.8)	1975 (94.6)
Routine place to go for health care, yes, n (%)	6510 (84.9)	1319 (74.7)	1415 (84.6)	1933 (86.1)	1843 (87.9)
Income–poverty ratio, median (IQR)	3.2 (1.5-4.9)	1.3 (0.5-2.1)	2.3 (1.0-3.6)	2.9 (1.5-4.3)	5.0 (4.2-5.9)
Overall LS7 category, n (%)					
Ideal	2397 (34.9)	333 (21.1)	396 (25.1)	661 (31.4)	1007 (49.6)
Intermediate	5021 (61.4)	1236 (72.0)	1199 (69.5)	1495 (64.8)	1091 (49.2)
Poor	353 (3.7)	123 (6.9)	102 (5.4)	92 (3.9)	36 (1.3)

AA indicates associate of arts; GED, general equivalency degree; HS, high school; IQR, interquartile range; and LS7, Life's Simple 7.

(86.7%) were free of CVD history and had complete data for an LS7 score. Participants lacking 1 or more components of a complete LS7 score were less likely to be of the non-Hispanic White racial category and had a slightly lower income–poverty ratio. Table 1 shows the characteristics of the sample cohort. Median age of the participants was 48.4 years (interquartile range, 36.2-60.7 years). Men comprised 47.5% of the overall

sample. The proportions of White, Black, Hispanic, and Asian participants were similar to nationally estimated distributions.[15] Most participants were insured and reported routine health care access. Just over one-third (2397, 34.9%) of participants met the ideal criteria for the overall LS7 score. At baseline, the cohort showed differences in educational attainment by race and ethnicity. For example, non-Hispanic Asian participants had a relatively greater proportion of college and higher educational attainment.

LS7 Analysis

Table 2 shows the distribution of overall and individual LS7 metrics by level of educational attainment. Achievement of ideal CVH varied significantly by level of educational attainment. For all metrics except diet and cholesterol, as educational level increased, the criteria for ideal health were more often met. The number of participants achieving ideal levels of healthy eating was too small to determine statistical significance. In regard to cholesterol, statistical significance was not met for differences across groups (P=0.08), and there was not a stepwise improvement in achievement of ideal levels with increasing level of educational attainment. Figure 1 shows the achievement of ideal CVH metrics by education dichotomized as less than high school versus greater than or equal to high school.

Multivariable Logistic Regression Results

The proportional odds assumption was valid in all models (P>0.05). Across all models in Table 3, the interaction term of race and ethnicity was statistically significant (P<0.01). In the full model (Model 2), the conditional effects of the interaction age, routine place to go for health care, and income–poverty ratio were found to have significant associations with being in a higher LS7 group (more ideal CVH). The effect of education across race and ethnicity is shown with odds and 94% CIs after controlling for age and sex. Odds are interpreted as the odds of a participant being in a higher LS7 group as compared with the referent group. Across all racial and ethnic groups, a dose-response relation was observed where increased educational attainment was associated with increased odds of being in the higher LS7 groups. The P value for trend for education level is P<0.001.

Figure 2 shows the comparisons across race and ethnicity, and education on the odds scale (data from Table S2). Trends of the cardiovascular health benefits of education are demonstrated across racial and ethnic groups, adjusted for age and sex. Among non-Hispanic Black participants, completing high school or high school general equivalency degree was not significantly associated with increased odds of better CVH

(odds ratio [OR], 0.99 [95% CI, 0.69–1.43]). However, for non-Hispanic White participants, completing high school or high school general equivalency degree was significantly associated with increased odds of better cardiovascular health, and only non-Hispanic White participants experienced this benefit (OR, 1.46 [95% CI, 1.06–2.02]). Trends of the cardiovascular health benefits of education across race and ethnicity were not equal, because the greatest benefit is detected in the non-Hispanic White group, whereas non-Hispanic Black participants and non-Hispanic Asian participants appear to have smaller cardiovascular health benefits from increased education.

DISCUSSION

In this nationally representative cross-sectional analysis of 8199 adults, we found that LS7 differs by race and education, a relationship that persisted after adjusting for confounding variables. Our findings demonstrate that educational attainment has distinct associations with ideal CVH with a differential health benefit of education on CVH by race. For example, non-Hispanic White race individuals with a graduate-level education had the highest odds of being in a higher LS7 category when compared with the less than high school referent group.

Our results show that although educational attainment modifies the relationship between race and CVH, education does not overcome the effect of race. In particular, Black participants at both the highest and lowest education levels experienced some of the least ideal CVH indices. We also show that Asian and Hispanic participants did not obtain the same degree of CVH benefit as did their White counterparts, even at increasing levels of educational attainment. Therefore, we redemonstrate that racial-group membership partly modifies the effect of socioeconomic status (as exemplified by educational attainment) on disparate health outcomes.[14,18–21] Notably, the Asian participants exhibited a relatively attenuated benefit across level of educational attainment. This finding may be attributable to overall high LS7 across all levels of educational attainment among Asian participants.

Educational attainment is an important measure of socioeconomic status and has been proven to influence health and longevity.[1] The pattern of differential race-based health outcomes, irrespective of educational status, is consistent with the theory that racial minority groups do not gain the same degree of protective effects of elevated socioeconomic status as do those who are White.[18] Although higher educational attainment and other improved socioeconomic factors may be expected to confer improved health outcomes, racially minoritized people in the higher strata may continue to encounter barriers that dampen the potential

Table 2. Distribution of Overall and Individual LS7 Metrics by Level of Educational Attainment

	Less than HS, n=1692	HS/GED, n=1697	Some college or AA degree, n=2248	College graduate or above, n=2134	*P* value
Overall LS7, n (weighted %)					<0.01
Ideal	333 (21.1)	396 (25.1)	661 (31.4)	1007 (49.6)	
Intermediate	1236 (72.0)	1199 (69.5)	1495 (64.8)	1091 (49.2)	
Poor	123 (6.9)	102 (5.4)	92 (3.9)	36 (1.3)	
Physical activity, n (weighted %)					<0.01
Ideal	825 (52.1)	982 (60.5)	1406 (63.7)	1380 (67.9)	
Intermediate	256 (14.6)	272 (15.6)	328 (14.8)	343 (15.6)	
Poor	611 (33.3)	443 (23.9)	514 (21.5)	411 (16.5)	
Diet, n (weighted %)					<0.01*
Ideal	0 (0)	3 (0.1)	2 (0.2)	5 (0.3)	
Intermediate	413 (22.4)	433 (23.1)	700 (30.3)	911 (39.2)	
Poor	1279 (77.6)	1261 (76.8)	1546 (69.5)	1218 (60.5)	
Smoking, n (weighted %)					<0.01
Ideal	1245 (71.0)	1212 (70.3)	1735 (77.7)	1956 (91.8)	
Intermediate	41 (2.8)	53 (3.6)	60 (3.1)	27 (1.1)	
Poor	406 (26.2)	432 (26.1)	453 (19.1)	151 (7.1)	
BMI, n (weighted %)					<0.01
Ideal	369 (21.7)	413 (22.5)	523 (22.1)	760 (35.1)	
Intermediate	602 (35.7)	566 (34.4)	692 (31.0)	727 (34.5)	
Poor	721 (42.6)	718 (43.1)	1033 (46.8)	647 (30.4)	
Cholesterol, n (weighted %)					0.08
Ideal	1030 (61.0)	997 (56.3)	1330 (57.7)	1264 (58.9)	
Intermediate	460 (26.7)	496 (30.9)	615 (27.7)	633 (29.6)	
Poor	202 (12.3)	204 (12.8)	303 (14.6)	237 (11.5)	
Blood pressure, n (weighted %)					<0.01
Ideal	612 (39.8)	667 (41.2)	971 (45.0)	1069 (51.8)	
Intermediate	696 (41.6)	663 (39.1)	883 (38.8)	768 (35.9)	
Poor	384 (18.6)	367 (19.7)	394 (16.2)	297 (12.3)	
Glycohemoglobin, n (weighted %)					<0.01
Ideal	803 (54.3)	955 (61.9)	1368 (66.8)	1442 (74.2)	
Intermediate	590 (31.7)	524 (28.0)	624 (23.6)	526 (20.2)	
Poor	299 (14.0)	218 (10.1)	256 (9.6)	166 (5.6)	

AA indicates associate of arts; BMI, body mass index; GED, general equivalency degree; HS, high school; and LS7, Life's Simple 7.

*The level of significance was determined using the intermediate and poor categories. The ideal group was excluded because of limited observations in that category.

health benefits of upward social mobility found among the racial majority.[18]

Our findings from NHANES of race-based differences in ideal CVH factors, irrespective of education, has been previously documented in the literature. A recently published analysis of NHANES showed that race and educational attainment were independently associated with LS7 but did not show how these covariates interacted.[19] In another prior analysis of NHANES data, researchers found a significant interaction between race and education on perceived health status, but as education levels increased, Black adults did not have the same improvement in self-rated health as White adults.[20] A study of the third NHANES cycle published in 1998 showed that CVD risk factors were higher among Black women and Latinas than for White women. After adjusting for years of education, the difference dissipated, but highly significant differences in other risk factors remained.[21] Thus, our analysis is different from these prior studies in that we assessed the interaction between educational attainment and race, and through ordinal logistic regression, and found the

Table 3. Multivariable Ordinal Logistic Regression Modeling the Cumulative Odds of a Participant Being in a Higher Life's Simple 7 Group

	Model 1			Model 2		
	OR	95% CI	*P* value	OR	95% CI	*P* value
Race and ethnicity (ref=non-Hispanic White)			<0.01			<0.01
Hispanic	1.10	0.80–1.52	0.52	1.20	0.87–1.66	0.26
Non-Hispanic Asian	3.40	2.39–4.83	<0.01	3.65	2.47–5.39	<0.01
Non-Hispanic Black	0.91	0.66–1.25	0.58	1.03	0.72–1.47	0.87
Education (ref=less than HS)			<0.01			<0.01
HS/GED	1.44	1.05–2.04	0.02	1.42	1.00–1.88	0.05
Some college or AA degree	1.86	1.37–2.72	<0.01	1.81	1.31–2.62	<0.01
College or greater	4.29	3.17–6.01	<0.01	4.12	2.70–5.08	<0.01
Education×race and ethnicity			<0.01			<0.01
Age (per 5-y change)	0.85	0.83–0.87	<0.01	0.85	0.83–0.87	<0.01
Sex (referent=men)	1.08	0.95–1.27	0.29	1.07	0.96–1.30	0.15
Health insurance (referent=yes)				0.87	0.76–1.07	0.23
Routine place to go for health care (referent=yes)				1.24	1.04–1.48	0.02
Income–poverty ratio				1.11	1.04–1.18	<0.01
C-statistic	0.70			0.71		

AA indicates associate of arts; GED, general equivalency degree; HS, high school; and OR, odds ratio.

benefits of higher educational attainment were greatest for White participants than for other groups. The non-Hispanic White participants achieved a nearly exponential increase in CVH whereas other groups did not.

Our results differ from a South Florida survey analysis that found that Latinx participants had the highest proportion with ideal CVH scores, and Black participants had the lowest proportion. In that study, there were no statistically significant interactions of education and ethnicity on CVH measures, possibly because of the study being underpowered or enrolling a relatively healthy sample.[22] Others have found that in addition to race, ethnicity and nativity may also factor into the association of education and cardiovascular outcomes among White, Latinx, and Asian Californians. In that study, race-based differences in CVH were greatest among the least educated.[23]

The mechanisms by which education exerts positive effects on health outcomes are likely multifactorial. In our analysis, incorporation of insurance, income–poverty ratio, and access to care did not significantly affect the outcome. Nevertheless, others have shown that higher educational attainment is associated with access to better employment, higher income, and therefore, more economic stability to access care and to prioritize self-management activities necessary to remain healthy.[24] Alternatively, education likely yields a direct benefit on health through health knowledge, health literacy, and effective chronic disease management.[25] Moreover, educational attainment leads to elevated social capital that provides the needed resources to better cope with life stressors and normalizes healthy living.[24] Additionally, we would assert that the relation between education and health is likely bidirectional, such that more ideal health conditions facilitate educational attainment in early life.[26]

Furthermore, ideal CVH has shown longitudinal benefits, and LS7 has been associated with increased longevity.[27] In addition, it has been shown that non-Hispanic Black and Hispanic people who have graduated high school live nearly 8 and 14 years longer, respectively, than White people with less than a high school level of education.[1] Importantly, examinations by sex and race reveal lower levels of CVH among less-educated women, especially women of color.[28,29] But what are the mechanisms for differential CVH and life expectancy among minoritized individuals despite elevated education or socioeconomic status? A proposed physiologic mechanism is found in the accrued generational stress related to facing disadvantage and the subsequent accelerated biological aging.[30] For example, in a study of pregnant women, it was found that physiologic markers of lifelong stress were correlated with race and level of educational attainment.[31] Therefore, despite higher levels of education, college-educated Black women have worse maternal outcomes than White women with less than a high school education.[32] The fact that disparities persist even in the

highest income and educational groups suggests that more upstream factors are needed to explain racial and ethnic differences.

The fundamental cause of the disparate outcomes, limitations in life expectancy, and different stress levels has been attributed to structural racism.[33] In the United States, historically marginalized groups include Black, Latinx, and Indigenous people and their health disparities stem from perpetuation of racial injustices.[34] Racial differences in outcomes likely result from the social determinants of health[35,36] and the policies that create and perpetuate such injustices. Accordingly, the potential to attain ideal health is impacted by the multiplicative effects of race and other social determinants. Clinically, this translates into the need for health care strategies that overcome structural barriers to health. Policy solutions should address multifaceted challenges including neighborhood infrastructure and environmental risk factors that disproportionately endanger the health of minoritized individuals.[37]

Strengths and Limitations

Our analysis has several strengths. First, we leveraged a large, nationally representative cohort with complete sociodemographic variables, including the key social factors of income, education, and access to health care. Furthermore, NHANES provides ethnic and racial diversity by oversampling of underrepresented populations, thereby facilitating our analysis. Last, our statistical approach facilitated our examination of the effect modification of CVH and education by race and ethnicity, thereby helping to disentangle the mechanisms of race-based CVD disparities.

The analysis has multiple important limitations as well. First, although our goal was to help interpret the causal pathway between social determinants and CVD, the cross-sectional nature of the survey data does not allow us to determine temporality between the independent variable and the outcome. Second, the NHANES cohort is racially diverse and nationally representative, but does not account for people who identify as Indigenous Americans or multiethnic individuals in numbers sufficient for reliable analysis. Similarly, the data set does not account for geographic diversity such as evaluating urban versus rural populations, a potential contributing social factor to level of sociodemographic factors. Likewise, the study only included noninstitutionalized people, which could bias the sample toward a healthier population with less severe disease. Third, the data set is subject to unmeasured confounding. For example, we are not able to adjust for health behaviors like medication adherence, which could affect the CVH outcome. Finally, the analyses of characteristics associated with having low versus high numbers of LS7

metrics only included participants with data for all LS7 metrics, theoretically introducing selection bias. However, only a limited proportion (13.3%) of the sample was missing the outcome measure, and our approach to exclude those without complete LS7 scores is likely biasing our results toward the null.

CONCLUSIONS

In summary, we found a significant interaction between race and ethnicity and educational attainment on CVH. Educational attainment does not yield equitable improvements in minoritized individuals. Our findings show that more work is needed to understand the societal barriers preventing individuals from racial and ethnic minority groups from achieving ideal CVH. Future studies should test interventions to overcome race-based disparities despite access to adequate education.

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Supplemental Material

Table S1. Categorization of each CVH metric as Poor, Intermediate, or Ideal.

CVH metric	Poor	Intermediate	Ideal
Smoking status	Current	Former, ≤12 months	Never or quit >12 months
Body mass index (kg/m^2)	≥30	25-29.9	18.5-24.9
Physical activity (min/week)	None	1-149 moderate or 1-74 vigorous 1-149 moderate + 2x vigorous 0-60 min of moderate or vigorous every day	≥150 moderate or ≥75 vigorous ≥150 moderate + 2x vigorous ≥60 of moderate or vigorous every day
Healthy diet pattern, number of components*	0-1	2-3	4-5
Total cholesterol (mg/dL)	≥240	200-239	<200
Glycohemoglobin (%)	≥6.5	5.7-6.49	<5.7
Blood pressure (mmHg)	SBP≥140 or DBP≥90	SBP 120-139 or DBP 80-89 or treated to goal	<120 SBP / <80 DBP

*Five healthy eating components: consume ≥4.5 cups/d of fruits and vegetables, ≥2 servings/week of fish, ≥3 servings/d of whole grains, no more than 36 oz/week of sugar-sweetened beverages, and no more than 1500 mg/d of sodium.

Table S2. Differences of Education*Race/Ethnicity Least Squares Means adjusted for age and sex.

Race/Ethnic Group	Reference Educational Attainment Group	Standard Error	Odds (95% CI)
NH Black	College graduate or above	0.18	2.14 (1.48, 3.10)
	Some college or AA degree	0.17	1.47 (1.03, 2.09)
	HS/GED	0.18	0.99 (0.69, 1.43)
	Less than HS (referent)	-	-
NH White	College graduate or above	0.15	4.39 (3.21, 6.00)
	Some college or AA degree	0.17	1.94 (1.38, 2.72)
	HS/GED	0.16	1.46 (1.06, 2.02)
	Less than HS (referent)	-	-
Hispanic	College graduate or above	0.21	3.18 (2.09, 4.83)
	Some college or AA degree	0.12	1.62 (1.27, 2.07)
	HS/GED	0.13	1.25 (0.95, 1.64)
	Less than HS (referent)	-	-
NH Asian	College graduate or above	0.14	1.45 (1.10, 1.92)
	Some college or AA degree	0.24	1.04 (0.64, 1.69)
	HS/GED	0.22	1.05 (0.66, 1.65)
	Less than HS (referent)	-	-