Distribution of Cardiovascular Health by Individual- and Neighborhood-Level Socioeconomic Status

Findings From the Jackson Heart Study

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ABSTRACT

Background: Data demonstrate a positive relationship between socioeconomic status (SES) and cardiovascular health (CVH).

Objective: To assess the association between individual- and neighborhood-level SES and CVH among participants of the JHS (Jackson Heart Study), a community-based cohort of African Americans in Jackson, Mississippi.

Methods: We included all JHS participants with complete SES and CVH information at the baseline study visit (n = 3,667). We characterized individual- and neighborhood-level SES according to income (primary analysis) and education (secondary analysis), respectively. The outcome of interest for these analyses was a CVH score, based on 7 modifiable behaviors and factors, summed to a total of 0 (worst) to 14 (best) points. We utilized generalized estimating equations to account for the clustering of participants within the same residential areas to estimate the linear association between SES and CVH.

Results: The median age of the participants was 55 years, and 64% were women. Nearly one-third of eligible participants had individual incomes <\$20,000 and close to 40% lived in the lowest neighborhood income category (<\$25,480). Adjusted for age, sex, and neighborhood SES, there was an average increase in CVH score of 0.31 points associated with each 1-category increase in individual income. Similarly, each 1-category increase in neighborhood SES was associated with a 0.19-point increase in CVH score. These patterns held for our secondary analyses, which used educational attainment in place of income. These data did not suggest a synergistic effect of individual- and neighborhood-level SES on CVH.

Conclusions: Our findings suggest a potential causal pathway for disparities in CVH among vulnerable populations. These data can be useful to the JHS community to empower public health and clinical interventions and policies for the improvement of CVH.

The American Heart Association (AHA) and the American Stroke Association (ASA) both promote Life's Simple 7: 7 healthy behaviors and factors via the Centers for Disease Control's Million Hearts initiative [1]. Life's Simple 7 comprises the modifiable behaviors and health factors of body mass index (BMI), cholesterol, blood pressure, smoking status, fasting glucose, physical activity, and diet. This metric is designed to evaluate cardiovascular health (CVH), but is also endorsed for measuring brain health [2]; Life's Simple 7 is associated not only with incident cardiovascular disease (CVD), but also incident cancer, stroke, and mortality [3-7]. We recently reported a lower risk of stroke for every unit increase in CVH score (Life's Simple 7) among African Americans (AA) in the JHS (Jackson Heart Study) [8].

Americans of lower socioeconomic status (SES) have poorer CVD outcomes relative to other SES groups: higher rates of myocardial infarction, stroke, and cardiovascular-related death [9]. In previous ARIC (Atherosclerosis Risk in Communities) study, analyses comprising AA participants in Jackson, Mississippi, neighborhood SES—operationalized as median household income—was associated with CVD incidence [10], receipt of medical procedures for CVD [11], and CVD death [12]. In addition, Americans of lower SES have a higher prevalence of cardiovascular risk factors such as elevated blood pressure, diabetes [13], and cholesterol

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[14,15]. Evidence from existing studies supports a positive relationship between SES and the AHA/ASA's Life's Simple 7, yet these associations have not been evaluated among AA [9,16]. Such information would be critical to the community to be able to develop public health and clinical interventions and policies for the improvement of CVH.

CVH behaviors and factors display geographic variation that may be at least partly due to factors associated with neighborhood SES [9]. Data are available that demonstrate a positive relationship between neighborhood-level SES and CVH. In the MESA (Multi-Ethnic Study of Atherosclerosis), the investigators found neighborhood characteristics—including access to healthy foods, an environment that supports physical activity, and higher neighborhood SES—were associated with better overall CVH, even after adjustment for individual-level SES [15]. These findings are consistent with previous reports of higher incident CVD [10], lower receipt of revascularization procedures (angioplasty, stent, and coronary artery bypass graft) [11], and poorer medical management of CVD among those of lower versus higher neighborhood SES [17].

The objective of this study was to assess the relationship between individual- and neighborhood-level SES and CVH among participants of the JHS, a community-based cohort of AA in Jackson, Mississippi. Specifically, this study will expand on understanding the distribution of CVH as measured by AHA/ASA's Life's Simple 7 according to neighborhood- and individual-level SES. We hypothesized that neighborhood-level SES would have an effect on CVH independent of individual-level SES. This information will be critical to the development of public health and clinical interventions and policies for the improvement of CVH in this community.

MATERIAL AND METHODS

Data used in analyses were provided by the JHS, a longitudinal cohort study intended to evaluate risk factors associated with CVD among AA [18]. There were 5,306 participants recruited from volunteers in the Jackson metropolitan area (25%), randomly selected residents of Jackson (17%), eligible residents from Jackson within the ARIC cohort study (31%) [19], and relatives of JHS (22%) or ARIC (5%) participants. Data collection methods have been described in greater detail previously [18,20]. Briefly, baseline measures were collected on demographic and socioeconomic characteristics, medical history, laboratory values, physical examination, cardiac testing, medications, and behavioral factors.

Individual-level SES included baseline self-reported family income and highest degree or years of school completed baseline. Neighborhood-level SES included median household income [10-12] and the percentage of persons age 25 years or older with at least a bachelor's degree, and was derived from the participant's address at baseline assessment and geocoded to the level of the U.S. Census Tract (CT) using year 2000 data. We included all JHS participants with complete SES and CVH score component information at the baseline study visit (n = 3,667).

Our outcome of interest was CVH, as defined by the AHA/ASA [21] using measures for participant's smoking status, fasting blood glucose, cholesterol, blood pressure, BMI, and diet and physical activity (Online Table 1). CVH was operationalized in the JHS as follows [8]: we used an overall CVH score to represent the continuum of CVH that is based on the number of ideal (2), intermediate (1), and poor (0) CVH metrics present at baseline. The overall CVH score summed to a total of 0 (worst) to 14 (best) points and were derived from categories of smoking, fasting glucose, cholesterol, blood pressure, and BMI, along with diet and physical activity [4].

Details of definitions for poor, intermediate, and ideal categories are provided in Online Table 1. Briefly, smoking was considered ideal among those who never smoked, intermediate for participants who had quit within a year, and poor for those who were current smokers. Participants with normal fasting glucose measures were scored as ideal, elevated measures were intermediate, and abnormal values were considered poor, with a comparable evaluation for cholesterol and blood pressure CVH components. Those with BMI within normal ranges (<25 kg/m^2) were categorized as ideal, whereas values between 25 and 29.9 kg/m^2 were considered intermediate, and BMI >30 kg/m^2 as poor.

As described in our previous study [8], we used the JHS food frequency questionnaire, a shorter version of the Delta food frequency questionnaire [22], to calculate the healthy diet score [23] according to achievement of a healthy diet pattern: ideal (4 to 5 points), intermediate (2 to 3 points), poor (0 to 1 points). We used the Baecke questionnaire [24] to convert the frequency of participation in as many as 4 sports and in walking in the previous year to minutes per week of moderate or vigorous physical activity and in turn to categories for this metric: meets guidelines (ideal), some activity (intermediate), and none (poor) [4].

Our primary exposures of interest were individual- and neighborhood-level income. Individual-level SES was defined at baseline by self-reported annual family income categories: <$20,000 (referent); $20,000 to 50,000; $50,000 to 75,000; >$75,000. Neighborhood-Level SES was defined at the level of the U.S. CT as median household income in year 2000 using geocoded participant addresses that were then categorized into tertiles defined by all CT in the JHS catchment area: low (referent): <$25,480; middle: $25,481 to 35,375; high: >$35,375. Covariates included in the analyses were age and sex, but not additional behavioral or clinical factors, which are likely on the causal pathway between SES and CVH.

Because there are different ways to characterize SES, we conducted a secondary analysis using individual- and neighborhood-level education as the SES variables of interest. For these analyses, individual-level SES was defined at baseline by number of years of education and categorized as less than high school (referent), graduation from high school or completion of Tests of General Education Development, some college or associate's degree, bachelor's

TABLE 1. Baseline characteristics of eligible JHS participants, overall (N = 3,667) and by individual- and neighborhood-level income

		Individual-level income				Neighborhood-level income		
	Overall (N = 3,667)	<$20,000 (n = 1,024)	$20,000–50,000 (n = 1,358)	$50,000–75,000 (n = 670)	>$75,000 (n = 615)	<$25,480 (n = 1,460)	$25,481–35,375 (n = 1,047)	>$35,375 (n = 1,160)
Demographics								
Age, yrs	55.1 (45.0–64.4)	61.1 (48.3–69.9)	54.8 (45.0–64.0)	51.7 (43.3–59.8)	51.9 (44.8–60.2)	61.2 (49.7–69.0)	53.9 (45.8–63.0)	49.8 (41.5–58.9)
Female	2,360 (64.4)	767 (74.9)	922 (67.9)	387 (57.8)	284 (46.2)	984 (67.4)	682 (65.1)	694 (59.8)
Medical history								
Diabetes	679 (18.5)	251 (24.5)	261 (19.2)	95 (14.2)	72 (11.7)	345 (23.6)	182 (17.4)	152 (13.1)
Physical examination/labs								
Body mass index, kg/m^2	30.4 (26.8–35.5)	31.0 (27.0–36.9)	30.8 (27.0–35.6)	30.1 (26.7–35.1)	29.4 (26.1–33.2)	30.7 (27.1–36.0)	30.4 (26.6–35.5)	30.1 (26.6–34.8)
Systolic blood pressure, mm Hg	125.7 (115.6–136.7)	128.4 (117.4–141.3)	125.7 (116.5–136.7)	122.9 (113.7–133.0)	122.9 (114.7–133.9)	127.5 (117.4–139.4)	125.7 (115.6–136.7)	122.9 (113.7–133.0)
Diastolic blood pressure, mm Hg	75.9 (70.1–81.7)	75.0 (69.2–80.9)	75.9 (70.1–81.7)	75.9 (70.1–80.9)	76.7 (71.7–81.7)	75.0 (69.2–80.9)	76.7 (70.1–81.7)	75.9 (70.9–81.7)
Total cholesterol, mg/dl	196.0 (172.0–223.0)	197.0 (171.0–227.0)	197.0 (173.0–223.0)	196.0 (172.0–220.0)	195.0 (173.0–220.0)	197.0 (173.0–225.0)	197.0 (172.0–222.0)	196.0 (170.0–221.5)
HDL cholesterol, mg/dl	50.0 (41.0–60.0)	51.0 (42.0–61.0)	50.0 (42.0–60.0)	48.0 (41.0–59.0)	48.0 (40.0–57.0)	50.0 (42.0–61.0)	50.0 (42.0–60.0)	49.0 (41.0–58.0)
Fasting plasma glucose, mg/dl	91.0 (85.0–100.0)	93.0 (86.0–105.0)	91.0 (86.0–100.0)	91.0 (85.0–98.0)	90.0 (84.0–98.0)	93.0 (87.0–104.0)	91.0 (85.0–100.0)	90.0 (84.0–97.0)
Behavioral factors								
Smoking history								
Never smoked or quit >1 yr	3,179 (86.7)	844 (82.4)	1,177 (86.7)	597 (89.1)	561 (91.2)	1,236 (84.7)	898 (85.8)	1,045 (90.1)
Former smoker quit ≤1 yr	22 (0.6)	6 (0.6)	10 (0.7)	1 (0.1)	5 (0.8)	7 (0.5)	7 (0.7)	8 (0.7)
Current smoker	466 (12.7)	174 (17.0)	171 (12.6)	72 (10.7)	49 (8.0)	217 (14.9)	142 (13.6)	107 (9.2)
Physical activity								
None	1,699 (46.3)	573 (56.0)	661 (48.7)	270 (40.3)	195 (31.7)	800 (54.8)	483 (46.1)	416 (35.9)
0–<150 min/week moderate or 0–<75 min/week vigorous or 0–<150 min/week moderate/vigorous	1,227 (33.5)	315 (30.8)	453 (33.4)	229 (34.2)	230 (37.4)	450 (30.8)	351 (33.5)	426 (36.7)

(continued)

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TABLE 1. Continued

	Overall (N = 3,667)	Individual-level income <$20,000 (n = 1,024)	$20,000–50,000 (n = 1,358)	$50,000–75,000 (n = 670)	>$75,000 (n = 615)	Neighborhood-level income <$25,480 (n = 1,460)	$25,481–35,375 (n = 1,047)	>$35,375 (n = 1,160)
≥150 min/wk moderate or ≥75 min/week vigorous or ≥150 min/week moderate/vigorous	741 (20.2)	136 (13.3)	244 (18.0)	171 (25.5)	190 (30.9)	210 (14.4)	213 (20.3)	318 (27.4)
Diet								
0–1 components	2,226 (60.7)	640 (62.5)	841 (61.9)	413 (61.6)	332 (54.0)	893 (61.2)	627 (59.9)	706 (60.9)
2–3 components	1,409 (38.4)	378 (36.9)	503 (37.0)	255 (38.1)	273 (44.4)	554 (37.9)	409 (39.1)	446 (38.4)
4–5 components	32 (0.9)	6 (0.6)	14 (1.0)	2 (0.3)	10 (1.6)	13 (0.9)	11 (1.1)	8 (0.7)
Medications								
Cholesterol treatment	426 (11.6)	132 (12.9)	161 (11.9)	69 (10.3)	64 (10.4)	200 (13.7)	112 (10.7)	114 (9.8)
Blood pressure treatment	1,809 (49.3)	587 (57.3)	680 (50.1)	297 (44.3)	245 (39.8)	818 (56.0)	524 (50.0)	467 (40.3)
Diabetes treatment	442 (12.1)	166 (16.2)	176 (13.0)	56 (8.4)	44 (7.2)	231 (15.8)	118 (11.3)	93 (8.0)
Continuous Life Simple 7 score								
Life simple 7 CVH score	7.4 ± 2.0	6.9 ± 2.0	7.3 ± 1.9	7.8 ± 2.0	8.2 ± 1.9	7.0 ± 1.9	7.4 ± 1.9	8.0 ± 2.0
Individual and neighborhood income								
Individual income								
<$20,000	1,024 (27.9)	N/A	N/A	N/A	N/A	577 (39.5)	294 (28.1)	153 (13.2)
$20,000–50,000	1,358 (37.0)	N/A	N/A	N/A	N/A	591 (40.5)	423 (40.4)	344 (29.7)
$50,000–75,000	670 (18.3)	N/A	N/A	N/A	N/A	183 (12.5)	183 (17.5)	304 (26.2)
>$75,000	615 (16.8)	N/A	N/A	N/A	N/A	109 (7.5)	147 (14.0)	359 (30.9)
Neighborhood income								
<$25,480	1,460 (39.8)	577 (56.3)	591 (43.5)	183 (27.3)	109 (17.7)	N/A	N/A	N/A

$25,481—35,375	1,047 (28.6)	294 (28.7)	423 (31.1)	183 (27.3)	147 (23.9)	N/A	N/A	N/A
>$35,375	1,160 (31.6)	153 (14.9)	344 (25.3)	304 (45.4)	359 (58.4)	N/A	N/A	N/A
Individual education								
Less than high school	581 (15.8)	372 (36.3)	176 (13.0)	21 (3.1)	12 (2.0)	363 (24.9)	165 (15.8)	53 (4.6)
High school/GED	910 (24.8)	350 (34.2)	371 (27.3)	127 (19.0)	62 (10.1)	390 (26.7)	309 (29.5)	211 (18.2)
Some college or associate's degree	889 (24.2)	214 (20.9)	387 (28.5)	182 (27.2)	106 (17.2)	310 (21.2)	269 (25.7)	310 (26.7)
At least a bachelor's degree	632 (17.2)	64 (6.3)	236 (17.4)	158 (23.6)	174 (28.3)	166 (11.4)	167 (16.0)	299 (25.8)
Graduate/professional	655 (17.9)	24 (2.3)	188 (13.8)	182 (27.2)	261 (42.4)	231 (15.8)	137 (13.1)	287 (24.7)
Neighborhood education								
Individuals within a neighborhood who have a college education, %	18.4 (12.3—28.4)	15.1 (10.0—18.5)	17.5 (12.1—26.1)	23.5 (16.8—33.2)	27.5 (18.4—43.6)	13.4 (9.9—18.4)	16.8 (12.8—18.5)	42.6 (23.7—43.6)

Values are n (%), median (interquartile range), or mean ± SD.
GED, Tests of General Education Development; HDL, high-density lipoprotein; JHS, Jackson Heart Study; N/A, not applicable.

TABLE 2. Effect of SES on CVH score among JHS participants (N = 3,667)

Model	Parameter	Effect estimate (95% CI)	p Value
1	Individual income, per category increase	0.34 (0.28 to 0.40)	<0.001
	Female	0.02 (−0.14 to 0.17)	0.84
	Age, per 5-yr increase	−0.19 (-0.22 to 0.16)	<0.001
2	Neighborhood income, per category increase	0.32 (0.21 to 0.42)	<0.001
	Female	−0.10 (−0.25 to 0.05)	0.18
	Age, per 5-yr increase	−0.18 (−0.22 to 0.15)	<0.001
3	Individual income, per category increase	0.31 (0.24 to 0.37)	<0.001
	Neighborhood income, per category increase	0.19 (0.09 to 0.28)	<0.001
	Female	0.02 (−0.13 to 0.17)	0.81
	Age, per 5-yr increase	−0.17 (−0.21 to 0.14)	<0.001
4	Individual income, per category increase	0.34 (0.19 to 0.49)	<0.001
	Neighborhood income, per category increase	0.22 (0.03 to 0.42)	0.03
	Interaction between neighborhood and individual income	−0.02 (−0.09 to 0.05)	0.65
	Female	0.02 (−0.13 to 0.17)	0.81
	Age, per 5-yr increase	−0.17 (−0.20 to 0.14)	<0.001

CI, confidence interval; CVH, cardiovascular health; JHS, Jackson Heart Study; SES, socioeconomic status.

TABLE 3. Effect of categorical SES on CVH score among JHS participants (N = 3,667)

Model	Parameter	Effect estimate (95% CI)	p Value
1	Individual income category 2 vs. 1	0.29 (0.13 to 0.44)	<0.001
	Individual income category 3 vs. 1	0.63 (0.47 to 0.80)	<0.001
	Individual income category 4 vs. 1	1.01 (0.81 to 1.21)	<0.001
	Female	0.02 (−0.13 to 0.17)	0.82
	Age, per 5-yr increase	−0.19 (−0.22 to 0.16)	<0.001
2	Neighborhood income category 2 vs. 1	0.27 (0.07 to 0.47)	0.009
	Neighborhood income category 3 vs. 1	0.63 (0.42 to 0.85)	<0.001
	Female	−0.10 (−0.25 to 0.05)	0.18
	Age, per 5-yr increase	−0.18 (−0.22 to 0.15)	<0.001
3	Individual income category 2 vs. 1	0.27 (0.12 to 0.42)	<0.001
	Individual income category 3 vs. 1	0.57 (0.40 to 0.75)	<0.001
	Individual income category 4 vs. 1	0.93 (0.71 to 1.15)	<0.001
	Neighborhood income category 2 vs. 1	0.17 (0.01 to 0.32)	0.03
	Neighborhood income category 3 vs. 1	0.37 (0.19 to 0.56)	<0.001
	Female	0.02 (−0.13 to 0.17)	0.80
	Age, per 5-yr increase	−0.17 (−0.21 to 0.14)	<0.001
4	Individual income category 2 vs. 1	0.21 (−0.00 to 0.43)	0.05
	Individual income category 3 vs. 1	0.54 (0.29 to 0.80)	<0.001
	Individual income category 4 vs. 1	1.07 (0.69 to 1.46)	<0.001
	Neighborhood income category 2 vs. 1	0.16 (−0.09 to 0.41)	0.21
	Neighborhood income category 3 vs. 1	0.28 (−0.07 to 0.62)	0.12
	Income interaction 1: individual income category 2 × neighborhood category 2	0.00 (−0.33 to 0.34)	0.99
	Income interaction 2: individual income category 2 × neighborhood category 3	0.26 (−0.10 to 0.62)	0.15
	Income interaction 3: individual income category 3 × neighborhood category 2	0.05 (−0.34 to 0.44)	0.79
	Income interaction 4: individual income category 3 × neighborhood category 3	0.10 (−0.36 to 0.56)	0.68
	Income interaction 5: individual income category 4 × neighborhood category 2	−0.09 (−0.63 to 0.45)	0.75
	Income interaction 6: individual income category 4 × neighborhood category 3	−0.14 (−0.65 to 0.38)	0.60
	Female	0.02 (−0.13 to 0.17)	0.81
	Age, per 5-yr increase	−0.17 (−0.21 to 0.14)	<0.001

Abbreviations as in Tables 1 and 2.

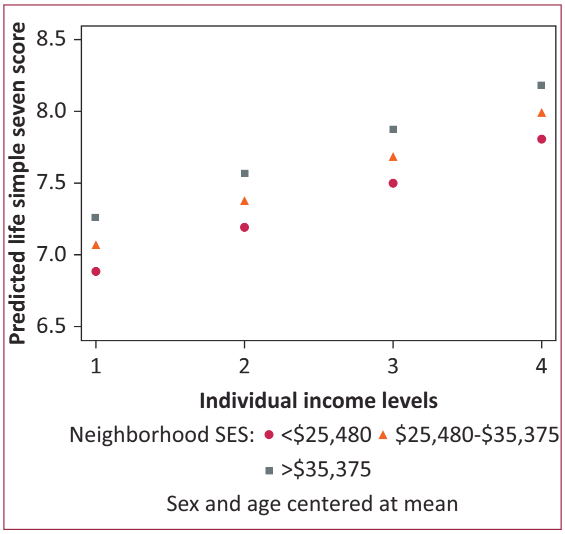

FIGURE 1. Effect of individual- and neighborhood-level socioeconomic status (SES) on cardiovascular health score among Jackson Heart Study participants (n = 3,667).

degree, or graduate/professional degree. Neighborhood-level education was defined as the percentage of CT residents with at least a bachelor's degree.

Statistical analyses

We described the distribution of baseline characteristics in the JHS population using frequencies and percentages for categorical variables and medians and interquartile ranges or means with SD for continuous variables. For continuous CVH score, Kruskal-Wallis tests were used to assess differences between categories of individual and neighborhood income, whereas differences between categories of CVH and SES were evaluated via chi-square tests. To estimate the effect of SES on CVH score, we used linear modeling with a stepped model building approach, controlling for age and sex, as follows: individual SES (model 1); neighborhood SES (model 2); individual SES and neighborhood SES (model 3); model 3 plus an interaction term for individual SES and neighborhood SES (model 4). We additionally assessed for SES × sex interactions. We utilized generalized estimating equations with an exchangeable correlation structure to account for the clustering of participants within the same CT.

In primary analyses, SES was included as an ordinal variable to estimate the effect of a 1-category increase on CVH score. An interaction term between individual and neighborhood SES was included in model 4 to test for potential synergistic effects. We also analyzed the effect of modeling SES as a categorical variable, with reference set to the lowest category, to better understand the influence of increasing SES on CVH score—specifically, to detect threshold effects and to assess the linear trend of the effect of SES on CVH score.

Our secondary analysis using education rather than income employed the same stepped model building strategy as the primary analysis. In a sensitivity analysis among participants for whom missing CVH score component data were imputed (n = 822), missing data were handled as follows. For glucose, we imputed either to the nonfasting glucose measurement, when available, or otherwise to the overall median glucose value. We imputed all other continuous variables to the median value, dichotomous variables to "no," and multichotomous variables to the most frequent categorical value. We selected this imputation strategy as it was most compatible with applying respective scores in clinical and public health settings. We excluded participants who had missing SES information (n = 817). The analysis described was then repeated on the imputed dataset (n = 4,489). We used a 2-tailed $\alpha = 0.05$ to establish statistical significance and reported 95% confidence intervals. All analyses were done using SAS version 9.4 (SAS Institute, Cary, North Carolina) statistical software.

RESULTS

After exclusions for missing CVH and SES data, there were 3,667 participants included in the primary analysis. As shown in Table 1, the median age of eligible participants was 55 years and 64% were women, and the majority of participants were not diabetic, nonsmokers, and not taking cholesterol medications. However, almost one-half (49%) were taking blood pressure medication and 46% reported no physical activity (Table 1). In addition, nearly one-third of eligible participants had individual incomes <$20,000 and close to 40% lived in the lowest neighborhood income category (<$25,480). Although the majority of participants with low individual-level income lived in lower-income neighborhoods and the majority of participants with high individual-level income lived in higher-income neighborhoods, the correlation of SES across levels of aggregation was not perfect (Online Table 2).

For both individual and neighborhood levels of income, there was a stepwise increase in CVH score (continuous and categorical) as income category increased (Online Tables 3 and 4). Results from our models indicate that those with higher individual- and neighborhood-level SES had higher CVH scores ($p < 0.001$ for both) (Table 2). In model 3 adjusted for age, sex, and neighborhood SES, there was an average increase in CVH score of 0.31 points associated with each 1-category increase in individual income. Similarly, each 1-category increase in neighborhood SES was associated with a 0.19-point increase in CVH score. However, there was no evidence of effect modification between individual and neighborhood SES as evidenced by the interaction term (model 4; $p = 0.65$).

We observed similar findings when individual and neighborhood SES were modeled as categorical variables (Table 3). Specifically, individuals earning at least $75,000 had a 0.93-point higher CVH score on average than those

TABLE 4. Effect of categorical individual- and neighborhood-level education on CVH score among JHS participants (N = 3,667)

Model	Parameter	Effect estimate (95% CI)	p Value
1	HS graduate vs. <HS	0.14 (−0.08 to 0.35)	0.21
	Some college or associate's degree vs. <HS	0.27 (0.04 to 0.50)	0.02
	Bachelor's degree vs. <HS	0.75 (0.52 to 0.98)	<0.001
	Graduate/professional degree vs. <HS	1.03 (0.81 to 1.25)	<0.001
	Female	−0.13 (−0.28 to 0.01)	0.08
	Age, per 5-yr increase	−0.19 (−0.22 to 0.15)	<0.001
2	Neighborhood education: per 5% increase in individuals with bachelor's degree	0.10 (0.07 to 0.12)	<0.001
	Female	−0.11 (−0.25 to 0.04)	0.15
	Age, per 5-yr increase	−0.19 (−0.22 to 0.16)	<0.001
3	HS graduate vs. <HS	0.12 (−0.10 to 0.34)	0.29
	Some college or associate's degree vs. <HS	0.23 (−0.01 to 0.46)	0.06
	Bachelor's degree vs. <HS	0.67 (0.43 to 0.91)	<0.001
	Graduate/professional degree vs. <HS	0.93 (0.69 to 1.16)	<0.001
	Neighborhood education: per 5% increase in individuals with bachelor's	0.06 (0.03 to 0.09)	<0.001
	Female	−0.12 (−0.27 to 0.03)	0.10
	Age, per 5-yr increase	−0.18 (−0.22 to 0.15)	<0.001
4	HS graduate vs. <HS	−0.14 (−0.59 to 0.32)	0.55
	Some college or associate's degree vs. <HS	0.05 (−0.36 to 0.46)	0.82
	Bachelor's degree vs. <HS	0.34 (−0.14 to 0.82)	0.17
	Graduate/professional degree vs. <HS	0.66 (0.23 to 1.08)	0.002
	Neighborhood education: per 5% increase in individuals with bachelor's	−0.02 (−0.11 to 0.08)	0.76
	Education interaction 1: HS graduate × neighborhood education	0.08 (−0.06 to 0.22)	0.25
	Education interaction 2: some college or associate's degree × neighborhood education	0.06 (−0.06 to 0.18)	0.30
	Education interaction 3: bachelor's degree × neighborhood education	0.09 (−0.03 to 0.21)	0.13
	Education interaction 4: graduate/professional degree × neighborhood education	0.08 (−0.01 to 0.17)	0.07
	Female	−0.12 (−0.27 to 0.03)	0.11
	Age, per 5-yr increase	−0.18 (−0.22 to 0.15)	<0.001

HS, high school; other abbreviations as in Tables 1 and 2.

earning <\$20,000 after adjustment for covariates (model 3; $p \leq 0.001$). Individuals residing in neighborhoods with median incomes >\$35,375 on average had a CVH score 0.37 points higher than participants living in neighborhoods with incomes <\$25,480 after adjustment for covariates (model 3) (Table 3).

To demonstrate the relationship between increasing individual and neighborhood SES and CVH score, we graphed predicted CVH scores using parameter estimates from model 3 in Table 2 (Figure 1). Those with higher individual incomes had higher CVH, and with each increase in neighborhood income, there was an additive positive improvement in CVH score.

In our secondary analyses, we evaluated the relationship between education as a proxy for income and CVH score. Compared with an individual-level education of less than high school, there were statistically significant differences in CVH for bachelor's degree education and for graduate/professional levels, respectively (Table 4). For example, individuals with a bachelor's degree, had on average, a CVH score of 0.67 points higher than that of their less—than—high school counterparts, after adjusting for covariates. Additionally, individuals with graduate/professional degrees had on average a CVH score of 0.93 points compared with those with less than a high school education (model 3; $p < 0.001$) (Table 4). Neighborhood-level education had a similar association with CVH score. Specifically, for each 5% increase in the percentage of adults with a bachelor's degree in a neighborhood, there was a 0.06-point increase in CVH score, after adjustment for covariates (model 3; $p < 0.001$). However, the interaction terms between individual and neighborhood education were null, reflecting the findings of the primary analysis.

Results from sensitivity analyses for the imputed CVH missing data cohort (n = 4,489) did not alter conclusions reached with the primary analyses (results not shown), nor were any SES × sex interactions statistically significant.

DISCUSSION

We observed an improvement in CVH with increasing SES. Overall, our results indicate that those with higher levels of individual- and neighborhood-level SES have better CVH. Specifically, we demonstrated an increase in CVH score with the additive effects of higher individual- and neighborhood-level SES. These patterns held for our primary analyses, which used income to define SES, as well as our secondary analyses, which used educational attainment in place of income. These data did not suggest a synergistic effect of individual- and neighborhood-level SES on CVH. A prospective study is needed to confirm the observed associations and to evaluate whether individual or neighborhood SES are most closely related to changes in CVH over time.

Our findings are consistent with studies that have reported an inverse relationship between SES and CVD, particularly in high-income countries [10,25,26]. Beyond being consistent with other studies, our findings suggest a potential causal pathway for disparities in CVD among vulnerable populations. Low CVH scores are linked to poor CVD outcomes, and targeting public health interventions to improve CVH scores among low SES individuals may have substantial societal implications. Indeed, there is evidence of widening disparities in CVD by SES in the United States [27]. Data from the 2009 California Health Interview Survey indicated that higher education was associated with better CVH in terms of its individual components [16]. Although another study demonstrated an interaction between SES levels, such that the joint impact of low individual- and low neighborhood-level SES had a much larger negative effect on CVH compared with the independent effects of those variables, our data did not support this conclusion [28]. It is possible that our study sample did not have sufficient variability across strata of SES to detect such a difference.

Social determinants of health, including SES, stress, and racial discrimination have been associated with CVH utilizing slightly different metrics than we used in our analysis [29]. Collectively, these studies have contributed to our knowledge of individual- and neighborhood-level factors that influence our health. Persons with a higher income or education are likely to be able to afford healthier foods and to dedicate discretionary time to physical activity compared with persons of lower income or education. Individual-level SES can also influence the type of health insurance a person can afford and thus the quality of health care they are able to access. Meanwhile, persons living in areas of lower SES often have lower health literacy as well as a decreased availability of healthy foods, safe places to exercise, and health care accessibility as compared to persons living in areas of higher SES [25,30].

Strengths of this analysis include a well-characterized population of AA participants and data with which to define SES and CVH. This is the first study we are aware of to assess the association between individual- and neighborhood-level SES and CVH score in a population of AA participants. Complete SES data at the individual and CT level allowed us to assess the robustness of SES-CVH associations using both income and education as proxies for SES. Our imputation strategy allowed us to perform secondary analyses and quantify SES-CVH relationships in a more complete sample of participants.

A limitation of these data is that the findings represent the experience of participants in the JHS and are most directly generalizable to AA residents of Jackson, Mississippi, but not necessarily representative of AA populations across the United States. Our data do not capture the underlying neighborhood factors, such as access to preventive care, racial discrimination, or social support features, which may explain our results. Whereas we have previously acknowledged not adjusting for factors that may be on the causal pathway, we also were not able to adjust for factors directly related to biologic and behavior factors comprising the CVH score, such as low-density lipoprotein cholesterol or total caloric intake. It should also be noted that there currently is a limited understanding of what constitutes a clinically meaningful change in CVH score, which limits the interpretation of these data, although previous studies have demonstrated decreasing CVD risk with each 1-point increase in CVH [4]. A future direction of this work is to establish evidence regarding the amount of change in CVH that results in improved cardiovascular outcomes.

Our findings have public health implications for clinicians who are treating individual patients as well as for policymakers who are seeking to provide an environment that supports CVH. A multidimensional framework has been developed for assessing and monitoring disparities in CVH [31]. Notably, the framework requires cooperation and collaboration among community groups, organizations, academia, health care, and other stakeholders to ameliorate CVH disparities. Baseline distributions and trends in CVH according to geography or individual- or neighborhood-level SES characteristics can be used to inform comprehensive policy and individual-level strategies to improve CVH in selected subpopulations [30,32].

CONCLUSIONS

Our findings suggest a potential causal pathway for disparities in CVH among vulnerable populations. These data can be useful to the JHS community to empower public health and clinical interventions and policies for the improvement of CVH.

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