ORIGINAL RESEARCH

Social Determinants of Cardiovascular Health in US Adolescents: National Health and Nutrition Examination Surveys 1999 to 2014

Sean D. Connolly, DO, MS; Donald M. Lloyd-Jones, MD, ScM; Hongyan Ning, MD, MS; Bradley S. Marino, MD, MPP, MSCE, MBA; Lindsay R. Pool, PhD, MPH; Amanda M. Perak, MD, MS

BACKGROUND: Cardiovascular health (CVH) is suboptimal in US adolescents. Social determinants of health (SDOH) may affect CVH. We examined SDOH by race and ethnicity and assessed for associations between SDOH and CVH among US adolescents.

METHODS AND RESULTS: We analyzed data from the National Health and Nutrition Examination Survey for 3590 participants aged 12 to 19 years from 1999 to 2014. SDOH variables were chosen and an SDOH score assigned (range, 0–7 points; higher=more favorable). CVH was classified according to American Heart Association criteria. We estimated population prevalence and used multivariable linear and polytomous logistic regression for associations between SDOH and CVH. SDOH varied by group, with the non-Hispanic White group (n=1155) having a higher/better mean SDOH score compared with non-Hispanic Black (n=1223) and Mexican American groups (n=1212). Associations between SDOH and CVH differed between racial and ethnic groups (interaction \( P < 0.0001 \)). For the non-Hispanic White group, each additional favorable SDOH variable was associated with a CVH score higher/better by 0.3 points (\( \beta = 0.3, P < 0.0001 \)), 20\% higher odds for moderate (versus low) CVH (odds ratio [OR], 1.2 [95\% CI, 1.1–1.4]), and 80\% higher odds for high/favorable (versus low) CVH (1.8 [1.5–2.1]). Associations between SDOH and CVH were more modest among the Mexican American group (\( \beta = 0.12, P = 0.001 \); OR 1.1 [1.0–1.2] for moderate CVH; OR, 1.3 [1.1–1.6] for high CVH) and were not significant among the non-Hispanic Black group (\( \beta = 0.07; P = 0.464 \)).

CONCLUSIONS: SDOH and CVH were more favorable for non-Hispanic White adolescents compared with non-Hispanic Black and Mexican American adolescents. SDOH were strongly associated with CVH among the non-Hispanic White group. Racially and culturally sensitive public policy approaches may improve CVH in US adolescents.

Key Words: cardiovascular health ■ health inequities ■ social determinants of health

The World Health Organization defines social determinants of health (SDOH) as “the circumstances in which people are born, grow, live, work, and age, and the systems put in place to deal with illness.”

SDOH include factors related to economic stability, education, health care access, residential environments, and social context and support. In adults, cumulative social risk is associated with a decreased likelihood of achieving ideal cardiovascular health (CVH)—as defined by the American Heart Association using the 7 key metrics of diet, physical activity, smoking, body mass index, blood pressure, lipids, and glucose—which in turn is associated with higher all-cause mortality, cardiovascular disease (CVD) events, and chronic diseases of aging. Additionally, 2 recent analyses demonstrated that a simple count of unfavorable SDOH in midlife was associated with incident fatal and nonfatal coronary heart disease and stroke.
Less is known about the associations of SDOH with CVH during childhood or adolescence. Certain individual SDOH domains have been linked to individual CVH metrics. For example, differences in obesity prevalence in adolescence have been noted by socioeconomic position and by self-reported race and ethnicity, as a proxy for SDOH exposures. However, data are lacking on the association between a global index of SDOH and total CVH (based on all 7 metrics) during youth. CVH is suboptimal among US adolescents: by age 12 to 19 years, <1% have all 7 CVH metrics at ideal levels, and <50% have at least 5 of 7 at ideal levels. Investigation of relationships between SDOH and CVH in US youth may provide important public health information to inform strategies that prevent the early loss of CVH during childhood and adolescence.

The goal of this analysis was to estimate the distribution of SDOH in US adolescents and to investigate the association between SDOH and CVH, both overall and by self-reported racial and ethnic groups, given known differences in CVH metrics and SDOH exposures by race and ethnicity. We hypothesized that there are differences in a global SDOH index across racial and ethnic groups and that more favorable SDOH are associated with higher CVH.

METHODS
Study Participants
We used cross-sectional data from the National Health and Nutrition Examination Survey (NHANES), which used a complex, multistage probability sampling design to select a representative sample of the civilian noninstitutionalized US population. Participants were interviewed at home and were invited to attend a mobile examination center where they underwent various examinations and provided a blood sample. The questionnaires, protocols, and coding for NHANES have been described. NHANES data collection has been approved by the National Center for Health Statistics Research Ethics Review Board at each survey cycle. Parents or guardians of survey participants aged <18 years provided written informed consent for the child, and children aged ≥7 years gave their assent as well.

To have adequate sample size, we a priori included adolescents aged 12 to 19 years from recent survey cycles (1999–2014) who had data available for all 7 CVH and all 7 SDOH variables and who self-/parent-/guardian-reported their racial and ethnic group as Mexican American (MA), non-Hispanic Black (NHB), or non-Hispanic White (NHW) (n=3590). Individuals from other racial and ethnic groups were not included because the NHANES sampling strategy did not allow for reliable calculation of subpopulation estimates. Starting in 2004, NHANES began to oversample Latino/Hispanic groups who identify in categories other than MA; however, for consistency in reporting and to ensure adequate sample size, we used the category MA.

Demographic Characteristics
Age, sex, and racial and ethnic group were collected during home interviews by self or parent/guardian report from provided categories.

Social Determinants of Health
SDOH variables were chosen to represent the 5 broad constructs of SDOH as defined by the Office of Disease Prevention and Health Promotion’s Healthy

---

CLINICAL PERSPECTIVE
What Is New?
- A novel combined social determinants of health (SDOH) score was created, and differences were observed between racial and ethnic groups, with the non-Hispanic White group having more favorable SDOH compared with Mexican American and non-Hispanic Black groups.
- Cardiovascular health (CVH) levels differed across racial and ethnic groups, with the non-Hispanic White group having higher CVH levels compared with the Mexican American and non-Hispanic Black groups.
- SDOH score was associated with CVH among non-Hispanic White adolescents and to a lesser degree among Mexican American adolescents, but not among non-Hispanic Black adolescents.

What Are the Clinical Implications?
- Our finding that the association between SDOH and CVH differed by race and ethnicity has important implications for the goal of improving adolescent CVH.
- It suggests that public policy and public health initiatives aimed only at equalizing certain SDOH variables may not fully resolve disparities in CVH and that other means of promoting resilience and mitigating marginalization-related diminished return should be sought.

Nonstandard Abbreviations and Acronyms
CVH cardiovascular health
MA Mexican American
NHANES National Health and Nutrition Examination Survey
NHB non-Hispanic Black
NHW non-Hispanic White
People 2030 and World Health Organization (economic stability, education, health care access, residential environment, and social context and support) and for their availability in NHANES (Table 1). Data on residential environment are not contained in publicly available NHANES data and so were not examined.

Economic stability was assessed using self-reported measures of household poverty level index, household food security status, and home ownership. Household poverty level (poverty versus non-poverty) was calculated as the ratio of monthly family income to poverty levels defined by US Department of Health and Human Services guidelines and dichotomized at 1.85 based on common eligibility guidelines for federal programs. Household food security level was determined based on responses to the US Food Security Survey Module and dichotomized as food secure (≤2 affirmative responses) or food insecure. Home ownership was dichotomized as “owned” versus “rented or other.”

Education was assessed by self-reported measures of household head education attainment. Household head educational attainment used the highest level completed, dichotomized as high school or less (≤high school) or any education beyond high school (>high school). Health care access was assessed by self-reported access to routine place for health care (defined as “yes” if the participant reported the routine place was a doctor’s office or other health clinic, and “no” if the participant reported no routine place or reported using a hospital emergency room) and health insurance status (yes/no). Finally, social context was assessed by self-reported household head relationship status (defined as “living single” (widowed or divorced, separated, or never married) or “non-living single” (married or living with a partner)) and indirectly through stratification by race and ethnicity.

A total SDOH score was created by assigning 1 point for each favorable SDOH variable, with a range from 0 (no favorable SDOH) to 7 (all favorable SDOH). Each variable was weighted equally, as has been done in prior analyses in adults and as is done for the CVH score (detailed below).

### CVH Metrics

CVH was defined using American Heart Association criteria for adolescents for the 7 CVH metrics including diet, physical activity, smoking, body mass index, blood pressure, total cholesterol, and glucose (Table 2). Dietary intake was assessed via 2 interviewer-administered 24-hour recalls. All dietary factors were calculated with the use of the MyPyramid Equivalents Database according to the methodology established by the US Department of Agriculture Center for Nutrition Policy and Promotion. Physical

---

**Table 1. SDOH Metric Definitions**

| SDOH metric | NHANES metric | Measures used | Favorable SDOH score=1 point |
|-------------|---------------|---------------|-----------------------------|
| Economic stability | Poverty level index | Ratio of monthly family income to poverty levels | ≥1.85 |
| Household food security level | ≤2 affirmative responses to US Food Security Survey Module | Secure |
| Home ownership | Owned or being bought | Owned |
| Household head education attainment | Highest level of schooling completed | ≥High school |
| Health care access | Access to routine place for health care | Yes: doctor’s office, HMO, clinic |
| Health insurance status | Insured |
| Residential environment | NA | Not living |

HMO indicates health maintenance organization; NHANES, National Health and Nutrition Examination Survey; and SDOH, social determinants of health.

*Based on World Health Organization and Healthy People 2030 definitions.
activity was self-reported as frequency and duration of specific activities according to intensity, and total minutes per day of moderate-to-vigorous physical activity were calculated. Smoking status was defined based on the response to questions about whether the participant had ever tried cigarette smoking.

Standardized measurements of weight and height were used to calculate body mass index as weight in kilograms divided by height in meters squared. Age- and sex-specific percentiles for body mass index were obtained using previously established Centers for Disease Control Growth Charts. Blood pressure was measured at least 3 (up to 4) times in a seated position after 5 minutes of rest. The average of all blood pressure measurements was used to calculate percentiles according to age, sex, and height.

For the large majority of participants (93.8%), blood was drawn in the fasting state. The remaining participants attended an afternoon exam, and blood was drawn nonfasting. Self-reporting fasting times of 8.5 to 24 hours were required for the measurement of fasting glucose. Both fasting and nonfasting samples of total cholesterol were used in the final analysis. Blood samples were obtained and sent to central laboratories for determination of total cholesterol and plasma glucose.

Each of the 7 CVH metrics was categorized as poor, intermediate, or ideal (Table 2). A total CVH score was calculated by assigning points to each metric (0=poor, 1=intermediate, and 2=ideal) and summing across all 7 metrics, for a total score of 0 to 14 points.

### Statistical Analysis

All statistical analyses were performed with the use of SAS 9.3 (SAS Institute, Cary, NC). SAS procedure SURVEYFREQ was used to incorporate the complex, multistage sampling design of NHANES in the statistical analyses and estimate means and prevalence for the population of noninstitutionalized US adolescents aged 12 to 19 years. We calculated population-weighted prevalence and mean estimates for the SDOH score and its components as well as the CVH score and its categories. We elected a priori to examine SDOH and CVH both overall and by self-reported racial and ethnic group because of known differences in both individual SDOH and CVH by race and ethnicity. Although racial and ethnic group is itself a social construct, certain authorities such as the World Health Organization and the CDC do not consider it an SDOH; rather, it is often correlated with SDOH because of underlying institutionalized and perpetuated racism, and the SDOH and their drivers must be better understood and addressed. To model the association between the SDOH score and CVH, we used linear regression.
for the continuous CVH score and polytomous logistic regression for the categorical (high/moderate/low) CVH score. Regression analyses were adjusted for sex and age, and an interaction term for self-reported racial and ethnic group was tested; the interaction term was significant in both the linear ($P<0.001$) and logistic ($P=0.003$) models, so results are reported stratified by racial and ethnic group. In a sensitivity analysis, we repeated regression analyses with additional adjustment for exam cycle to account for temporal changes in SDOH or CVH; findings were nearly identical (data not shown). In secondary analyses, to explore the components of the SDOH score, we calculated polychoric correlations among dichotomous SDOH components and examined associations between individual dichotomous SDOH components and total CVH scores, after adjustment for demographics (model 1) and the other SDOH components (model 2). Because of concerns about potential for both type I and type II error, these secondary analyses are considered exploratory and should be interpreted with caution.

RESULTS
Among 3590 participants included, 33.8% were MA, 34.1% were NHB, and 32.2% were NHW (Table 3). The 3590 participants represented 8,692,435 US adolescents with a population-weighted mean age of 15.3 years (95% CI, 15.2–15.3).

Social Determinants of Health
Prevalence estimates of SDOH variables and scores are displayed in Table 3 and Figure 1A. NHW adolescents had higher prevalence of favorable levels for all 7 SDOH variables when compared with MA and NHB adolescents. Differences were most striking for poverty level, for which 71% (95% CI, 68%–75%) of NHW adolescents had a poverty level index $>$1.85 versus 34% (30%–37%) for MA adolescents and 39% (34%–44%) for NHB adolescents. Among US adolescents overall, the mean SDOH score was 5.2 (95% CI, 5.1–5.3) out of 7 (Table 3). NHW adolescents had a higher mean SDOH score (5.7 [5.6–5.8]) compared with MA adolescents (4.1 [4.0–4.3]) and NHB adolescents (4.2 [4.0–4.4]). Among NHW adolescents, 39.7% (95% CI, 36%–44%) had favorable levels of all 7 SDOH variables, compared with only 7.2% (6%–9%) of MA adolescents and 10% (7%–13%) of NHB adolescents (Figure 1A).

Cardiovascular Health
The distributions of CVH scores (0–14 points) and categories (high, moderate, low) are shown in Figure 1B and Figure 2. Among adolescents overall, the mean CVH score was 8.8 (95% CI, 8.7–8.9) out of 14. Significant differences were observed between racial and ethnic groups, with a higher mean CVH score in NHW adolescents (8.9 [95% CI, 8.8–9.1]) compared with MA adolescents (8.6 [95% CI, 8.4–8.7]) and NHB adolescents (8.6 [95% CI, 8.4–8.7]). Similarly, a greater percentage of NHW adolescents had high CVH (11% [95% CI, 10%–13%]) compared with MA adolescents (5% [95% CI, 4%–6%]) and NHB adolescents (5% [95% CI, 4%–7%]).

Associations Between SDOH and Cardiovascular Health
The mean SDOH score for each CVH category is shown in Figure 2. Among US adolescents overall, mean SDOH scores were higher in more favorable CVH categories. This pattern was most apparent among NHW adolescents, and to some extent among MA adolescents, but less prominent among NHB adolescents.

Table 4 shows adjusted analyses of the association between SDOH and CVH, stratified by self-reported racial and ethnic group because an interaction term was statistically significant. Among NHW adolescents, higher (more favorable) SDOH scores were associated with higher (more favorable) CVH; specifically, each 1-point higher SDOH score was associated with a higher CVH score by 0.3 points (P<0.0001), 1.2 times greater odds for moderate (versus low) CVH (odds ratio [OR], 1.2 [95% CI, 1.1–1.4]) and 1.8 times greater odds for high (versus low) CVH (OR, 1.8 [95% CI, 1.5–2.1]). Among MA adolescents, the association between SDOH and CVH was statistically significant but more modest compared with that of NHW adolescents, and among NHB adolescents, a statistically significant association between SDOH and CVH was not detected (Table 4).

Secondary Analyses of Individual Components of the SDOH Score
Correlation coefficients among individual dichotomous SDOH components ranged from 0.01 (negligible) to 0.62 (moderate; Table 5). The strongest correlations were observed between poverty level and other factors including home ownership (0.62), household food security (0.57), and household head education (0.57) as well as between health insurance status and access to a routine place for health care (0.55).

In the overall population of adolescents, after adjustment for age, sex, and racial and ethnic group (Table 6, model 1), each of the 7 favorable SDOH components was significantly associated with higher CVH scores. After additional adjustment for the other 6 SDOH components (Table 6, model 2), 3 of the 7 favorable SDOH components were significantly associated with higher CVH scores: household head education >high school, household food security, and household head education.
nonsingle living status. Patterns varied by self-identified race and ethnicity; among MA youth and NHW youth, 5 of the 7 SDOH were significantly associated with CVH (although components varied), whereas among NHB youth, only 1 SDOH (household head education) was significantly associated with the CVH score (Table 6, model 1). After additional adjustments for the other SDOH components, results were mostly unchanged, but some estimated regression coefficients changed sign among MA youth, likely because of collinearity with other variables (Table 6, model 2). Notably, in these secondary analyses, robust quantitation was limited by lack of power and many comparison groups.

### Table 3. Prevalence of SDOH Levels in US Adolescents (Aged 12–19 Years), National Health and Nutrition Examination Surveys, 1999 to 2014

| Characteristics | Overall (n=3590) | Mexican American (n=1212) | Non-Hispanic Black (n=1223) | Non-Hispanic White (n=1155) |
|-----------------|-----------------|--------------------------|---------------------------|---------------------------|
| **Sex**         |                 |                          |                           |                           |
| Male            | 53 (51–55)      | 52 (48–56)               | 55 (51–58)                | 53 (50–56)                |
| Female          | 47 (45–49)      | 48 (45–52)               | 45 (42–49)                | 47 (44–50)                |
| **Age, y**      |                 |                          |                           |                           |
| 12–15           | 55 (52–57)      | 57 (54–61)               | 54 (51–56)                | 54 (51–56)                |
| 16–19           | 45 (43–48)      | 43 (39–46)               | 46 (42–49)                | 46 (42–49)                |
| **SDOH**        |                 |                          |                           |                           |
| Poverty level index |             |                          |                           |                           |
| ≤1.85           | 39 (36–42)      | 66 (63–69)               | 61 (56–66)                | 29 (25–32)                |
| >1.85           | 61 (58–64)      | 34 (30–37)               | 39 (34–44)                | 71 (68–75)                |
| Household head education |           |                          |                           |                           |
| ≤High school   | 56 (53–59)      | 74 (70–79)               | 52 (49–56)                | 35 (31–39)                |
| >High school   | 44 (41–47)      | 25 (21–30)               | 48 (44–51)                | 65 (61–69)                |
| Household food security level |         |                          |                           |                           |
| Insecure       | 18 (16–19)      | 29 (26–33)               | 30 (26–34)                | 12 (10–14)                |
| Secure         | 82 (80–84)      | 71 (67–74)               | 70 (66–74)                | 88 (86–90)                |
| Household head relationship status |         |                          |                           |                           |
| Living single  | 29 (27–31)      | 26 (23–30)               | 57 (53–61)                | 23 (20–26)                |
| Nonsingle living | 71 (70–73)     | 74 (70–77)               | 42 (38–47)                | 77 (75–80)                |
| Home ownership | 31 (28–33)      | 43 (39–47)               | 58 (53–62)                | 22 (19–25)                |
| Rented, other  | 69 (67–72)      | 57 (53–61)               | 42 (38–47)                | 78 (75–81)                |
| Owned          | 11 (9–12)       | 21 (18–25)               | 11 (9–13)                 | 8 (7–10)                  |
| Access to routine place for health care |          |                          |                           |                           |
| No or hospital ER | 89 (88–91)     | 79 (75–82)               | 89 (87–91)                | 92 (90–93)                |
| Yes: doctor’s office, HMO, clinic |          |                          |                           |                           |
| Health insurance |             |                          |                           |                           |
| Uninsured      | 12 (10–13)      | 32 (28–35)               | 12 (10–14)                | 8 (6–9)                   |
| Insured        | 88 (87–90)      | 68 (65–72)               | 88 (86–90)                | 92 (91–94)                |
| Mean total SDOH score (out of 7) | 5.2 (5.1–5.3) | 4.1 (4.0–4.3)           | 4.2 (4.0–4.4)           | 5.7 (5.6–5.8)           |

ER indicates emergency room; HMO, health maintenance organization; and SDOH, social determinants of health. *P value is for the comparison of each SDOH variable’s prevalence by racial and ethnic group.

### DISCUSSION

Among US adolescents in the period 1999 to 2014, there were significant differences in the prevalence and distribution of SDOH levels between self-reported racial and ethnic groups, with NHW adolescents having more favorable SDOH on average compared with MA adolescents and NHB adolescents. There were also differences in CVH levels across racial and ethnic groups, which similarly were more favorable among NHW adolescents compared with MA adolescents and NHB adolescents. The total SDOH score was significantly associated with CVH levels among NHW adolescents, and to a lesser degree among MA adolescents, but not among NHB adolescents.
Previous work has described racial and ethnic inequities among adolescents for individual SDOH, such as poverty, food security, insurance status, and access to health care, with results showing more favorable individual SDOH for NHW adolescents than for MA or NHB adolescents. Our findings confirm and extend this work by demonstrating a similar pattern of differences in social circumstances between racial and ethnic groups using a combined SDOH score. A prior study by Shay et al showed that from 2005 to 2010, the CVH of NHW adolescents was better when compared with the CVH of MA or NHB adolescents. We also found differences in CVH by self-reported race and ethnicity, with a mean CVH score difference of 0.3 points between NHW adolescents and MA or NHB adolescents. This difference may seem modest, but it is expected to translate into a significant health advantage for NHW individuals and widening disparities, as a CVH score higher by 1 point in young adulthood has been associated with a 20% to 31% lower hazard ratio for incident premature CVD events and mortality. Moreover, a recent analysis showed distinct long-term trajectories in CVH starting at age 8 years, with more rapid declines occurring in those with modestly poorer CVH in childhood, such that differences in CVH between trajectory groups were substantial by adulthood. These differences were in turn associated with substantial differences in midlife carotid intimal-media thickness, a noninvasive measure of...
CVD risk. Such patterns of age-related divergence would, over time, further increase the differences in CVH observed here and lead to magnified differences in CVH-related outcomes such as CVD events, mortality, and quality of life.31

Previous studies have also examined the association between individual SDOH variables and individual CVH metrics in adolescents. For example, adolescents from low-income (versus high-income) families had greater prevalence of obesity, low-quality diet, physical inactivity, and smoking during the 1999 to 2014 period, and the prevalence of obesity increased during the 1999 to 2014 period among adolescents from low- and middle-income, but not high-income, families.32 Food insecurity has also been associated with cardiovascular risk factors among youth. Compared with youth from food-secure households, those from food-insecure households were more likely to have overweight or obesity33 and more likely to smoke.34 Additionally, studies have shown associations in adolescents between low parental education level and hypertension,35 public health insurance and poor blood glucose control in those with type I diabetes,36 and single-parent households and poor dietary habits.37 These studies provide valuable insights into the contribution of individual SDOH to specific CVH

Table 4. Association Between SDOH Score and CVH Status Among US Adolescents, Stratified by Racial and Ethnic Group

| SDOH Score Variable | Estimated Regression Coefficient (SE; *p* value) for CVH Score | Odds Ratio (95% CI) for Moderate (vs Low) CVH | Odds Ratio (95% CI) for High (vs Low) CVH | *p* Value for Race and Ethnicity Interaction |
|---------------------|---------------------------------------------------------------|-----------------------------------------------|-------------------------------------------|--------------------------------------------|
| SDOH score, per +1 point | Mexican American: 0.12 (0.03; 0.001) | 1.1 (1–1.2) | 1.3 (1.1–1.6) | <0.001 |
|                     | Non-Hispanic Black: 0.07 (0.04; 0.464) | 1.1 (1–1.2) | 1.1 (0.9–1.3) | 0.003 |
|                     | Non-Hispanic White: 0.3 (0.03; <0.0001)  | 1.2 (1.1–1.4) | 1.8 (1.5–2.1) |                             |

CVH indicates cardiovascular health; OR, odds ratio; and SDOH, social determinants of health.
variables. Our study is unique in that we examined the association between a composite of 7 SDOH variables and total CVH levels among adolescents, suggesting for the first time that for this composite set of binary SDOH variables, the association between SDOH and CVH was significant and differed by self-reported racial and ethnic group.

In our study, although a favorable SDOH score was associated with higher CVH among NHW adolescents, this association was less pronounced in MA adolescents, and there was no significant association found among NHB adolescents. The concept that the health benefits of certain socioeconomic resources are systematically smaller for MA individuals and NHB individuals than for NHW individuals has been previously described and termed “marginalization-related diminished return.”

Studies of racial and ethnic health disparities related to various socioeconomic factors have shown that parental education attainment, employment, and neighborhood safety are associated with health gains in NHW youth more so than for MA or NHB youth, whereas higher income is associated with equal reduction in mortality between racial and ethnic groups. It has been hypothesized that the positive effects of social and economic resources are diminished for NHB, Hispanic, Asian American, and Native American individuals because of structural factors, such as segregation, racism, and discrimination. Our findings are consistent with the concept of marginalization-related diminished return and may indicate that unequal health benefits from socioeconomic resources occur in US adolescents. Additionally, or perhaps alternatively, our findings could suggest the importance of other, unmeasured SDOH factors in MA and NHB adolescents, such that a more complete set of SDOH would allow a relationship between SDOH and CVH to be observed among all racial and ethnic groups. Further research with a robust set of SDOH is necessary to better understand the potential impacts of racism, segregation, and discrimination as well as other SDOH on CVH in US adolescents to inform public health efforts to reduce health disparities.

It is also notable that among adolescents with moderate and high CVH, mean SDOH scores were substantially lower for MA adolescents (4.2 and 4.7) and NHB adolescents (4.3 and 4.3), respectively, compared with NHW adolescents (5.7 and 6.3). The preservation of CVH in the face of high risk (ie, unfavorable SDOH), suggests the presence of unmeasured resiliency factors among some MA and NHB adolescents. The present analysis of NHANES data offered national representativeness but only a limited set of SDOH variables. For example, no data were available on neighborhood and built environments, culture and
Table 6. Adjusted* Associations of Individual SDOH Component Levels with CVH Scores, Overall, and by Race and Ethnicity

| SDOH Component | Estimated regression coefficient (95% CI) for CVH score | Overall | Non-Hispanic White | Non-Hispanic Black | Mexican American |
|----------------|--------------------------------------------------------|---------|-------------------|-------------------|------------------|
|                | Model 1       | Model 2 | Model 1       | Model 2 | Model 1       | Model 2 | Model 1       | Model 2 |
| Poverty level index >1.85 (vs ≤1.85) | 0.44 (0.26 to 0.63) | 0.16 (−0.1 to 0.42) | 0.62 (0.36 to 0.89) | 0.3 (0.09 to 0.51) | 0.03 (−0.18 to 0.24) | −0.16 (−0.45 to 0.14) | 0.07 (0 to 0.14) | −0.15 (−0.24 to −0.07) |
| Household head education >HS (vs ≤HS) | 0.59 (0.41 to 0.78) | 0.48 (0.28 to 0.68) | 0.74 (0.56 to 0.92) | 0.56 (0.36 to 0.77) | 0.22 (0.02 to 0.43) | 0.25 (0 to 0.5) | 0.29 (0 to 0.57) | 0.29 (0.17 to 0.4) |
| Household food secure (vs insecure) | 0.58 (0.38 to 0.78) | 0.41 (0.15 to 0.67) | 0.94 (0.61 to 1.26) | 0.68 (0.4 to 0.96) | 0.08 (−0.15 to 0.31) | 0.02 (−0.22 to 0.26) | 0.28 (0.04 to 0.51) | 0.13 (0.06 to 0.2) |
| Household head marital status nonsingle living (vs single living) | 0.31 (0.11 to 0.5) | 0.23 (0.01 to 0.46) | 0.37 (0.18 to 0.56) | 0.25 (0.03 to 0.46) | 0.13 (−0.08 to 0.34) | 0.19 (−0.04 to 0.43) | 0.27 (−0.04 to 0.58) | 0.21 (0.12 to 0.3) |
| Home ownership: owned (vs rented or other) | 0.26 (0.09 to 0.42) | −0.04 (−0.24 to 0.17) | 0.31 (0.06 to 0.56) | −0.15 (−0.36 to 0.05) | 0.11 (−0.11 to 0.34) | 0.12 (−0.18 to 0.41) | 0.22 (−0.02 to 0.47) | 0.2 (0.1 to 0.3) |
| Access to routine place for health care such as doctor’s office, HMO, clinic (vs no or hospital ER) | 0.29 (0.02 to 0.57) | 0.07 (−0.24 to 0.39) | 0.29 (−0.14 to 0.71) | 0 (−0.43 to 0.42) | 0.1 (−0.31 to 0.52) | −0.11 (−0.54 to 0.33) | 0.47 (0.24 to 0.69) | 0.52 (0.45 to 0.59) |
| Health insurance: insured (vs uninsured) | 0.41 (0.19 to 0.64) | 0.22 (−0.03 to 0.48) | 0.69 (0.29 to 1.09) | 0.44 (0.14 to 0.74) | 0.24 (−0.13 to 0.6) | 0.22 (−0.17 to 0.6) | 0.08 (−0.14 to 0.29) | −0.15 (−0.24 to −0.21) |

CVH indicates cardiovascular health; ER, emergency room; HMO, health maintenance organization; and HS, high school.

*Model 1 is adjusted for sex and age; in the overall sample it is also adjusted for race and ethnicity. Model 2 is additionally adjusted for the levels of the other 6 SDOH components.
language, or social context and support. It is possible that MA and NHB individuals with moderate and high CVH and lower SDOH scores observed in our study had favorable unmeasured levels of neighborhood, and/or social support factors that offset individual unfavorable SDOH. However, individuals who self-identify as Hispanic or Black disproportionately reside in neighborhoods that are socioeconomically disadvantaged. Differences in culture and language among MA and NHB individuals have been associated with negative health outcomes compared with NHW individuals, with several studies citing the contribution of such implicit bias, racism, and discrimination on health outcomes. Social support may provide some resilience to MA and NHB youth, as both secular and religious emotional support have been shown to be important health determinants, particularly among non-White individuals. Social support may provide some resilience to MA and NHB youth, as both secular and religious emotional support have been shown to be important health determinants, particularly among non-White individuals. Individual psychosocial well-being, and its determinants, may also contribute to resilience. Further research in alternative data sets is needed to examine associations of a broad set of potential resiliency factors with CVH among a diverse sample of US adolescents.

Because most US adolescents do not have ideal CVH, and CVH generally worsens with age, it is likely that disparities in CVH among adolescents will translate into disparities in CVD morbidity and mortality in adulthood. It is estimated that only 45% of US adolescents aged 12 to 19 years have ≥5 ideal CVH components, and that number decreases to 31.6% for those aged 20 to 39 years and 10.6% for those aged 40 to 59 years. Thus, strategies are needed to preserve high levels of CVH through childhood and adolescence and “deliver” children to young adulthood with high CVH. This concept of “squaring the curve” of CVH across the life course will require measuring, monitoring, and modifying CVH from the beginning of life, and understanding the societal factors associated with CVH in adolescents is 1 piece of this complex puzzle. Our finding that the association between SDOH and CVH differed by race and ethnicity has important implications for the goal of improving adolescent CVH. It suggests that public policy and public health initiatives aimed only at equalizing certain SDOH variables may not fully resolve disparities in CVH and that other means of promoting resilience and eliminating structural racism and implicit bias should be sought.

The results of our secondary analyses examining individual SDOH components are exploratory and should be interpreted with caution, but they yielded a few interesting, hypothesis-generating observations. First and not surprisingly, some SDOH components (such as poverty and household head education) were correlated with each other. Second, and relatedly, although in the overall population each of the SDOH components was significantly associated with CVH, some associations were attenuated when all 7 components were in the model simultaneously. This may have been because of limited sample sizes and lack of power but also likely reflects the complexity in disentangling causal webs of correlated SDOH, particularly in a cross-sectional analysis. Third, in stratified analyses, associations between individual SDOH components and CVH differed by self-identified race and ethnicity, with only 1 significant component (household head education) among NHB youth but 5 significant components each among MA and NH-W youth. These findings further suggest that SDOH may have differential effects according to social context, proxied by race and ethnicity.

The results of this study should be interpreted considering its strengths and limitations. A major strength of our study is the use of a nationally representative sample of US adolescents to examine important SDOH and CVH. Another strength was the incorporation of multiple SDOH together, which we accomplished through the creation of an SDOH score that included multiple SDOH components. There were also several limitations. First, the cross-sectional design of the study prevents the confirmation of a prospective association between SDOH and CVH. Second, our analysis used CVH and SDOH scores, which count the number of factors at suboptimal levels instead of weighing the factors differently based upon different strengths of association with the outcome. For CVH, this was done because there are data suggesting that each metric adds incremental predictive value for CVH, and associations of the CVH score with health outcomes have appeared to be linear across the range of scores (0–14 points) in many adult studies. We created an SDOH score to serve similarly as a simplified tool and match the scoring method for CVH. Although this approach has been applied in adults, it has not been studied previously in adolescents, so its validity for assessing total SDOH in this population is uncertain. Third, assessment of SDOH was limited by the availability of variables in NHANES, and as described above, many SDOH such as neighborhood environment and social support were not included. Additionally, individual-level (as opposed to household-level) SDOH that predict adolescent CVH, such as the child’s own exposure to a high concentration of major life events, were not included in our SDOH data set. Further study of the relationships between SDOH and CVH is needed in samples of adolescents with more extensive SDOH data. Fourth, power was limited for some analyses, particularly stratified analyses with many covariates in secondary analyses, and secondary analyses should be interpreted as exploratory because of potential for both type I and type II error. Fifth, because of limitations of sampling in NHANES, we could not provide robust data for racial and ethnic groups other than MA, NHB.
and NHW adolescents. Future study in other data sets with larger numbers of adolescents from diverse racial and ethnic groups is needed. Sixth, NHANES has observed non/early/late-response bias among adults such that socially disadvantaged adults who responded (versus did not respond) to NHANES surveys were often less healthy. If such bias were present among youth participants, this could lead to an overestimate of the association between CVH and SDOH, but this is unknown. Seventh, the data collection for this analysis concluded in 2014, and although total CVH has been generally stagnant among US adolescents through 2020, it is unknown whether recent changes in social factors—especially as relates to the COVID-19 pandemic beginning in 2020—may impact the studied relationships. Future research using other data sets (until NHANES accumulates enough postpandemic data) could be useful to address this question.

In conclusion, between 1999 and 2014 there were significant differences in SDOH and CVH across self-reported racial and ethnic groups among US adolescents. A direct association between more favorable SDOH and more favorable CVH was strongest among NHW adolescents, modest among MA adolescents, and not significant among NHB adolescents. Further research is needed to better understand drivers of the differential association between SDOH and CVH by race and ethnicity, including public policy and public health initiatives and potential resiliency factors that may be leveraged to improve CVH, among US adolescents.

ARTICLE INFORMATION
Received May 13, 2022; accepted October 11, 2022.

Affiliations
Department of Cardiology, Ann & Robert H. Lurie Children’s Hospital of Chicago, Chicago, IL (S.D.C., B.S.M., A.M.P.); Department of Preventive Medicine, Feinberg School of Medicine, Northwestern University, Chicago, IL (D.M.L., H.N., L.R.P.); Department of Cardiology, Nemours Children’s Health, Wilmington, DE (S.D.C.); and Now with Department of Pediatric Cardiology, Cleveland Children’s Clinic, Cleveland, OH (B.S.M.).

Sources of Funding
None.

Disclosures
None.

REFERENCES
1. Marmot M, Friel S, Bell R, Houweling TA, Taylor S; Commission on Social Determinants of Health. Closing the gap in a generation: health equity through action on the social determinants of health. Lancet. 2008;372:1661–1669. doi: 10.1016/S0140-6736(08)61690-6
2. Havranek EP, Mujahid MS, Barr DA, Blair IV, Cohen MS, Cruz-Flores S, Davey-Smith G, Dennison-Himmelfarb CR, Lauer MS, Lockwood DW, et al. Social determinants of risk and outcomes for cardiovascular disease: a scientific statement from the American Heart Association. Circulation. 2015;132:873–898. doi: 10.1161/CIR.0000000000000228
3. Healthy People 2030, U.S Department of Health and Human Services, Office of Disease Prevention and Health Promotion. Social determinants of health. https://health.gov/healthypeople/objectives-and-data/social-determinants-health. Accessed December 29, 2021.
4. Caleyachetty R, Echouffo-Tcheugui JB, Muennig P, Zhu W, Munter P, Shimbo D. Association between cumulative social risk and ideal cardiovascular health in US adults: NHANES 1999-2006. Int J Cardiovasc Imaging. 2015;31:296-300. doi: 10.1007/s10550-014-0550-2
5. Lloyd-Jones DM, Hong Y, Labarthe D, Mozaffarian D, Appel LJ, Van Horn L, Greenlund K, Daniels S, Nichol G, Tomaselli GF, et al. Defining and setting national goals for cardiovascular health promotion and disease reduction: the American Heart Association’s strategic impact goal through 2020 and beyond. Circulation. 2010;121:586–613. doi: 10.1161/CIRCULATIONAHA.109.192703
6. Folsom AR, Yatsuya H, Nettleton JA, Lutsey PL, Cushman M, Rosamond WD; ARIC Study Investigators. Community prevalence of ideal cardiovascular health, by the American Heart Association definition, and relationship with cardiovascular disease incidence. J Am Coll Cardiol. 2011;57:1690–1696. doi: 10.1016/j.jacc.2010.11.041
7. Allen NB, Zhao L, Liu L, Davilgus M, Liu K, Fries J, Shih YT, Garside D, Vu TH, Stamler J, et al. Favorable cardiovascular health, compression of morbidity, and healthcare costs: forty-year follow-up of the CHA study (Chicago Heart Association Detection Project in Industry). Circulation. 2017;135:1693–1701. doi: 10.1161/CIRCULATIONAHA.116.029252
8. Yang Q, Cogswell ME, Flanders WD, Hong Y, Zhang Z, Loustalot F, Gillespie C, Merritt R, Hu FB. Trends in cardiovascular health metrics and associations with all-cause and CVD mortality among US adults. JAMA. 2012;307:1273–1283. doi: 10.1001/jama.2012.339
9. Safford MM, Reshefnyak E, Sterling MR, Richman JS, Munter P, Dantzor RW, Booth L, Pinheiro LC. Number of social determinants of health and fatal and nonfatal incident coronary heart disease in the REGARDS study. Circulation. 2021;143:244–253. doi: 10.1161/CIRCULATIONAHA.120.048026
10. Reshefnyak E, Ntamatinguro M, Pinheiro LC, Howard VJ, Carson AP, Martin KD, Safford MM. Impact of multiple social determinants of health on incident stroke. Stroke. 2020;51:2445–2453. doi: 10.1161/STROKEAHA.120.028930
11. Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of childhood and adult obesity in the United States, 2011-2012. JAMA. 2014;311:806–814. doi: 10.1001/jama.2014.732
12. Shay CM, Ning H, Daniels SR, Rooks CR, Gidding SS, Lloyd-Jones DM. Status of cardiovascular health in US adolescents: prevalence estimates from the National Health and Nutrition Examination Surveys (NHANES) 2005-2010. Circulation. 2013;127:1369–1376. doi: 10.1161/CIRCULATIONAHA.113.001559
13. Centers for Disease Control and Prevention, National Center for Health Statistics. National Health and Nutrition Examination Survey. https://www.cdc.gov/nchs/nhanes/. Accessed December 29, 2021.
14. Johnson CL, Paulose-Ram R, Ogden CL, Carroll MD, Kruszon-Moran D, Doehrmann SM, Curtin LR. National health and nutrition examination survey: analytic guidelines, 1999-2010. Vital Health Stat 13. 2013;21–24.
15. U.S. Department of Health & Human Services. Office of the Assistant Secretary for Planning and Evaluation. Poverty Guidelines, Research, and Measurement. https://aspe.hhs.gov/POVERTY/index.shtml. Accessed December 29, 2021.
16. U.S. Department of Agriculture Food and Nutrition Services. Supplemental Nutrition Assistance Program (SNAP) eligibility. 2019. https://www.fns.usda.gov/snap/recipient/eligibility. Accessed December 29, 2021.
17. U.S. Department of Agriculture Food and Nutrition Services. Special Supplemental Nutrition Program for Women, Infants, and Children (WIC). 2019. https://www.fns.usda.gov/wic/frequently-asked-questions-about-wic. Accessed December 29, 2021.
18. Connell CL, Nord M, Lofton KL, Yadrick K. Food security of older children can be assessed using a standardized survey instrument. J Nutr. 2004;134:2566–2572. doi: 10.1093/jn/134.10.2566
19. Britten P, Marcoe K, Yamini S, Davis C. Development of food intake patterns for the MyPyramid food guidance system. J Nutr Educ Behav. 2006;38:578–592. doi: 10.1016/j.jneb.2006.08.007
20. Kuczmarski RJ, Ogden CL, Guo SS, Grummer-Strawm LM, Flegal KM, Mei Z, Wei R, Curtin LR, Roche AF, Johnson CL. 2000 CDC growth charts for the United States: methods and development. Vital Health Stat 11. 2002;11–190.
21. National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents. The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in...
