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ORIGINAL ARTICLE

# Social Determinants of Cardiovascular Risk, Subclinical Cardiovascular Disease, and Cardiovascular Events

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**BACKGROUND:** Although there is research on the impact of social determinants of health (SDOHs) on cardiovascular health, most existing evidence is based on individual SDOH components. We evaluated the impact of cumulative SDOH burden on cardiovascular risk factors, subclinical atherosclerosis, and incident cardiovascular disease events.

**METHODS AND RESULTS:** We included 6479 participants from the MESA (Multi-Ethnic Study of Atherosclerosis). A weighted aggregate SDOH score representing the cumulative number of unfavorable SDOHs, identified from 14 components across 5 domains (economic stability, neighborhood and physical environment, community and social context, education, and health care system access) was calculated and divided into quartiles (quartile 4 being the least favorable). The impact of cumulative SDOH burden on cardiovascular risk factors (hypertension, diabetes, dyslipidemia, smoking, and obesity), systemic inflammation, subclinical atherosclerosis, and incident cardiovascular disease was evaluated. Increasing social disadvantage was associated with increased odds of all cardiovascular risk factors except dyslipidemia. Smoking was the risk factor most strongly associated with worse SDOH (odds ratio [OR], 2.67 for quartile 4 versus quartile 1 [95% CI, 2.13–3.34]). Participants within SDOH quartile 4 had 33% higher odds of increased high-sensitivity C-reactive protein (OR, 1.33 [95% CI, 1.11–1.60]) and 31% higher risk of all cardiovascular disease (hazard ratio, 1.31 [95% CI, 1.03–1.67]), yet no greater burden of subclinical atherosclerosis (OR, 1.01 [95% CI, 0.79–1.29]), when compared with those in quartile 1.

**CONCLUSIONS:** Increasing social disadvantage was associated with more prevalent cardiovascular risk factors, inflammation, and incident cardiovascular disease. These findings call for better identification of SDOHs in clinical practice and stronger measures to mitigate the higher SDOH burden among the socially disadvantaged to improve cardiovascular outcomes.

**Key Words:** cardiovascular disease ■ disparities ■ equity ■ risk factors ■ social determinants of health

Cardiovascular disease (CVD) is a leading cause of morbidity and mortality in the United States.[1] Advances in research leading to the identification and control of risk factors as well as optimized therapies for those with established disease have led to a remarkable decline in CVD mortality over the past 5 decades in the United States.[2] However, these benefits have not been observed equally across economic and social groups, with those most disadvantaged shouldering a higher burden of CVD and CVD mortality.[3]

Although research exists on the impact of social determinants of health (SDOHs) on cardiovascular health,

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## CLINICAL PERSPECTIVE

### What Is New?

- We developed a comprehensive social determinant of health measure, evaluating its association with cardiovascular risk factors, subclinical cardiovascular disease (CVD), and incident CVD.
- Increasing social disadvantage was associated with traditional cardiovascular risk factors (especially smoking), inflammation, and incident CVD but not coronary artery calcium.

### What Are the Clinical Implications?

- In spite of gains made in CVD risk reduction over the past few decades, upstream social circumstances may be limiting further gains; therefore, efforts aimed at CVD risk reduction should focus on addressing these upstream social factors.

### Nonstandard Abbreviations and Acronyms

| | |
|---|---|
| **MESA** | Multi-Ethnic Study of Atherosclerosis |
| **SDOH** | social determinant of health |

most of the existing evidence is based on individual SDOHs such as education and income or, at best, a composite of a few SDOH measures such as socioeconomic position,[4,5] with only few studies focusing on cumulative SDOH burden.[6–8] It is known that multiple SDOHs may interact to influence cardiovascular health.[9] Despite recent calls to better understand the impact of cumulative social disadvantage on overall cardiovascular health,[9] information remains sparse in understanding the impact of SDOHs on cardiovascular risk factors, subclinical CVD, and incident CVD.

To further enrich the current understanding of the connection between SDOHs and CVD, we sought to examine the association between a comprehensive measure of cumulative social disadvantage and multiple dimensions of the CVD process, including (1) cardiovascular risk factors, (2) cardiovascular risk profile, (3) subclinical coronary atherosclerosis, (4) systemic inflammation, and (5) incident CVD events. For this purpose, we used data from the NIH-funded MESA (Multi-Ethnic Study of Atherosclerosis), a carefully phenotyped cardiovascular cohort study with rich baseline SDOH data.

## METHODS

The data that support the findings of this study are available through the National Heart, Lung, and Blood Institute Biologic Specimen and Data Repository Information Coordinating Center. Requests for access to the data can be made through the website: https://biolincc.nhlbi.nih.gov/studies/mesa/.

### Setting: MESA

We used data from MESA, a community-based prospective cohort study of individuals free of clinically overt CVD, aged 45 to 84 years at enrollment. Participants were 6814 men and women of 4 self-identified racial and ethnic groups (non-Hispanic White, non-Hispanic Black, Hispanic, and Chinese American) recruited from 6 sites across the United States, between the years 2000 and 2002. The MESA protocol was approved by the Institutional Review Boards of all collaborating institutions and by the National Heart, Lung, and Blood Institute, and all participants signed informed consent. Further details of the methods used in MESA have been described previously and are available online.[10] The MESA data required for the present analysis was accessed through the National Heart, Lung, and Blood Institute Biologic Specimen and Data Repository Information Coordinating Center.[11]

### Study Design and Population

For the present analysis, we conducted cross-sectional analyses using MESA baseline data and longitudinal analyses using follow-up data for incident CVD events at a median of 14 years of follow-up. Individuals with missing information on any of the SDOH metrics used for this analysis (4.92%) were excluded from the study population. No other inclusion/exclusion criteria were implemented.

### Ascertainment of SDOHs in MESA and Aggregate SDOH Index

As a summary of cumulative social burden, we created an aggregate SDOH index based on the framework described by the Healthy People 2030 initiative, which categorizes SDOH into 5 domains (economic stability, neighborhood and physical environment, education, community and social context, and health care access and quality).[12] Using the SDOH information collected via questionnaires at MESA baseline, we constructed a list of 14 items under the 5 domains. Economic stability included SDOH related to employment, income, other sources of wealth, house tenure, and financial strain. Education included formal educational attainment. Community and social context involved SDOH related to social support, marital status, chronic stress, neighborhood cohesion, and discrimination. Health care access and quality included information about having a usual source of care and health insurance. Finally, neighborhood and physical environment included variables related to neighborhood problems

and neighborhood safety. Table S1 presents the specific MESA questions and variables used to define the final list of 14 SDOH items used for our aggregate SDOH index. Of note, some of the 14 items were obtained from a composite of items. As an example, chronic stress was obtained from the 5-item chronic burden scale.[13,14]

Each of the 14 items was dichotomized, and participants were assigned a score of 1 if adverse (eg, unsafe neighborhood) or 0 otherwise (eg, safe neighborhood). Among the 5 domains, some (eg, community and social context) included significantly more items than others (eg, education); therefore, we weighted the domains to ensure that they had equal weights, irrespective of the number of items included in each. Weighting was done such that each domain had a total possible score of 0.2. The scores of the 5 domains were then summed to define the final SDOH aggregate index, which ranged from 0 to 1, with higher scores representing more adverse SDOHs. The distribution of SDOH scores was then divided into quartiles for the statistical analyses.

## Cardiovascular Risk Factors, Subclinical CVD, and CVD Events

Our outcomes of interest were 5 cardiovascular risk factors (ie, hypertension, diabetes, dyslipidemia, current smoking, and obesity), subclinical coronary atherosclerosis (assessed using the coronary artery calcium [CAC] score), systemic inflammation (assessed using hs-CRP [high-sensitivity C-reactive protein]), and incident CVD events. Hypertension was defined as systolic blood pressure≥130 mm Hg, diastolic blood pressure≥80 mm Hg, or hypertension medication use.[15] Diabetes was defined as fasting glucose of ≥126 mg/dL, diabetes medication use, or self-reported physician diagnosis of diabetes. Dyslipidemia was defined as low-density lipoprotein cholesterol of ≥130 mg/dL or high-density lipoprotein cholesterol of <40 mg/dL in men or <50 mg/dL in women, or statin use with low-density lipoprotein cholesterol of ≥90 mg/dL. Obesity was defined as a body mass index of ≥30 kg/m$^2$ among non-Chinese Americans and ≥27 kg/m$^2$ for Chinese Americans.

Consistent with previous studies, and based on the 5 cardiovascular risk factors assessed, we defined "cardiovascular risk profile" on the basis of the number of risk factors reported, and an individual was classified as having a poor (≥4), average (2, 3), or optimal (0–1) cardiovascular risk factor profile.[16,17]

Depending on the field site, CAC was measured using electron beam computed tomography or multidetector-row helical computed tomography. In both cases, the measurements used a common, standard protocol and CAC was scored using the Agatston method. A detailed description of the MESA cardiac computed tomography protocol was published previously.[18] Assessment of hs-CRP levels was conducted as part of the baseline measurements in MESA of biomarkers and was conducted in all participants using a BNII nephelometer (N-High Sensitivity CRP; Dade Behring Inc, Deerfield, IL).

Details of the CVD event adjudication process were described previously[10] and are available online at http://www.mesa-nhlbi.org. For our present analyses, our incident CVD outcomes of interest were "all CVD" events (primary end point, inclusive of fatal/nonfatal myocardial infarction, fatal/nonfatal stroke, resuscitated cardiac arrest, other CVD death, definite angina, and probable angina followed by revascularization) and "hard CVD" events (secondary end point, inclusive of fatal/nonfatal myocardial infarction, fatal/nonfatal stroke, resuscitated cardiac arrest, and other CVD death).

## Statistical Analysis

We described the baseline characteristics of the study participants, overall and by SDOH quartiles. Age was compared using the Kruskal–Wallis test and categorical variables using the chi-squared test.

We described the age-adjusted prevalence of cardiovascular risk factors across SDOH quartiles, stratified by sex. We also described the age-adjusted distribution of CAC scores (0, 1–100, and >100) and hs-CRP levels (<1 mg/L, 1–2.99 mg/L, and ≥3.0 mg/L) across SDOH quartiles and by sex. We used the 2010 US Census Population Data to obtain age-standardized estimates.

For our cross-sectional analyses, we used logistic regression to model the association between SDOH quartiles and each cardiovascular risk factor. Three models were used: model 1 adjusted for age and sex, model 2 adjusted for model 1+race or ethnicity, and model 3 further adjusted for cardiovascular risk factors other than the outcome of interest. Multinomial logistic regression was used to model the association between SDOH quartiles and cardiovascular risk factor profile, adjusting for models 1 and 2 above. We also modeled the association between SDOH quartiles and CAC >100 (versus 0–100) as well as hs-CRP ≥3.0 mg/dL (versus <3.0 mg/dL) using logistic regression, adjusting for models 1 to 2 described above. Because of the anti-inflammatory effects of statins and aspirin as well as the paradoxical increase in coronary artery calcification with statin use, our hs-CRP and CAC analyses adjusted for statin and aspirin use in model 3.

For our analyses of incident events, we used Poisson regression with postestimation to obtain age-adjusted incidence rates of all and hard CVD events, computed as number of events per 1000 person-years.

Cox regression models were used to evaluate the association between SDOH quartiles and CVD events, adjusting for models 1 to 3 as for CAC and hs-CRP described above.

We further examined the association between SDOH quartiles and the outcomes of interest (ie, cardiovascular risk factors, CAC, hs-CRP, and incident CVD events) by race and ethnicity. These can be found in the Supplemental Materials (Tables S3–S6). All analyses were performed using Stata version 16 (StataCorp, College Station, TX).

# RESULTS

## Study Population

Our study population included 6479 MESA participants. Mean age (SD) was 62.0 (10.2) years, and 53% were women. Overall, 2528 (39.0%) individuals were non-Hispanic White, 1775 (27.4%) were non-Hispanic Black, 1395 (21.5%) were Hispanic, and 781 (12.1%) were Chinese American.

## Aggregate SDOH Index

The distribution of our weighted SDOH score is shown in Figure S1. The weighted SDOH score ranged from 0 to 0.83 with a median (interquartile range) of 0.25 (0.14–0.38). The weighted SDOH score was distributed into quartiles of increasing disadvantage as follows: quartile 1 (scores 0–0.14), quartile 2 (scores 0.15–0.25), quartile 3 (scores 0.26–0.38), and quartile 4 (score≥0.39). The prevalence of the individual components of our SDOH index are shown in Table S2. The least prevalent adverse SDOH was unemployment (2.3%), and the most prevalent was low income (57.6%).

## Baseline Characteristics

A total of 1912 (29.5%) participants belonged to SDOH–quartile I, that is, the least disadvantaged, while 1580 (24.4%) belonged to SDOH–quartile 4 (ie, the most disadvantaged). Compared with individuals in SDOH–quartile 1, those in SDOH–quartile 4 were more likely to be women (58.9% versus 43.9%) and to be non-Hispanic Black (29.2%) or Hispanic (43.0%) (Table 1). Approximately 15% of participants were statin users at baseline, while 20% were aspirin users at baseline. The proportion of aspirin and statin users was lower with higher SDOH burden.

## SDOH and Cardiovascular Risk Factors

The age-adjusted prevalence of cardiovascular risk factors by SDOH quartiles is shown in Figure 1. In women, there was a higher prevalence of all cardiovascular risk factors with higher SDOH quartiles, while for men this pattern was seen only for diabetes and smoking. In both sexes, the steepest increases in cardiovascular risk factors across SDOH quartiles were seen for diabetes and smoking. Also, women belonging to SDOH quartile 4 had almost twice the prevalence of obesity compared with those in quartile 1 (44.3% versus 25.3%).

In logistic regression models evaluating the association between SDOH quartiles and cardiovascular

**Table 1. Baseline Characteristics of Study Participants**

| | SDOH quartiles | | | | | | |
|---|---|---|---|---|---|---|---|
| | All | 1 | 2 | 3 | 4 | *P* value (global test) | **P* value (quartile 1 vs quartile 4) |
| N | 6479 | 1912 (29.5) | 1444 (22.3) | 1543 (23.8) | 1580 (24.4) | | |
| Age, y (SD) | 62.0 (10.2) | 61.8 (10.0) | 61.3 (10.2) | 62.9 (10.5) | 62.0 (10.2) | <0.001 | <0.001 |
| Sex | | | | | | <0.001 | <0.001 |
| Women | 3407 (52.6) | 839 (43.9) | 726 (50.3) | 911 (59.0) | 931 (58.9) | | |
| Men | 3072 (47.4) | 1073 (56.1) | 718 (49.7) | 632 (41.0) | 649 (41.1) | | |
| Race and ethnicity | | | | | | <0.001 | <0.001 |
| Non-Hispanic White | 2528 (39.0) | 1020 (53.4) | 683 (47.3) | 512 (33.2) | 313 (19.8) | | |
| Non-Hispanic Black | 1775 (27.4) | 447 (23.4) | 400 (27.7) | 466 (30.2) | 462 (29.2) | | |
| Hispanic | 1395 (21.5) | 138 (7.2) | 218 (15.1) | 376 (24.4) | 663 (42.0) | | |
| Chinese American | 781 (12.1) | 307 (16.1) | 143 (9.9) | 189 (12.3) | 142 (9.0) | | |
| Statin use | 964 (14.9) | 305 (16.0) | 213 (14.8) | 235 (15.2) | 211 (13.4) | 0.19 | 0.001 |
| Aspirin use | 1235 (19.9) | 439 (24.0) | 293 (21.1) | 278 (18.8) | 225 (14.9) | <0.001 | <0.001 |

Results presented as number (%) unless specified otherwise.
Comparisons between quartiles were done using chi-square test for categorical variables and Kruskall–Wallis test for age.
SDOH indicates social determinant of health.
**P* values specifically comparing quartile 1 quartile 4.

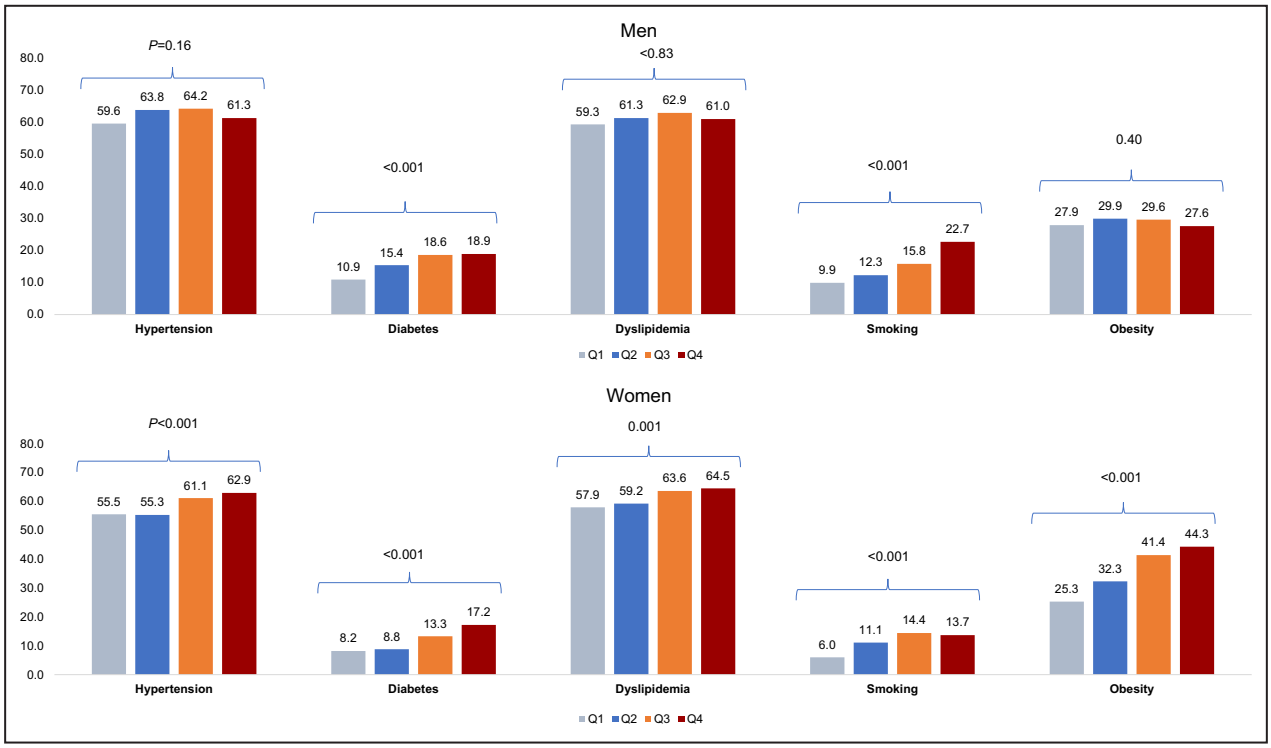


**Figure 1. Age-adjusted prevalence (%) of cardiovascular risk factors by SDOH quartiles, in men (A) and women (B).**
Q indicates quartile; and SDOH, social determinant of health.

risk factors, there was a stepwise increase in the odds of all cardiovascular risk factors with increasing SDOH quartiles (Table 2). In models adjusted for age, sex, and race and ethnicity, the cardiovascular risk factor most strongly associated with SDOH was smoking, with nearly 3-fold odds of smoking for SDOH–quartile 4 versus quartile 1 (odds ratio [OR], 2.67 [95% CI, 2.13–3.34]). Conversely, the weakest associations with SDOHs were observed for dyslipidemia. The observed associations persisted after further adjustment for cardiovascular risk factors except for dyslipidemia.

In stratified analyses by race and ethnicity, we found overall consistent trends of increasing odds of risk factors across all groups, except for Chinese Americans. Specifically, among Chinese Americans, apart from smoking and dyslipidemia, the odds increased from quartile 1 to quartile 2 and subsequently decreased (Table S3).

## SDOHs and Cardiovascular Risk Profile

We observed consistent findings in analyses of the association between SDOHs and the summary construct of "cardiovascular risk factor profile." Using an optimal profile as reference, individuals in SDOH–quartile 4 had 38% higher odds (OR, 1.38 [95% CI, 1.19–1.61]) of having an average risk profile and 2.6-fold higher odds (OR, 2.57 [95% CI, 1.82–3.63]) of having a poor risk profile compared with individuals in SDOH–quartile 1, after adjusting for age, sex, and race or ethnicity (Table 3).

## SDOHs, CAC, and Inflammation

The respective age-adjusted distributions of CAC scores and hs-CRP levels are shown in Figure 2. For CAC, numbers were stable across SDOH quartiles, and we did not find any pattern in the proportion of participants with CAC >0 or CAC >100 with higher SDOH quartiles, in either men or women. In contrast, there was an increase in the proportion of participants with high hs-CRP (≥3.0 mg/L) with increasing SDOH quartiles. Among men, 21.9% of participants in SDOH–quartile 1 had a high hs-CRP compared with 33.4% in SDOH–quartile 4, while among women 39.6% of participants in SDOH–quartile 1 had high hs-CRP compared with 47.1% in quartile 4.

In analyses modeling the association between SDOH quartiles and CAC >100 (compared with CAC ≤100), the association was null across all models (Table 4). In analyses stratified by race and ethnicity and sex, these associations were null across all subgroups except for Hispanic individuals, where we found lower odds of CAC>100 for individuals in SDOH–quartile 4 compared with those in quartile 1 (Table S4 and S5). For hs-CRP, in the model adjusted for age, sex, and race and ethnicity, there was a stepwise increase in

**Table 2. Baseline Associations Between SDOH Quartiles and Cardiovascular Risk Factors**

| | Hypertension | Diabetes | Dyslipidemia | Current smoking | Obesity |
|---|---|---|---|---|---|
| SDOH Quartiles | Model 1 | | | | |
| Quartile 1 | Reference | Reference | Reference | Reference | Reference |
| Quartile 2 | 1.11 (0.96–1.28) | 1.52 (1.21–1.90)* | 1.03 (0.89–1.18) | 1.64 (1.31–2.06)* | 1.27 (1.09–1.47)* |
| Quartile 3 | 1.36 (1.17–1.57)* | 1.97 (1.59–2.43)* | 1.17 (1.02–1.35)* | 2.23 (1.79–2.77)* | 1.53 (1.32–1.77)* |
| Quartile 4 | 1.31 (1.13–1.51)* | 2.40 (1.96–2.96)* | 1.19 (1.04–1.37)* | 2.66 (2.15–3.29)* | 1.57 (1.36–1.81)* |
| | Model 2 | | | | |
| Quartile 1 | Reference | Reference | Reference | Reference | Reference |
| Quartile 2 | 1.06 (0.91–1.23) | 1.42 (1.12–1.77)* | 1.00 (0.87–1.16) | 1.57 (1.25–1.98)* | 1.16 (0.99–1.35) |
| Quartile 3 | 1.27 (1.09–1.48)* | 1.59 (1.28–1.98)* | 1.11 (0.96–1.28) | 2.16 (1.73–2.70)* | 1.35 (1.16–1.57)* |
| Quartile 4 | 1.22 (1.04–1.42)* | 1.74 (1.39–2.16)* | 1.06 (0.91–1.23) | 2.67 (2.13–3.34)* | 1.28 (1.09–1.50)* |
| | Model 3 | | | | |
| Quartile 1 | Reference | Reference | Reference | Reference | Reference |
| Quartile 2 | 1.01 (0.87–1.18) | 1.36 (1.08–1.72)* | 0.98 (0.85–1.13) | 1.59 (1.27–2.01)* | 1.16 (0.99–1.36) |
| Quartile 3 | 1.22 (1.04–1.42)* | 1.49 (1.19–1.87)* | 1.05 (0.91–1.21) | 2.19 (1.75–2.74)* | 1.31 (1.12–1.53)* |
| Quartile 4 | 1.17 (0.99–1.38) | 1.65 (1.32–2.06)* | 1.00 (0.86–1.17) | 2.68 (2.13–3.37)* | 1.25 (1.06–1.47)* |

Results presented as odds ratios from logistic regression models with 95% CIs.
Model 1: Adjusted for age and sex.
Model 2: Adjusted for model 1 and race or ethnicity.
Model 3: Adjusted for model 2 plus cardiovascular risk factors.
SDOH indicates social determinant of health.
*Statistically significant.

the odds of high hs-CRP with increasing SDOH quartiles. Participants in quartiles 2, 3, and 4 had 1.0 fold (OR, 1.03 [95% CI, 0.89–1.21]), 1.2 fold (OR, 1.18 [95 CI=1.02–1.37]) and 1.4 fold (OR=1.35 [95 CI=1.15–1.58]) odds of high hs-CRP, respectively, relative to those in quartile 1. Upon adjustment for cardiovascular risk factors and preventive medication use, these associations were fully attenuated. We found similar patterns in analyses stratified by race and ethnicity, although these were not statistically significantly, probably because of lack of statistical power (Table S4). In analyses stratified by sex, we found similar patterns for men and women and found no major difference between the 2 groups except a relatively stronger effect of SDOH–quartile 4 for men versus women (*P* for interaction=0.01). (Table S5).

**Table 3. Baseline Associations Between SDOH Quartiles and Cardiovascular Risk Factor Profile**

| SDOH quartiles | Model 1 | Model 2 |
|---|---|---|
| **Average cardiovascular risk profile (vs optimal)** | | |
| Quartile 1 | Reference | Reference |
| Quartile 2 | 1.21 (1.05–1.40)* | 1.15 (1.00–1.33) |
| Quartile 3 | 1.60 (1.39–1.85)* | 1.42 (1.23–1.65)* |
| Quartile 4 | 1.72 (1.49–1.99)* | 1.38 (1.19–1.61)* |
| Poor cardiovascular risk profile (vs optimal) | | |
| Quartile 1 | Reference | Reference |
| Quartile 2 | 2.00 (1.40–2.85)* | 1.81 (1.27–2.58)* |
| Quartile 3 | 3.73 (2.69–5.18)* | 2.97 (2.13–4.15)* |
| Quartile 4 | 3.84 (2.77–5.33)* | 2.57 (1.82–3.62)* |

Results presented as relative prevalence ratios from multinomial regression models with 95% CIs. An optimal cardiovascular risk profile was set as reference.
Model 1: Adjusted for age and sex.
Model 2: Adjusted for age, sex, and race or ethnicity.
SDOH indicates social determinant of health.
*Statistically significant.

## SDOHs and CVD Events

Age-adjusted CVD event rates by SDOH quartiles are shown in Figure 3. Overall, event rates were higher for all CVD than for hard CVD events and for men compared with women. The highest event rate (21.3 per 1000 person-years) was recorded for CVD all among men in SDOH–quartile 4, while the lowest event rate (5.0 per 1000 person-years) was recorded among women in SDOH–quartile 1. While we saw a general pattern of increasing CVD event rates with increasing SDOH quartiles, there were variations between some quartiles. Specifically, the highest rates in men were observed in SDOH–quartile 4, while for women the highest rates were those for SDOH–quartile 3.

In Cox regression analyses, the hazard of all CVD events increased with higher SDOH quartiles (Table 5). In the model adjusted for age and sex, individuals in SDOH–quartile 4 had 1.5-fold (hazard ratio [HR], 1.47 [95% CI, 1.22–1.77]) the hazard of all CVD compared with those in quartile 1. Further adjustment for race and ethnicity (model 2) slightly attenuated these

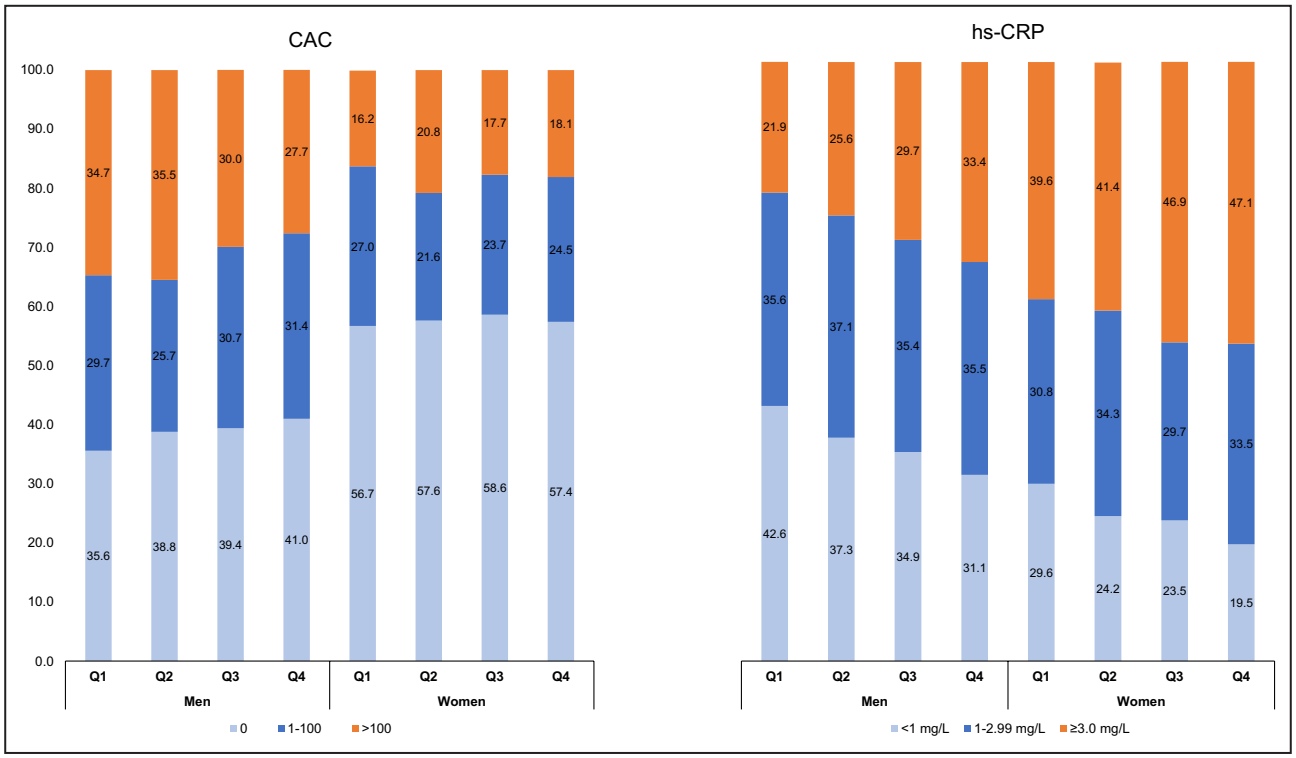


**Figure 2. Age-adjusted distribution (%) of CAC scores (left) and hs-CRP levels (right) across SDOH quartiles, stratified by sex.**
CAC indicates coronary artery calcium; hs-CRP, high sensitivity C-reactive protein; Q, quartile; and SDOH, social determinant of health.

associations, although remained statistically significant for quartiles 3 and 4. Individuals in SDOH–quartile 4 had 1.5-fold (HR, 1.46 [95% CI, 1.20–1.78]). Upon further adjustment for cardiovascular risk factors as well as preventive medication use (model 3), the associations were further attenuated and remained significant for quartiles 3 and 4.

Similar associations in terms of point estimates were noted for CVD hard events. However, the 95% CIs were wider and included the null value in model 3. In analyses stratified by race and ethnicity, we found similar patterns for all groups (Table S6).

## DISCUSSION

In this community-based study of a multiethnic cohort of US adults free of clinical CVD at baseline, we found that increasing social disadvantage was independently associated with higher odds of hypertension, diabetes, smoking, and obesity but not dyslipidemia; and with a worse cardiovascular risk profile. Social disadvantage was also associated with higher odds of high levels of systemic inflammation but not with a higher burden of subclinical coronary atherosclerosis. Furthermore, increasing social disadvantage was associated with a higher risk of all CVD events during follow-up in analyses adjusted for sociodemographic characteristics—an association that was partly mediated by a higher burden of cardiovascular risk factors. To our knowledge, this is the first study to assess the association between cumulative social disadvantage and multiple aspects of CVD, including (1) cardiovascular risk factors, (2) cardiovascular risk profile, (3) systemic inflammation, (4) subclinical coronary plaque, and (5) incident CVD events during follow-up.

Prior studies exploring the association between SDOH measures such as socioeconomic status (SES) and cardiovascular risk factors also found similar associations. For instance, in a study by Winkleby et al[19] evaluating the association between SES (assessed using education, income, and occupation) and cardiovascular risk factors among >2000 adults aged 25 to 64 years, lower educational attainment was associated with higher prevalence of smoking, higher systolic and diastolic blood pressure, higher total cholesterol, and lower high-density lipoprotein cholesterol. Low income was associated with increased prevalence of smoking and low high-density lipoprotein cholesterol, whereas having an unskilled job was associated with a higher prevalence of smoking.

Beyond SES, other social factors such as neighborhood disadvantage and poor social cohesion have been associated with increased risk of hypertension and diabetes.[20–24] Our study complements

**Table 4. Baseline Associations Between SDOH Quartiles, Subclinical Coronary Disease (CAC>100 vs CAC≤100) and Systemic Inflammation (hs-CRP>3.0 vs ≤3.0 mg/L)**

| | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| CAC >100 (vs CAC ≤100) | | | |
| Quartile 1 | Reference | Reference | Reference |
| Quartile 2 | 1.04 (0.87–1.24) | 1.07 (0.89–1.28) | 1.04 (0.86–1.26) |
| Quartile 3 | 0.87 (0.73–1.03) | 0.98 (0.82–1.17) | 0.90 (0.74–1.08) |
| Quartile 4 | 0.84 (0.70–1.00) | 1.01 (0.83–1.22) | 0.90 (0.73–1.09) |
| hs-CRP ≥3.00 mg/L (vs ≤3.0 mg/L) | | | |
| Quartile 1 | Reference | Reference | Reference |
| Quartile 2 | 1.14 (0.98–1.33) | 1.03 (0.89–1.21) | 0.96 (0.81–1.13) |
| Quartile 3 | 1.29 (1.12–1.49)* | 1.18 (1.02–1.37)* | 1.04 (0.89–1.23) |
| Quartile 4 | 1.59 (1.37–1.84)* | 1.35 (1.15–1.58)* | 1.16 (0.98–1.37) |

Results presented as odds ratios from logistic regression models with 95% CIs.

Model 1: Adjusted for age and sex.

Model 2: Adjusted for model 1 and race or ethnicity.

Model 3: Adjusted for model 2 + cardiovascular risk factors (hypertension, diabetes, dyslipidemia, smoking, and obesity) and statin and aspirin use.

CAC indicates coronary artery calcium; hs-CRP, high sensitivity C-reactive protein; and SDOH, social determinant of health.

*Statistically significant.

**Table 5. Longitudinal Associations Between SDOH Quartiles and Incident Atherosclerotic CVD Events During Follow-Up**

| | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| CVD all | | | |
| Quartile 1 | Reference | Reference | Reference |
| Quartile 2 | 1.06 (0.87–1.29) | 1.06 (0.87–1.29) | 1.01 (0.83–1.24) |
| Quartile 3 | 1.42 (1.18–1.70)* | 1.42 (1.18–1.70)* | 1.28 (1.06–1.54)* |
| Quartile 4 | 1.47 (1.22–1.77)* | 1.46 (1.20–1.78)* | 1.36 (1.11–1.66)* |
| CVD hard | | | |
| Quartile 1 | Reference | Reference | Reference |
| Quartile 2 | 1.00 (0.79–1.26) | 0.96 (0.76–1.22) | 0.94 (0.74–1.19) |
| Quartile 3 | 1.46 (1.18–1.80)* | 1.40 (1.13–1.73)* | 1.24 (0.99–1.55) |
| Quartile 4 | 1.50 (1.21–1.87)* | 1.39 (1.10–1.75)* | 1.27 (1.00–1.61) |

Results presented as hazard ratios from Cox regression models with 95% CIs.

Model 1: Adjusted for age and sex.

Model 2: Adjusted for model 1 and race or ethnicity.

Model 3: Adjusted for model 2 + cardiovascular risk factors (hypertension, diabetes, dyslipidemia, smoking, and obesity), statin and aspirin use.

CVD indicates cardiovascular disease; and SDOH, social determinants of health.

*Statistically significant.

the current literature using an aggregate measure of SDOH disadvantage combining 5 domains and 14 items. In our study, increasing social disadvantage was associated with higher odds of hypertension, diabetes, smoking, and obesity. While a large body of evidence suggests that differences in health behaviors account for some of the social gradient in health,[25] these behaviors are affected by social circumstances. The socially disadvantaged face several barriers to achieving optimal cardiovascular health. Additionally, social disadvantage may be associated with factors such as lower health literacy, which in turn may limit an individual's understanding and use of resources for primordial and primary prevention such as improved diet and exercise and tobacco cessation.[26] They also face barriers to equitable living and often face adverse work conditions, which have implications for cardiovascular health.[25]

In our study, we observed a consistent increase in the age-adjusted prevalence of all cardiovascular risk factors with increasing SDOH quartiles for women but not for men. In the latter, while there was a uniform increase in the age-adjusted prevalence of diabetes and smoking, this was not the case with hypertension, dyslipidemia, and obesity. Among men, the relatively low prevalence of obesity for SDOH–quartile 4 relative to quartile 3 may be attributable to the relatively high burden of smoking in SDOH–quartile 4, as nicotine is a known metabolic stimulant and appetite suppressant.[27] Additionally, previous studies have shown that the differences in obesity prevalence by social gradient are higher for women than for men.[28]

While CVD mortality has declined over the past few decades, largely because of the identification and control of cardiovascular risk factors and enhanced screening, this decline has halted over recent years, especially among the socially disadvantaged.[2] These factors may be attributable to disparities in risk factor control that continue to exist. For instance, while smoking prevalence has reduced in the general population, previous studies have shown that large disparities in this risk factor continue to exist.[29] In our study, smoking was the risk factor most strongly associated with the most unfavorable SDOH. Furthermore, while risk factors such as diabetes and hypertension may involve the use of medications, control of behavioral risk factors such as smoking may be difficult to achieve. Disparities in tobacco use, and variability in smoking cessation,[30] may be influenced by unequal distribution of resources, power, and services that are aimed at tobacco prevention.[31] Unfavorable social circumstances such as living in low-income communities is associated with a higher density of tobacco retail points and point-of-sale advertising, less exposure to meaningful information about the harms of smoking, and a lower likelihood of adopting smoke-free laws.[31]

Although prior studies have found associations between social disadvantage and inflammatory markers such as hs-CRP,[32,33] the association between SDOHs and CAC has been inconsistent.[34–36] In a study of 1067 participants free of clinically overt coronary artery disease, Djekic et al[37] found that lower area-level SES was associated with higher CAC burden. A similar association between lower education and higher CAC was

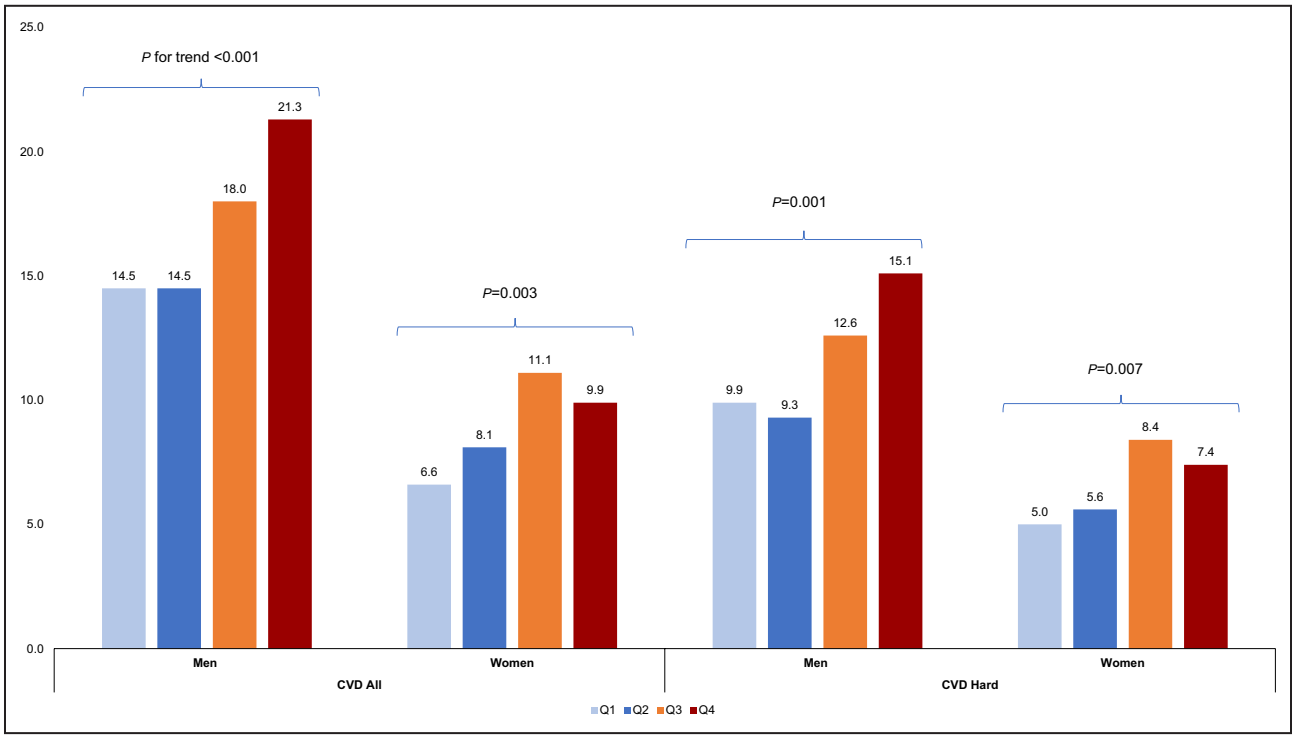


**Figure 3. Age-adjusted incidence rates (per 1000 person-years) of all and hard CVD events across SDOH quartiles, stratified by sex.**
CVD indicates cardiovascular disease; Q, quartile; and SDOH, social determinant of health.

also found, although these associations lost statistical significance after adjusting for cardiovascular risk factors. Interestingly, while Redondo-Bravo et al[38] found an association between education and subclinical atherosclerosis (defined as the presence of any atherosclerotic plaque in the carotid, aortic, or iliofemoral territories or having a CAC≥1), they found no such association for income. In another study by Diez-Roux et al,[34] the authors found a 17% higher probability of CAC >0 among non-Hispanic White adults with no high school diploma (compared with participants with at least a college degree) and a lower probability of CAC among Hispanic adults with no high school diploma. Furthermore, while low income was associated with higher probability of CAC >0 among non-Hispanic Black adults, this was not the case for other racial and ethnic groups. We did not find an association between SDOHs and CAC either. However, consistent with findings from Diez-Roux et al, we found lower odds of CAC >100 among Hispanic adults in SDOH–quartile 4, whereas this association was null for other racial and ethnic groups. The findings of a null association between SDOHs and CAC may be the consequence of the exclusion of participants with established CVD symptoms. This may have resulted in the selection of individuals relatively cardiovascular-healthier in the more disadvantaged SDOH strata. In addition, the results from our multivariable regression models suggest significant confounding by race and ethnicity in the analysis presented in Figure 2. Specifically, non-Hispanic White individuals tend to have a higher burden of CAC,[39] and the proportion of non-Hispanic White individuals decreased sharply the higher the SDOH quartile. The relatively smaller proportion of non-Hispanic White individuals in the most disadvantaged SDOH group is consistent with prior literature and speaks to the adverse social circumstances that some racial and ethnic minorities, especially Black and Hispanic adults, continue to face in the United States. Black and Hispanic individuals are less likely to have access to education and employment and tend to have lower family income on average. Additionally, they are more likely to live in deprived neighborhoods and face discrimination.[40]

Our findings of the association between social disadvantage and high hs-CRP are consistent with findings from Fraga et al, where the authors found an association between low SES and high hs-CRP, even after adjusting for confounders and potential mediators.[33] In a study by Ranjit et al[41] using MESA, the authors found a positive association between psychosocial factors (eg, cynical distrust, depression, and chronic stress) and markers of inflammation (interleukin-6, C-reactive protein, and fibrinogen). It has been suggested that the association between social disadvantage and inflammation may be explained by behavioral factors such

as smoking, heavy drinking, and physical inactivity.[33] This is consistent with our study, where we found a higher prevalence of smoking among the socially disadvantaged. Additionally, chronic inflammation is associated with periodontal disease, a phenomenon that is highly prevalent among the socially disadvantaged and may also contribute to this SDOH–inflammation association.[42–44] Our findings of higher prevalence of high hs-CRP among women is consistent with previous studies that have shown higher C-reactive protein levels compared with men,[45,46] a phenomenon that has been attributed to higher levels of subcutaneous fat among women.

We also found a positive association between cumulative social disadvantage and all CVD events. This is consistent with a recent study by Khan et al,[47] in which they found an association between social disadvantage (assessed using the social vulnerability index) and premature CVD mortality. In our study, adjusting for cardiovascular risk factors attenuated this association (model 3), suggesting that the increased risk of CVD events is mediated through the higher prevalence of cardiovascular risk factors with worse SDOH profile. In our analyses for hard CVD events, the point estimates were overall consistent with the results for all CVD events.

Our findings reinforce the need to address health disparities and improve cardiovascular health among the socially disadvantaged, with a dual focus on upstream SDOH factors and on CVD risk factors as key drivers of the excess CVD risk observed in those with the most adverse SDOH. First, primordial targeted efforts aimed at preventing the onset of traditional cardiovascular risk factors in the general population, but particularly in the most socially vulnerable. These should include a wide range of interventions, from structural and economic (ie, improving access to good schools), to expanding Medicaid to make health care more accessible, to policies facilitating the access to affordable healthy foods and regulating the currently aggressive advertising of unhealthy foods and cigarettes to racial and ethnic minorities. These must be coupled with interventions such as behavioral counseling or mass media campaigns for lower salt intake and smoking cessation.[48,49] Greater stakeholder partnerships, including health care, the food industry, and community organizations are also critical in mitigating these disparities. Second, a more aggressive screening of cardiovascular risk factors should be pursued in those more disadvantaged, and access to affordable treatment options should be facilitated once risk factors are detected. Finally, at the individual patient level, integrating SDOH assessment into existing clinical delivery support systems can help assess social risk, and this information could be used to seek support from relevant resources to ensure optimal care of those most vulnerable.

## Study Limitations

Because of the nature of our study population, our study is most applicable to urban Americans and may not apply to individuals in rural America or those outside the United States. Second, while our SDOH aggregate index contained variables from 5 different domains identified by the Healthy People 2030 SDOH model and 14 items, our group has been able to develop SDOH aggregate indices of up to 38 items using data from studies with a more extensive SDOH assessment such as the National Health Interview Survey.[7] Also, in the present 14-item index, the community and social context domain included the largest number of items. We attempted to correct this by weighting each domain equally. While this assumes equal weights of these domains, this may not be the case, and domains may exert differential impacts on cardiovascular health and outcomes.

Third, although CVD events were adjudicated, the SDOH variables were self-reported and therefore are subject to recall and social desirability bias. Also, SDOHs, which were assessed at MESA baseline, may have changed with time. Nevertheless, most of our findings were consistent with previous studies.

Fourth, although we adjusted for aspirin and statin users at baseline for some of our analyses to minimize confounding and avoid paradoxical trends in CVD events, our study did not account for interim use of these medications during follow-up. This phenomenon may have resulted in lower CVD event rates in some subgroups.

# CONCLUSIONS

Increasing social disadvantage is associated with cardiovascular risk factors, inflammation, and all CVD events despite no significant association with subclinical atherosclerosis. These findings call for strategies to alleviate the pervasive burden of adverse SDOHs on society's most disadvantaged subgroups to achieve more equitable cardiovascular outcomes. Greater screening of SDOHs in routine clinical practice and strong stakeholder partnerships are critical to ascertaining the true burden of SDOH and connecting socially vulnerable populations with the resources needed to mitigate observed inequities.

## ARTICLE INFORMATION

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## Disclosures

None.

## Supplemental Material

Tables S1–S6
Figure S1
References 13,14,50–52

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# SUPPLEMENTAL MATERIAL

**Table S1. Itemized questionnaire for social determinants of health domains in MESA.**

| Short version of items | Long version of items | Survey Responses | Analytic recode* |
|---|---|---|---|
| **ECONOMIC STABILITY** | | | |
| Employment | Current occupation? | Homemaker; Employed, full time; Employed, part time; Employed, on leave (health reasons); Employed, on leave (non-health reasons); Unemployed, <6 months; Unemployed, >6 months; Retired, not working; Retired, working; Retired, volunteering | 0 = "Employed, Retired or Homemaker"; 1 = "Never or Previously Employed" |
| Family Income | Gross family income, past 12 months | <$5,000; $5,000-$7,999; $8,000-$11,999; $12,000-$15,999; 16000-19999; 20000-24,999; 25000-29999; 30000-34999; 35000-39999; 40000-49999; 50000-74999; 75000-99999; 100000+ | 0 = "≥$50,000" 1 = "<$50,000 |
| House Tenure | Residence-Own or rent | Rent; Pay a mortgage; Own free and clear; Other No | 0 = "Pay a mortgage/Own free and clear"; 1 = "Rent/other" |
| Financial strain | Ongoing financial strain | Yes; No | 0 = "No"; 1 = "Yes" |
| **EDUCATION** | | | |
| Education | Education: Highest level completed | No schooling; Grades 1-8; Grades 9-11; Completed high school/GED; Some college but no degree; Technical School certificate; Associate degree; Bachelor's degree; Graduate or professional school | 0 = "≥Some college" 1 = "≤High school" |
| **COMMUNITY AND SOCIAL CONTEXT** | | | |
| Marital status | Marital status | Married/Living as married; Widowed; Divorced; Separated; Never married; Prefer not to answer | 0= "Living as married" 1= "Never married/Widowed/Divorced/Separated/ Widowed" |

| | | | |
|---|---|---|---|
| Social Support. Measured by the Emotional Social Support Index (From the following 5 items) [50] | | | From the aggregate sum of the following 9 items, divided into tertiles: 0 “High emotional/social support” = tertile 0-1; 1= “Low emotional/social support” (tertile 2) |
| Social support (Listen) | Someone available to listen to you | None of the time; A little of the time; Some of the time; Most of the time; All of the time | 1=“None of the time”; 2=“A little of the time”; 3=“Some of the time”; 4=“Most of the time”; 5=“All of the time” |
| Social support (Advice) | Someone available to give you advice | None of the time; A little of the time; Some of the time; Most of the time; All of the time | 1=“None of the time”; 2=“A little of the time”; 3=“Some of the time”; 4=“Most of the time”; 5=“All of the time” |
| Social support (Affection) | Someone available to show you love and affection | None of the time; A little of the time; Some of the time; Most of the time; All of the time | 1=“None of the time”; 2=“A little of the time”; 3=“Some of the time”; 4=“Most of the time”; 5=“All of the time” |
| Social support (Emotional support) | Someone available to provide emotional support | None of the time; A little of the time; Some of the time; Most of the time; All of the time | 1=“None of the time”; 2=“A little of the time”; 3=“Some of the time”; 4=“Most of the time”; 5=“All of the time” |
| Social support (Confide) | Sufficient contact with someone you can confide in | None of the time; A little of the time; Some of the time; Most of the time; All of the time | 1=“None of the time”; 2=“A little of the time”; 3=“Some of the time”; 4=“Most of the time”; 5=“All of the time” |
| Chronic Stress (Assessed using the chronic burden scale).[51,52] If participant answered “yes”, they were then asked how severe. Aggregate score of questions in which moderate to severe stress was reported. | | | 0 = “Low/Medium chronic stress” 1 = “High chronic stress” |
| Stress (Health problems, you) | Ongoing health problems (self), >6 months | Yes, No | 0 = "No"; 1 = "Yes" |
| Stress (Health problems, someone close) | Ongoing health problem (someone close to you), > 6 months | Yes, No | 0 = "No"; 1 = "Yes" |
| Stress (Job difficulties) | Ongoing job difficulties, > 6 months | Yes, No | 0 = "No"; 1 = "Yes" |

| | | | |
|---|---|---|---|
| Stress (Financial strain) | Ongoing financial strain, > 6 months | Yes, No | 0 = "No"; 1 = "Yes" |
| Stress (Relationship problems) | Ongoing relationship problems, > 6 months | Yes, No | 0 = "No"; 1 = "Yes" |
| | If “yes” to any of the above: How stressful? | Not very stressful; Moderately stressful; Very stressful | 1= “Not very stressful”; 2 = “Moderately stressful”; 3= “Very stressful” |
| Everyday Discrimination Composite Score (aggregate score from the following 9 questions):[53,54] | | | From the aggregate sum of the following 9 items, divided into tertiles: 0 = tertile 0-1; 1= tertile 2 |
| Discrimination (Courtesy) | Treated with less courtesy than others | Almost everyday; At least once a week; A few times a month; A few times a year; Less than once a year; Never | 1= “Almost everyday”; 2 =“At least once a week”; 3 = “A few times a month”; 4 = “A few times a year”; 5 = “Less than once a year”; 6 = “Never” |
| Discrimination (Respect) | Treated with less respect than others | Almost everyday; At least once a week; A few times a month; A few times a year; Less than once a year; Never | 1= “Almost everyday”; 2 =“At least once a week”; 3 = “A few times a month”; 4 = “A few times a year”; 5 = “Less than once a year”; 6 = “Never |
| Discrimination (Poor service) | Receive poorer services than others | Almost everyday; At least once a week; A few times a month; A few times a year; Less than once a year; Never | 1= “Almost everyday”; 2 =“At least once a week”; 3 = “A few times a month”; 4 = “A few times a year”; 5 = “Less than once a year”; 6 = “Never |
| Discrimination (Not smart) | People act as if you are not smart | Almost everyday; At least once a week; A few times a month; A few times a year; Less than once a year; Never | 1= “Almost everyday”; 2 =“At least once a week”; 3 = “A few times a month”; 4 = “A few times a year”; 5 = “Less than once a year”; 6 = “Never |
| Discrimination (Afraid) | People act as if they are afraid of you | Almost everyday; At least once a week; A few times a month; A few times a year; Less than once a year; Never | 1= “Almost everyday”; 2 =“At least once a week”; 3 = “A few times a month”; 4 = “A few times a year”; 5 = “Less than once a year”; 6 = “Never |
| Discrimination (Dishonest) | People act as if you are dishonest | Almost everyday; At least once a week; A few times a month; A few times a year; Less than once a year; Never | 1= “Almost everyday”; 2 =“At least once a week”; 3 = “A few times a month”; 4 = “A few times a year”; 5 = “Less than once a year”; 6 = “Never |
| Discrimination (Better) | People act as if they are better than you | Almost everyday; At least once a week; A few times a month; A few times a year; Less than once a year; Never | 1= “Almost everyday”; 2 =“At least once a week”; 3 = “A few times a month”; 4 = “A few times a year”; 5 = “Less than once a year”; 6 = “Never |

| | | | |
|---|---|---|---|
| Discrimination (Insult) | You are called names or insulted | Almost everyday; At least once a week; A few times a month; A few times a year; Less than once a year; Never | 1= “Almost everyday”; 2 =“At least once a week”; 3 = “A few times a month”; 4 = “A few times a year”; 5 = “Less than once a year”; 6 = “Never |
| Discrimination (Harassed) | You are threatened or harassed | Almost everyday; At least once a week; A few times a month; A few times a year; Less than once a year; Never | 1= “Almost everyday”; 2 =“At least once a week”; 3 = “A few times a month”; 4 = “A few times a year”; 5 = “Less than once a year”; 6 = “Never |
| Neighborhood Cohesion Composite Score (aggregate score from the following 5 questions): | | | From the aggregate sum of the following 5 items, divided into tertiles: 0 = tertile 1-2; 1= tertile 3 |
| Neighborhood cohesion (close knit) | Close-knit neighborhood | Strongly agree; Agree; Neither agree nor disagree; Disagree; Strongly disagree | 1=“Strongly agree”; 2=“Agree”;3= “Neither agree nor disagree”; 4= “Disagree”; 5= “Strongly disagree” |
| Neighborhood cohesion (help) | People willing to help their neighbors | Strongly agree; Agree; Neither agree nor disagree; Disagree; Strongly disagree | 1=“Strongly agree”; 2=“Agree”;3= “Neither agree nor disagree”; 4= “Disagree”; 5= “Strongly disagree” |
| Neighborhood cohesion (Get along) | People in neighborhood don’t get along | Strongly agree; Agree; Neither agree nor disagree; Disagree; Strongly disagree | 1=“Strongly agree”; 2=“Agree”;3= “Neither agree nor disagree”; 4= “Disagree”; 5= “Strongly disagree” |
| Neighborhood cohesion (Trust) | People in neighborhood can be trusted | Strongly agree; Agree; Neither agree nor disagree; Disagree; Strongly disagree | 1=“Strongly agree”; 2=“Agree”;3= “Neither agree nor disagree”; 4= “Disagree”; 5= “Strongly disagree” |
| Neighborhood cohesion (Values) | People in neighborhood do not share the same values | Strongly agree; Agree; Neither agree nor disagree; Disagree; Strongly disagree | 1=“Strongly agree”; 2=“Agree”;3= “Neither agree nor disagree”; 4= “Disagree”; 5= “Strongly disagree” |
| **NEIGHBORHOOD AND PHYSICAL ENVIRONMENT** | | | |
| Neighborhood problem (Aggregate score of the following 7 items) | | | From the aggregate sum of the following 7 items, 0 = “<10”; 1= “≥10” |
| Neighborhood problem (Violence) | Violence problem in neighborhood | Very serious problem; Somewhat serious problem; Minor problem; Not really a problem | 1 = “Not really a problem” 2 = “Minor problem”; 3 = “Somewhat a serious problem” 3 = “Very serious problem” |

| | | | |
|---|---|---|---|
| Neighborhood problem (Sidewalks) | Poor sidewalks in neighborhood | Very serious problem; Somewhat serious problem; Minor problem; Not really a problem | 1 = “Not really a problem” 2 = “Minor problem”; 3 = “Somewhat a serious problem” 3 = “Very serious problem” |
| Neighborhood problem (Trash) | Trash problems in neighborhood | Very serious problem; Somewhat serious problem; Minor problem; Not really a problem | 1 = “Not really a problem” 2 = “Minor problem”; 3 = “Somewhat a serious problem” 3 = “Very serious problem” |
| Neighborhood problem (Parks) | Lack of parks/playgrounds in neighborhood | Very serious problem; Somewhat serious problem; Minor problem; Not really a problem | 1 = “Not really a problem” 2 = “Minor problem”; 3 = “Somewhat a serious problem” 3 = “Very serious problem” |
| Neighborhood problem (Shopping) | Lack of adequate food shopping in neighborhood | Very serious problem; Somewhat serious problem; Minor problem; Not really a problem | 1 = “Not really a problem” 2 = “Minor problem”; 3 = “Somewhat a serious problem” 3 = “Very serious problem” |
| Neighborhood problem (Traffic) | Heavy traffic or speeding cars in neighborhood | Very serious problem; Somewhat serious problem; Minor problem; Not really a problem | 1 = “Not really a problem” 2 = “Minor problem”; 3 = “Somewhat a serious problem” 3 = “Very serious problem” |
| Neighborhood problem (Noise) | Excessive noise in neighborhood | Very serious problem; Somewhat serious problem; Minor problem; Not really a problem | 1 = “Not really a problem” 2 = “Minor problem”; 3 = “Somewhat a serious problem” 3 = “Very serious problem” |
| Neighborhood safety | How safe is your neighborhood from crime? | Very safe; somewhat safe; safe; Somewhat unsafe; Not at all safe | 0= “Very/somewhat safe/ safe”; 1= “Somewhat unsafe/Not at all safe” |
| **HEALTHCARE** | | | |
| Usual source of care | Where do you go for medical care | Doctor’s office/clinic; Hospital or emergency room; other | 0= “Doctor’s office/clinic”; 1=Hospital/emergency room, other |

| | | | |
|---|---|---|---|
| Health insurance | No health insurance | Yes; No | 0 = "No"; 1 = "Yes" |

*variables coded “1” considered adverse SDOH responses

**Table S2. Prevalence of individual adverse SDOH measures.**

| Individual Variables | Number (%) |
|---|---|
| **Economic Stability** | |
| Unemployed | 149 (2.3) |
| Low income | 3,725 (57.6) |
| Rent/Other | 2,116 (32.7) |
| Ongoing financial strain | 1,587 (24.5) |
| **Education** | |
| ≤High school degree | 2,293 (35.4) |
| **Community and Social Context** | |
| Not married | 2,533 (39.1) |
| Low emotional/social support | 1,631 (25.2) |
| Chronic stress | 1,539 (23.8) |
| High everyday discrimination | 1,933 (30.0) |
| Low social cohesion | 1,622 (25.1) |
| **Neighborhood and Built Environment** | |
| High neighborhood problems | 3,288 (50.8) |
| Unsafe neighborhood | 1,008 (15.6) |
| **Healthcare Access and Quality** | |
| Receive care from emergency room | 444 (6.9) |
| Uninsured | 563 (8.7) |

**Table S3. Association between SDOH quartiles and cardiovascular risk factors stratified by race/ethnicity.**

| | Hypertension | Diabetes | Dyslipidemia | Current smoking | Obesity |
|---|---|---|---|---|---|
| **Non-Hispanic White** | | | | | |
| **SDOH Quartiles** | | | ***OR (95% CI)*** | | |
| | | | **Model 1** | | |
| 1st Quartile | Reference | Reference | Reference | Reference | Reference |
| 2nd Quartile | 0.93 (0.76, 1.14) | 1.23 (0.82, 1.85) | 0.97 (0.79, 1.18) | 1.34 (0.97, 1.86) | 1.19 (0.95, 1.49) |
| 3rd Quartile | 1.24 (0.99, 1.56) | 1.69 (1.11, 2.57)* | 1.26 (1.01, 1.58)* | 1.72 (1.23, 2.42)* | 1.65 (1.31, 2.09)* |
| 4th Quartile | 1.53 (1.16, 2.02)* | 1.99 (1.24, 3.17)* | 1.36 (1.04, 1.77)* | 2.82 (1.95, 4.09)* | 1.87 (1.41, 2.47)* |
| | | | **Model 2** | | |
| 1st Quartile | Reference | Reference | Reference | Reference | Reference |
| 2nd Quartile | 0.88 (0.71, 1.09) | 1.17 (0.77, 1.77) | 0.95 (0.77, 1.16) | 1.36 (0.98, 1.90) | 1.25 (0.99, 1.58) |
| 3rd Quartile | 1.14 (0.90, 1.45) | 1.51 (0.98, 2.32) | 1.16 (0.92, 1.46) | 1.81 (1.28, 2.55)* | 1.58 (1.23, 2.02)* |
| 4th Quartile | 1.41 (1.05, 1.89)* | 1.65 (1.01, 2.67)* | 1.20 (0.91, 1.59) | 2.91 (1.99, 4.25)* | 1.74 (1.30, 2.34)* |
| **Non-Hispanic Black** | | | | | |
| | | | **Model 1** | | |
| 1st Quartile | Reference | Reference | Reference | Reference | Reference |
| 2nd Quartile | 1.26 (0.92, 1.71) | 1.38 (0.95, 1.99) | 1.18 (0.90, 1.56) | 1.61 (1.07, 2.42) | 1.24 (0.94, 1.64) |
| 3rd Quartile | 1.37 (1.01, 1.86)* | 1.60 (1.13, 2.26) | 1.18 (0.90, 1.54) | 2.36 (1.61, 3.45) | 1.32 (1.01, 1.72) |
| 4th Quartile | 1.37 (1.01, 1.86)* | 1.61 (1.13, 2.28) | 0.95 (0.73, 1.24) | 2.82 (1.94, 4.11) | 1.39 (1.06, 1.82) |
| | | | **Model 2** | | |
| 1st Quartile | Reference | Reference | Reference | Reference | Reference |
| 2nd Quartile | 1.19 (0.87, 1.64) | 1.30 (0.89, 1.89) | 1.14 (0.86, 1.51) | 1.66 (1.10, 2.50)* | 1.20 (0.90, 1.61) |
| 3rd Quartile | 1.30 (0.95, 1.78) | 1.47 (1.03, 2.11)* | 1.11 (0.85, 1.46) | 2.36 (1.60, 3.46)* | 1.29 (0.98, 1.71) |
| 4th Quartile | 1.26 (0.92, 1.73) | 1.47 (1.02, 2.11)* | 0.90 (0.69, 1.18) | 2.90 (1.98, 4.25)* | 1.47 (1.11, 1.95)* |

**Hispanic**

| | | | | | |
|---|---|---|---|---|---|
| | | | **Model 1** | | |
| 1st Quartile | Reference | Reference | Reference | Reference | Reference |
| 2nd Quartile | 1.19 (0.75, 1.89) | 1.99 (1.03, 3.87)* | 1.11 (0.70, 1.77) | 2.45 (1.11, 5.40)* | 0.87 (0.56, 1.36) |
| 3rd Quartile | 1.50 (0.98, 2.30) | 2.17 (1.17, 4.02)* | 0.88 (0.58, 1.34) | 3.19 (1.51, 6.75)* | 0.94 (0.63, 1.42) |
| 4th Quartile | 1.24 (0.83, 1.84) | 2.59 (1.44, 4.69)* | 1.03 (0.69, 1.54) | 3.18 (1.55, 6.55)* | 0.80 (0.55, 1.18) |
| | | | **Model 2** | | |
| 1st Quartile | Reference | Reference | Reference | Reference | Reference |
| 2nd Quartile | 1.18 (0.74, 1.89) | 1.98 (1.01, 3.89)* | 1.07 (0.67, 1.71) | 2.51 (1.14, 5.55)* | 0.81 (0.52, 1.28) |
| 3rd Quartile | 1.52 (0.98, 2.34) | 2.13 (1.14, 3.99)* | 0.84 (0.54, 1.28) | 3.31 (1.56, 7.04)* | 0.86 (0.56, 1.30) |
| 4th Quartile | 1.25 (0.83, 1.88) | 2.63 (1.44, 4.82)* | 0.97 (0.64, 1.45) | 3.17 (1.53, 6.56)* | 0.71 (0.48, 1.05) |

**Asian American**

| | | | | | |
|---|---|---|---|---|---|
| | | | **Model 1** | | |
| 1st Quartile | Reference | Reference | Reference | Reference | Reference |
| 2nd Quartile | 1.29 (0.84, 1.98) | 1.76 (1.00, 3.11) | 0.72 (0.48, 1.08) | 2.24 (0.91, 5.49) | 1.09 (0.65, 1.84) |
| 3rd Quartile | 1.01 (0.67, 1.51) | 1.24 (0.71, 2.18) | 0.94 (0.63, 1.38) | 3.00 (1.23, 7.33)* | 0.98 (0.59, 1.63) |
| 4th Quartile | 0.80 (0.52, 1.23) | 1.14 (0.60, 2.17) | 0.82 (0.55, 1.25) | 3.86 (1.64, 9.08)* | 0.77 (0.43, 1.36) |
| | | | **Model 2** | | |
| 1st Quartile | Reference | Reference | Reference | Reference | Reference |
| 2nd Quartile | 1.26 (0.81, 1.95) | 1.77 (0.99, 3.17) | 0.66 (0.44, 1.00) | 2.29 (0.92, 5.69) | 1.10 (0.64, 1.89) |
| 3rd Quartile | 1.01 (0.67, 1.53) | 1.22 (0.69, 2.16) | 0.90 (0.60, 1.33) | 3.03 (1.23, 7.46)* | 1.02 (0.61, 1.72) |
| 4th Quartile | 0.84 (0.54, 1.30) | 1.17 (0.61, 2.26) | 0.84 (0.55, 1.28) | 4.08 (1.70, 9.79)* | 0.74 (0.40, 1.37) |

*Statistically significant

Model 1: Adjusted for age and sex

Model 2: Adjusted for other cardiovascular risk factors

**Table S4. Associations between SDOH quartiles, subclinical coronary disease (CAC >100 vs. CAC ≤100) and systemic inflammation (hs-CRP >3.0 mg/L vs. ≤3.0 mg/L), stratified by race/ethnicity.**

| | CAC >100 | | hs-CRP >3.00 mg/L | |
|---|---|---|---|---|
| | Model 1 | Model 2 | Model 1 | Model 2 |
| | OR (95% CI) | | OR (95% CI) | |
| **Non-Hispanic White** | | | | |
| SDOH Quartiles | | | | |
| 1st Quartile | Reference | Reference | Reference | Reference |
| 2nd Quartile | 1.13 (0.88, 1.45) | 1.10 (0.84, 1.42) | 0.94 (0.76, 1.17) | 0.84 (0.67, 1.06) |
| 3rd Quartile | 1.06 (0.81, 1.38) | 0.96 (0.73, 1.28) | 1.09 (0.87, 1.37) | 0.97 (0.76, 1.24) |
| 4th Quartile | 1.42 (1.03, 1.95) | 1.16 (0.82, 1.63) | 1.57 (1.20, 2.06) | 1.14 (0.84, 1.54) |
| **Non-Hispanic Black** | | | | |
| 1st Quartile | Reference | Reference | Reference | Reference |
| 2nd Quartile | 1.02 (0.69, 1.50) | 1.02 (0.68, 1.53) | 1.04 (0.78, 1.38) | 1.00 (0.73, 1.36) |
| 3rd Quartile | 1.08 (0.75, 1.54) | 0.98 (0.67, 1.43) | 1.37 (1.04, 1.79) | 1.21 (0.91, 1.62) |
| 4th Quartile | 1.39 (0.97, 2.00) | 1.23 (0.84, 1.81) | 1.47 (1.12, 1.93) | 1.29 (0.96, 1.74) |
| **Hispanic** | | | | |
| 1st Quartile | Reference | Reference | Reference | Reference |
| 2nd Quartile | 0.94 (0.55, 1.61) | 0.84 (0.47, 1.48) | 1.39 (0.88, 2.18) | 1.37 (0.84, 2.22) |
| 3rd Quartile | 0.68 (0.42, 1.11) | 0.55 (0.33, 0.93) | 1.22 (0.81, 1.85) | 1.15 (0.74, 1.80) |
| 4th Quartile | 0.47 (0.29, 0.76) | 0.40 (0.24, 0.67) | 1.26 (0.85, 1.88) | 1.24 (0.81, 1.90) |
| **Asian American** | | | | |
| 1st Quartile | Reference | Reference | Reference | Reference |
| 2nd Quartile | 0.96 (0.57, 1.63) | 0.95 (0.55, 1.64) | 1.07 (0.58, 1.99) | 1.03 (0.54, 1.97) |
| 3rd Quartile | 0.78 (0.48, 1.26) | 0.81 (0.50, 1.33) | 0.96 (0.55, 1.68) | 0.87 (0.49, 1.55) |
| 4th Quartile | 0.74 (0.41, 1.31) | 0.76 (0.41, 1.40) | 1.11 (0.60, 2.04) | 1.15 (0.61, 2.17) |

*Statistically significant

Model 1: Adjusted for age and sex

Model 2: Adjusted for Model 1 + cardiovascular risk factors

**Table S5. Associations between SDOH quartiles, subclinical coronary disease (CAC >100 vs. CAC ≤100) and systemic inflammation (hs-CRP >3.0 mg/L vs. ≤3.0 mg/L), stratified by sex.**

| | CAC >100 | | | | hsCRP ≥3.00 mg/L | | | |
|---|---|---|---|---|---|---|---|---|
| | Model 1 | Model 2 | Model 3 | | Model 1 | Model 2 | Model 3 | |
| | OR (95% CI) | | | | OR (95% CI) | | | |
| **Men** | | | | | | | | |
| SDOH Aggregate Quartiles | | | | p for interaction | | | | p for interaction |
| 1st Quartile | Reference | Reference | Reference | | Reference | Reference | Reference | |
| 2nd Quartile | 0.99 (0.80, 1.23) | 1.03 (0.83, 1.29) | 1.01 (0.88, 1.27) | 0.87 | 1.19 (0.95, 1.48) | 1.09 (0.87, 1.37) | 1.03 (0.81, 1.31) | 0.01 |
| 3rd Quartile | 0.77 (0.62, 0.97) | 0.90 (0.71, 1.13) | 0.87 (0.68, 1.12) | | 1.22 (0.97, 1.53) | 1.05 (0.83, 1.33) | 0.95 (0.74, 1.22) | |
| 4th Quartile | 0.77 (0.61, 0.97) | 0.96 (0.74, 1.24) | 0.91 (0.69, 1.18) | | 1.90 (1.52, 2.37)* | 1.52 (1.20, 1.93)* | 1.41 (1.09, 1.82)* | |
| **Women** | | | | | | | | |
| 1st Quartile | Reference | Reference | Reference | | Reference | Reference | Reference | |
| 2nd Quartile | 1.16 (0.85, 1.58) | 1.18 (0.86, 1.61) | 1.14 (0.82, 1.57) | | 1.09 (0.89, 1.34) | 0.99 (0.80, 1.22) | 0.87 (0.69, 1.09) | |
| 3rd Quartile | 1.01 (0.76, 1.33) | 1.11 (0.84, 1.48) | 0.95 (0.70, 1.28) | | 1.32 (1.09, 1.60) | 1.27 (1.03, 1.55) | 1.06 (0.85, 1.32) | |
| 4th Quartile | 0.96 (0.71, 1.28) | 1.13 (0.83, 1.53) | 0.93 (0.67, 1.28) | | 1.43 (1.17, 1.73)* | 1.26 (1.02, 1.56)* | 1.02 (0.82, 1.27) | |

*Statistically significant

Model 1: Adjusted for age and race/ethnicity

Model 2: Adjusted for Model 1 + cardiovascular risk factors

**Table S6. Association between SDOH quartiles and incident CVD events stratified by race/ethnicity.**

| | CVD All | | CVD Hard | |
|---|---|---|---|---|
| | Model 1 | Model 2 | Model 1 | Model 2 |
| | HR (95% CI) | | HR (95% CI) | |
| **Non-Hispanic White** | | | | |
| **SDOH Aggregate Quartiles** | | | | |
| 1st | Reference | Reference | Reference | Reference |
| 2nd | 1.17 (0.90, 1.54) | 1.10 (0.83, 1.46) | 0.99 (0.64, 1.55) | 0.95 (0.60, 1.50) |
| 3rd | 1.53 (1.16, 2.01) | 1.34 (1.00, 1.79) | 1.25 (0.80, 1.97) | 1.20 (0.76, 1.89) |
| 4th | 1.70 (1.23, 2.35) | 1.42 (1.01, 2.01) | 1.65 (0.99, 2.77) | 1.43 (0.84, 2.43) |
| **Non-Hispanic Black** | | | | |
| 1st | Reference | Reference | Reference | Reference |
| 2nd | 0.95 (0.64, 1.42) | 0.92 (0.61, 1.39) | 0.50 (0.14, 1.77) | 0.41 (0.11, 1.47) |
| 3rd | 1.31 (0.93, 1.87) | 1.14 (0.79, 1.64) | 1.79 (0.81, 3.96) | 1.56 (0.69, 3.52) |
| 4th | 1.51 (1.06, 2.15) | 1.37 (0.95, 1.98) | 1.59 (0.63, 3.96) | 1.34 (0.53, 3.38) |
| **Hispanic** | | | | |
| 1st | Reference | Reference | Reference | Reference |
| 2nd | 0.81 (0.46, 1.42) | 0.86 (0.48, 1.56) | 0.65 (0.37, 1.15) | 0.58 (0.33, 1.03) |
| 3rd | 1.13 (0.70, 1.82) | 1.05 (0.63, 1.76) | 1.06 (0.66, 1.70) | 0.87 (0.53, 1.40) |
| 4th | 1.11 (0.70, 1.77) | 1.13 (0.68, 1.88) | 1.17 (0.72, 1.90) | 0.93 (0.57, 1.53) |
| **Asian American** | | | | |
| 1st | Reference | Reference | Reference | Reference |
| 2nd | 0.88 (0.47, 1.65) | 0.80 (0.42, 1.50) | 0.60 (0.27, 1.28) | 0.50 (0.23, 1.10) |
| 3rd | 1.20 (0.71, 2.01) | 1.17 (0.70, 1.97) | 0.91 (0.48, 1.73) | 0.76 (0.40, 1.45) |
| 4th | 0.76 (0.38, 1.52) | 0.77 (0.38, 1.56) | 0.83 (0.45, 1.55) | 0.68 (0.36, 1.28) |

*Statistically significant

Model 1: Adjusted for age and sex

Model 2: Adjusted for Model 1 + cardiovascular risk factors

**Figure S1. Distribution of weighted SDOH score.**