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Association between social determinants of health and premature atherosclerotic cardiovascular disease and sex differences in US adults: A cross-sectional study

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ABSTRACT

Background: Premature atherosclerotic cardiovascular disease (ASCVD) is a major public health issue, leading to productivity losses and higher healthcare costs. This study examines the association between social determinants of health (SDoH) and premature ASCVD, with a focus on sex differences.

Method: Data on self-reported SDoH based on Healthy People 2030 criteria were obtained from U.S. National Health and Nutrition Examination Surveys (2003–2018). Weighted logistic regression models were used to examine the relationship between SDoH (including eight sub-items and the cumulative number of unfavorable SDoH) and premature ASCVD. Analyses were further stratified by sex.

Result: A total of 40,536 participants aged ≥18 years (19,548 men and 20,888 women) were included in the analysis. The overall prevalence of premature ASCVD was 1756 cases, with a weighted estimate of 7,625,240. Although women had a lower prevalence of premature ASCVD (3.2 % [n = 784] vs. 4.3 % [n = 972]), they exhibited a higher level of unfavorable SDoH compared to men. Logistic regression indicated a 21 % increase in risk for each additional unfavorable SDoH (AOR = 1.21; 95 % CI, 1.16–1.26), and the cumulative number of unfavorable SDoH were positively associated with the odds of developing premature ASCVD (P for trend <0.01). Notably, the impact of unfavorable SDoH was greater in women, revealing significant sex disparities in susceptibility to premature ASCVD.

Conclusion: This study demonstrates that unfavorable SDoH significantly increase the risk of developing premature ASCVD. Furthermore, the cumulative effect of unfavorable SDoH pose a higher risk for women.

1. Introduction

Atherosclerotic cardiovascular disease (ASCVD) is a leading cause of morbidity and mortality worldwide, affecting more than 500 million people and causing 19 million deaths annually (Global incidence, prevalence, years lived with disability (YLDs), disability-adjusted life-years (DALYs), and healthy life expectancy (HALE) for 371 diseases and injuries in 204 countries and territories and 811 subnational locations, 1990–2021, 2024). Over the past 20 years, the incidence and mortality rates of ASCVD have declined globally and in many countries (Benjamin et al., 2018; Chen et al., 2023). However, this positive trend has not been consistent across all populations. Specifically, the decline in cardiovascular events among young and middle-aged adults has been less significant or, in some cases, stagnant (Benjamin et al., 2018; Gupta et al., 2014; Wilmot et al., 2015). Premature ASCVD among young adults presents an increasingly serious challenge (Chen et al., 2023).

Premature ASCVD in young adults is a growing public health issue, as it leads to lifelong productivity loss and greater healthcare costs. While most efforts to address ASCVD have traditionally targeted all age groups (Kontis et al., 2014), younger adults—particularly in terms of sex differences—require more focused attention (Lee et al., 2021). Research suggests that young women, in particular, may be less aware of their cardiovascular risk factors and are less likely to discuss preventive measures with healthcare providers (Vikulova et al., 2019; Singh et al.,

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2018). This highlights the need for sex-specific strategies in managing premature ASCVD.

In addition to traditional risk factors, health disparities are increasingly understood through the lens of social determinants of health (SDoH) (Huang et al., 2024; Wang et al., 2023; Mossadeghi et al., 2023), particularly in relation to premature disease and death (Bundy et al., 2023). A large multi-cohort study involving over 1.7 million individuals found that lower socioeconomic status significantly raises the risk of all-cause and cancer mortality (Bundy et al., 2023). In the U.S., factors such as lower educational attainment, poverty, and lack of health insurance contribute to widening mortality disparities across demographic groups (Chetty et al., 2016; Pappas et al., 1993; Luo et al., 2022). However, the impact of SDoH on premature ASCVD, and how these factors may differ between men and women, remains underexplored. This points to the need for further research to better understand the intersection of SDoH, sex, and premature ASCVD.

The aim of this study is to assess the relationship between multiple SDoH and premature ASCVD, and to explore the sex differences within these relationships. We hypothesize that the cumulative burden of adverse SDoH differs by sex and that a higher accumulation of SDoH were associated with a greater risk of premature ASCVD.

2. Method

2.1. Study population

The National Health and Nutrition Examination Survey (NHANES) is a series of cross-sectional, national surveys designed to assess the health and nutritional status of the civilian, noninstitutionalized US population. Detailed information on the study design, data collection protocols, and publicly available datasets can be accessed online (http://www.cdc.gov/nchs/nhanes.htm). This study utilizes data from 2007 to 2018. All study protocols were approved by the institutional review board of the National Center for Health Statistics, and participants provided written informed consent. This study included 40,536 participants age >/= 18 after excluding participants who lacked data on their number of premature ASCVD and SDoH.

2.2. Baseline characteristics

Participants completed a home interview and visited a mobile screening center for additional questionnaires, a physical examination, and blood sample collection. The home interview gathered information on personal medical history, including medication use for conditions like diabetes and hypertension. Smoking was defined as having smoked at least 100 cigarettes in one's lifetime and still smoking, while alcohol use was defined as consuming at least 12 alcoholic drinks in the past year.

2.3. SDoH assessment

To explore the impact of SDoH on premature ASCVD, we selected eight SDoH variables based on prior studies (Bundy et al., 2023). These variables, as defined by Healthy People 2030 (U.S. Department of Health and Human Services, 2000) and the World Health Organization (Marmot et al., 2008), include employment status, household poverty-to-income ratio, food security, education level, access to healthcare, health insurance type, homeownership, and marital status. More detailed descriptions of these variables are available in the **eTable 1**.

We calculated the cumulative number of unfavorable SDoH for each participant, ranging from 0 (no unfavorable SDoH) to 6 or more (≥6 unfavorable SDoH). Due to the small number of participants with 6, 7, or 8 unfavorable SDoH, these were grouped into a single category of "6 or more" to represent the most disadvantaged group.

2.4. Definition of premature ASCVD

Participants were asked if a doctor or health professional had ever diagnosed them with coronary heart disease, angina, heart attack, or stroke during the home interview. Those who answered "yes" were classified as having a history of ASCVD. Individuals who experienced an ASCVD event at age 55 or younger were included in the premature ASCVD cohort (Lee et al., 2021).

2.5. Statistical analysis

The weights applied in this study were based on the NHANES recommended methodology to adjust for the oversampling of specific demographic groups. The weight for each observation was calculated using the wtint2yr variable, which is a variable provided by NHANES for the 2-year sample interval. Specifically, the weight for each observation was adjusted by multiplying the inverse of 8 (1/8) to account for the sampling design. The continuous variables were expressed as the mean ± SE, and the categorical variables were presented as counts (percentages). Baseline characteristics between each group were compared using a *t*-test for continuous variables and an $\chi 2$ test for categorical variables.

To assess the relationship between SDoH and premature ASCVD, we performed multivariable logistic regression across three models. Model 1 was unadjusted (crude model). Model 2 adjusted for demographic factors, including age, sex, and race/ethnicity. Model 3 further included traditional cardiovascular risk factors such as BMI, smoking status, alcohol consumption, hypertension, chronic kidney disease (CKD), diabetes mellitus (DM), and hyperlipidemia. This progression allowed us to evaluate how each set of covariates influenced the association between SDoH and premature ASCVD. For each model, we calculated odds ratios (OR) with 95 % confidence intervals (CI) to quantify these associations. We also explored the relationship between individual SDoH components—such as employment, poverty-to-income ratio, and healthcare access—and premature ASCVD. To generalize the results to the national level, we used survey weights to estimate the prevalence of premature ASCVD across different SDoH categories. Additionally, we stratified these analyses by sex to assess potential sex differences in both the distribution of SDoH and their association with premature ASCVD. Interaction terms were included in the regression models to formally test for sex-specific differences in the effect of SDoH on ASCVD risk. Finally, we employed the Restricted Cubic Spline method to explore the nonlinear relationship between SDoH and premature ASCVD. To assess the robustness of our findings, we performed a sensitivity analysis by excluding individuals who developed ASCVD after the age of 55. In this analysis, the reference group consisted of those who did not develop ASCVD, while individuals with premature ASCVD (before age 55) were the primary group of interest.

All statistical analyses were conducted using R software (version 4.3.1; R Foundation for Statistical Computing, Vienna, Austria), utilizing the "survey" package to account for NHANES' complex design. Statistical significance was determined by two-sided *P*-values, with $P < 0.05$ considered significant across all analyses.

3. Result

This study involved 40,536 participants aged ≥18 years, including 20,888 women and 19,548 men (Table 1). In this study, men were younger than women, with a mean age of 46.6 years compared to 47.9 years. Among women, the proportion of Non-Hispanic Black participants was higher than among men (12.0 % [$n = 4490$] vs 10.3 % [$n = 4143$]). Notably, although women had a higher prevalence of CKD (10.6 % [$n = 2496$] vs 9.4 % [$n = 2417$]), they had a lower prevalence of hypertension, DM, and premature ASCVD compared to men (3.2 % [$n = 784$] vs 4.3 % [$n = 972$]). However, women were more likely to be obese than men (mean BMI = 29.1 vs 28.8, $P < 0.01$). Additionally, compared to men, women had relatively higher economic stability (employment,

Table 1
Characteristics of U.S. Adults by Sex (2003–2018).

Variable	Total N Mean ± SE / N (%) *N* = 40,536	Women Mean ± SE / N (%) *N* = 20,888	Men Mean ± SE / N (%) *N* = 19,548	*P* value
Age, years	47.3 ± 0.2	47.9 ± 0.2	46.6 ± 0.2	< 0.01
BMI, kg/m^2	29.0 ± 0.1	29.1 ± 0.1	28.8 ± 0.1	< 0.01
Race				< 0.01
Mexican American	6311 (8.1)	3230 (7.4)	3081 (8.8)	
Non-Hispanic Black	8633 (11.2)	4490 (12.0)	4143 (10.3)	
Non-Hispanic White	17,962 (68.4)	9124 (68.2)	8838 (68.5)	
Other Hispanic	3411 (5.1)	1872 (5.1)	1539 (5.0)	
Other Race	4219 (7.3)	2172 (7.3)	2047 (7.3)	
Drink	29,735 (77.6)	14,100 (85.2)	15,635 (93.3)	< 0.01
Smoke				< 0.01
Never	22,138 (54.4)	13,316 (61.0)	8822 (47.3)	
Former	9954 (24.6)	3958 (20.5)	5996 (29.0)	
Now	8425 (21.0)	3604 (18.5)	4821 (23.7)	
Hypertension	21,311 (48.5)	10,231 (45.0)	11,080 (52.2)	< 0.01
Diabetes mellitus				< 0.01
Impaired glucose tolerance	1209 (2.8)	658 (3.0)	551 (2.5)	
Impaired fasting glucose	1658 (4.3)	643 (3.3)	1015 (5.4)	
Diabetes mellitus	7206 (13.3)	3505 (13.0)	3701 (14.0)	
Chronic kidney disease	4913 (9.2)	2496 (10.6)	2417 (9.4)	< 0.01
Hyperlipidemia	26,854 (65.8)	14,043 (68.5)	12,811 (67.5)	0.18
SDoH	2.3 ± 0.0	2.4 ± 0.0	2.3 ± 0.0	< 0.01
Cumulative SDoH variable				< 0.01
0	5440 (20.6)	2486 (18.6)	2954 (22.7)	
1	6684 (20.9)	3431 (21.4)	3253 (20.4)	
2	6449 (16.5)	3325 (17.1)	3124 (15.9)	
3	6254 (13.8)	3282 (14.2)	2972 (13.3)	
4	6081 (11.9)	3174 (12.1)	2907 (11.8)	
5	5093 (9.1)	2717 (9.3)	2376 (8.8)	
6 or more	4535 (7.2)	2473 (7.3)	2062 (7.1)	
Premature ASCVD	1756 (3.7)	784 (3.2)	972 (4.3)	< 0.01

BMI, Body mass index; SDoH, Social Determinants of Health; ASCVD, Atherosclerotic Cardiovascular Disease.
SDoH are factors that influence health outcomes, including employment status, household poverty-to-income ratio, food security, education level, access to healthcare, health insurance type, homeownership, and marital status, as defined by Healthy People 2030 and the World Health Organization. A cumulative score of unfavorable SDoH (ranging from 0 to 6 or more) was calculated for each participant, with 6 or more representing the most disadvantaged group. ASCVD refers to individuals who experienced an ASCVD event (such as coronary heart disease, angina, heart attack, or stroke) at age 55 or younger.
P-values were obtained using a t-test for continuous variables and a chi-square (χ^2) test for categorical variables to compare baseline characteristics between groups.

poverty to income ratio, food security), social and community context (marital status), and unfavorable SDoH risk (all $P < 0.01$; **eTable 2**). The study population was further categorized according to premature ASCVD status. **eTable 3** shows that patients with premature ASCVD were more likely to be older, have comorbidities, and experience poor individual or cumulative SDoH (all $P < 0.01$).

Overall, the prevalence of premature ASCVD was 1756 cases, with a weighted count of 7,625,240. Logistic regression analyses revealed a 21 % increase in the risk of developing premature ASCVD for each additional SDoH risk factor, after adjusting for all traditional risk factors (adjusted odds ratio [AOR] = 1.21; 95 % CI, 1.16–1.26; Table 2). Model 1 indicated that individuals with six or more unfavorable SDoH variables had a threefold increased risk of premature ASCVD (OR = 3.43, 95 % CI: 2.67–4.40). Models 2 and 3 further supported these findings, showing elevated risks of premature ASCVD among participants with three, four, five, and six or more unfavorable SDoH variables. In the total population, all models showed a trend of increasing OR for premature ASCVD risk as the number of cumulative unfavorable SDoH variables increased (all P for trend <0.01). In sensitivity analyses, after excluding individuals with ASCVD onset after age 55, results were consistent with previous findings (**eTable 4**). Furthermore, restricted cubic spline regression analysis did not suggest a nonlinear relationship between the odds of developing premature ASCVD and cumulative unfavorable SDoH variables (*P* for overall <0.01, P for nonlinearity = 0.07; Fig. 1).

Table 3 presents the associations between eight SDoH sub-items and the odds of developing premature ASCVD, using a multivariate logistic regression model. Several factors were significantly associated with increased odds of premature ASCVD, including economic instability (unemployment [AOR = 2.70, 95 % CI: 2.36–3.10]; family income-to-poverty ratio below 300 % [AOR = 1.53, 95 % CI: 1.29–1.80]; marginal to very low food security [AOR = 1.88, 95 % CI: 1.57–2.26]), education below high school level (AOR = 1.25, 95 % CI: 1.08–1.45), lack of health insurance (AOR = 1.82, 95 % CI: 1.56–2.12), and lack of home ownership (AOR = 1.32, 95 % CI: 1.15–1.51). In contrast, being unmarried or not living with a partner was not significantly associated with premature ASCVD risk, and lacking regular healthcare access was inversely associated with the odds of developing premature ASCVD (AOR = 0.79, 95 % CI: 0.63–0.99). The sensitivity analysis, excluding individuals with ASCVD onset after age 55, yielded similar results (**eTable 5**).

Further analyses revealed an increasing prevalence of premature ASCVD with rising cumulative unfavorable SDoH in both men and women (eFigure 1). After full adjustment, the effect of cumulative unfavorable SDoH on premature ASCVD was more pronounced in women than in men (women: AOR = 1.30, 95 % CI: 1.23–1.37; men: AOR = 1.16, 95 % CI: 1.10–1.23; P for interaction <0.01; Table 4). This difference was especially notable at the highest level of cumulative unfavorable SDoH (women: AOR = 6.75, 95 % CI: 4.40–10.35; men: AOR = 2.91, 95 % CI: 2.01–4.23; Fig. 2). The interaction between sex and cumulative SDoH persisted in the sensitivity analysis, excluding individuals with ASCVD onset after age 55 (**eTable 6**).

4. Discussion

Our study demonstrated a correlation between each individual SDoH, except for regular health care access and marital status, and the presence of Premature ASCVD. Additionally, we observed a cumulative effect, indicating that individuals with multiple unfavorable SDoH were more likely to develop Premature ASCVD. Furthermore, we identified a sex difference in the relationship between cumulative unfavorable SDoH and Premature ASCVD. Specifically, while women had a lower prevalence of Premature ASCVD compared to men, they faced a higher risk of unfavorable SDoH, which in turn, more significantly increased their likelihood of developing Premature ASCVD.

The risk of ASCVD in younger individuals is a significant public health issue. Several strategies for assessing ASCVD risk in young adults have been proposed, including long-term or lifetime CVD risk scores (Jaspers et al., 2020) and risk percentiles based on age and sex (Cesena et al., 2023), similar to those used in coronary artery calcification (CAC) screening. Additionally, the use of polygenic risk scores to further refine ASCVD risk stratification in young adults is promising and remains an area of active research. However, it is still unclear whether SDoH, as factors significant as traditional risk factors in young people, could be integrated into future risk assessment strategies. Research has shown that unfavorable SDoH are major cardiovascular risk factors and may present a risk for ASCVD that is equal to or greater than that of traditional risk factors (Havranek et al., 2015; Schultz et al., 2018). Similarly,

Table 2
Odds ratios for the association between unfavorable cumulative Social Determinants of Health and premature Atherosclerotic Cardiovascular Disease in U.S. Adults (2003–2018).

Variable	Event/ All population	Weight event/ Weight number	Model 1	Model 2	Model 3
			OR (95 % CI)		
SDoH (per 1 risk number)	1756/40,536	7,625,240/197,218,364	1.20 (1.16,1.24)	1.30 (1.26,1.35)	1.21 (1.16,1.26)
Cumulative SDoH variable					
0	132/5440	944,278/41,285,511	1.00	1.00	1.00
1	220/6684	1,446,469/41,379,592	1.53 (1.18,1.98)	1.52 (1.17,1.98)	1.43 (1.08,1.88)
2	221/6449	991,371/32,799,439	1.32 (1.01,1.74)	1.34 (1.02,1.77)	1.11 (0.83,1.49)
3	235/6254	900,096/27,296,915	1.44 (1.16,1.80)	1.67 (1.34,2.09)	1.45 (1.14,1.85)
4	277/6081	1,142,263/23,327,685	2.14 (1.65,2.77)	2.80 (2.14,3.64)	2.25 (1.69,3.01)
5	313/5093	1,125,754/17,422,970	2.83 (2.26,3.53)	4.08 (3.23,5.16)	3.03 (2.32,3.95)
6 or more	358/4535	1,075,010/13,706,251	3.43 (2.67,4.40)	5.45 (4.17,7.12)	3.33 (2.50,4.45)
P for trend			<0.01	<0.01	<0.01

Model 1: Not adjusted. Model 2: Adjusted for age, sex, and race. Model 3: Adjusted for age, sex, race, drinking status, smoking status, body mass index, hypertension, hyperlipidemia, diabetes mellitus, chronic kidney disease.
SDoH, Social Determinants of Health.
Premature Atherosclerotic Cardiovascular Disease refers to individuals who experienced an ASCVD event (such as coronary heart disease, angina, heart attack, or stroke) at age 55 or younger.
SDoH are factors that influence health outcomes, including employment status, household poverty-to-income ratio, food security, education level, access to healthcare, health insurance type, homeownership, and marital status, as defined by Healthy People 2030 and the World Health Organization. A cumulative score of unfavorable SDoH (ranging from 0 to 6 or more) was calculated for each participant, with 6 or more representing the most disadvantaged group.

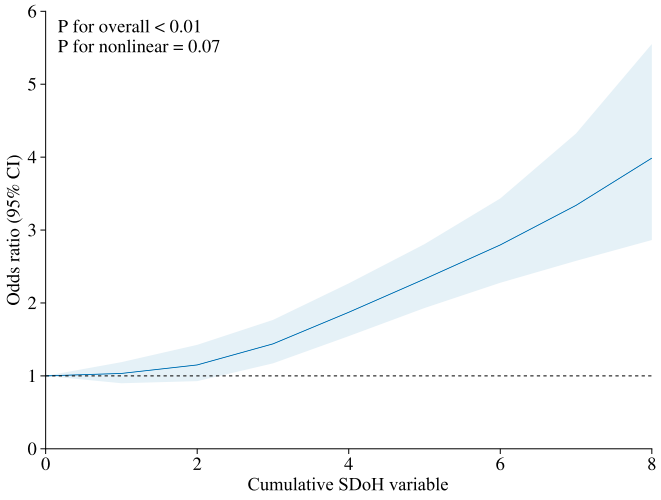

Fig. 1. Nonlinear Relationship Between Unfavorable Cumulative Social Determinants of Health and Premature Atherosclerotic Cardiovascular Disease in U.S. adults (2003–2018).

community-level SDoH have been linked to ASCVD risk (Powell-Wiley et al., 2022; Brandt et al., 2023; An et al., 2020; Sundquist et al., 1982; Topel et al., 2019). Our study confirms that individuals facing multiple unfavorable SDoH factors appear to be more vulnerable to Premature ASCVD. Although the inclusion of individual- and community-level SDoH in the ASCVD 10-year risk equation only modestly improved the ability to differentiate and calibrate risk for non-Hispanic Blacks (Xia et al., 2024), SDoH remain crucial for assessing Premature ASCVD risk, particularly given the rising prevalence of the disease in young adults. National public health policies are necessary to control and prevent Premature ASCVD, and such policies should likely incorporate SDoH at both the individual and regional levels.

One of the most important components of SDoH are economic stability, which includes factors like employment status, the PIR, and food security. Low socioeconomic status (SES) has been found to be a significant risk factor for the development of cardiovascular disease (CVD), comparable in importance to traditional risk factors (Schultz et al., 2018). For instance, each $10,000 increase in community median income is associated with a 10 % reduction in acute myocardial infarction (AMI) mortality.18533083 Job stability is another critical factor, with unemployment being linked to a higher CVD burden, regardless of SES. Studies have shown that the incidence of AMI increases within the first year of unemployment, and the cumulative number of job losses further elevates this risk (Dupre et al., 2012). Our study also found that poorer economic stability significantly raised the prevalence of Premature ASCVD. Differences in educational level represent another form of SDoH, influencing various health outcomes. Our study confirmed that lower educational attainment increased the prevalence of Premature ASCVD, possibly because education affects health literacy, cardiovascular risk factors, and future earning potential. It is well-established that cardiovascular health is heavily influenced by one's living environment. Poorer communities are strongly associated with chronic diseases, including coronary artery disease (CAD), stroke, diabetes, and hypertension, and our findings corroborate this (Lee et al., 1982). However, we did not observe that the Social and Community Context had an impact on Premature ASCVD, which may be due to our use of marital status as the sole indicator. This context includes multiple subdomains (Braveman and Parker Dominguez, 2021; Smedley and Smedley, 2005), such as the influence of race and sex on health, making it a complex area. Therefore, this conclusion should be interpreted cautiously. Interestingly, we found an inverse relationship between access to healthcare and health insurance on ASCVD prevalence, with poorer health insurance emerging as a risk factor. High healthcare costs deter individuals from seeking care, exacerbating income-based disparities in health outcomes (Cai et al., 2023). Additionally, rural residents often live far from healthcare centers, a situation worsened by the disproportionate closure of rural hospitals since 2010 (Romiopoulos et al., 2016), especially in states that have not expanded Medicaid coverage.

Previous studies have found that the association between individual and regional SDoH and ASCVD was generally similar for both men and women, with the exception that household income at the individual level was a stronger predictor of ASCVD risk in women than in men (Xia et al., 2024). Due to hormonal protection, the prevalence of premature ASCVD was lower in women. However, in our study, for women with higher cumulative SDoH risk, their ASCVD incidence was actually higher than that of men, effectively masking the protective effect of hormones. A 2017 meta-analysis of 44 studies involving over 22 million people found (Backholer et al., 2017) that while SDoH were associated with coronary heart disease (CHD) risk in both sexes, poor SDoH—including lower education, income, and higher area deprivation—was linked to significantly higher excess CHD risk in women compared to men. This meta-analysis supports our conclusions. Significant differences in the social structure of SDoH and environmental

Table 3
Odds ratios for the association between different components Social Determinants of Health and premature Atherosclerotic Cardiovascular Disease in US adult (2003–2018).

Variable	Event/ All population	Weight event/ Weight number	Model 1	Model 2	Model 3
			OR (95 % CI)		
Employment					
Employed, student, retired	919/30,328	4,410,086/160,551,577	1.00	1.00	1.00
Not employed	837/10,208	3,215,155/44,292,028	2.77 (2.44,3.14)	3.48 (3.05,3.97)	2.70 (2.36,3.10)
Family income to poverty ratio					
≥300 %	419/14,809	2,719,047/101,658,558	1.00	1.00	1.00
<300 %	1337/25,727	4,906,194/103,185,047	1.82 (1.57,2.10)	1.90 (1.64,2.21)	1.53 (1.29,1.80)
Food security					
Full security	996/28,590	4,951,590/159,168,430	1.00	1.00	1.00
Marginal, low, or very low security	760/11,946	2,673,650/45,675,175	1.94 (1.69,2.22)	2.60 (2.25,3.00)	1.88 (1.57,2.26)
Education level					
High school graduate or higher	1182/30,380	5,822,671/172,034,120	1.00	1.00	1.00
Less than high school	574/10,156	1,802,570/32,809,484	1.66 (1.46,1.88)	1.52 (1.31,1.76)	1.25 (1.08,1.45)
Regular health care access					
≥One regular health care facility	1570/32,968	6,833,394/168,977,757	1.00	1.00	1.00
None or emergency room	186/7568	791,847/35,865,848	0.54 (0.44,0.66)	0.72 (0.59,0.89)	0.79 (0.63,0.99)
Type of health insurance					
Private	647/21,283	3,501,943/128,880,973	1.00	1.00	1.00
Government or none	1109/19,253	4,123,298/75,962,631	2.05 (1.81,2.33)	2.09 (1.84,2.38)	1.82 (1.56,2.12)
Home ownership					
Own home	1028/25,000	4,991,919/138,608,638	1.00	1.00	1.00
Rent home or other arrangement	728/15,536	2,633,322/66,234,967	1.11 (0.99,1.24)	1.56 (1.38,1.76)	1.32 (1.15,1.51)
Marital status					
Married or living with a partner	975/24,100	4,643,970/129,894,384	1.00	1.00	1.00
Not married nor living with a partner	781/16,436	2,981,271/74,949,221	1.12 (0.98,1.28)	1.16 (1.01,1.34)	1.01 (0.86,1.19)

Model 1: Not adjusted. Model 2: Adjusted for age, sex, and race. Model 3: Adjusted for age, sex, race, drinking status, smoking status, body mass index, hypertension, hyperlipidemia, diabetes mellitus, chronic kidney disease.
Social Determinants of Health (SDoH) are factors that influence health outcomes, including employment status, household poverty-to-income ratio, food security, education level, access to healthcare, health insurance type, homeownership, and marital status, as defined by Healthy People 2030 and the World Health Organization. A cumulative score of unfavorable SDoH (ranging from 0 to 6 or more) was calculated for each participant, with 6 or more representing the most disadvantaged group.
Premature Atherosclerotic Cardiovascular Disease (ASCVD) refers to individuals who experienced an ASCVD event (such as coronary heart disease, angina, heart attack, or stroke) at age 55 or younger.

Table 4
Odds ratios for the association between cumulative unfavorable Social Determinants of Health and premature Atherosclerotic Cardiovascular Disease by sex in US adult (2003–2018).

Gender group	Model 1	Model 2	Model 3	*P* for interaction
	OR (95 % CI)			
Men	1.00	1.00	1.00	<0.01
Women	2.75 (2.43,3.12)	3.58 (3.14,4.09)	2.74 (2.38,3.15)	

Model 1: Not adjusted. Model 2: Adjusted for age and race. Model 3: Adjusted for age, race, drinking status, smoking status, body mass index, hypertension, hyperlipidemia, diabetes mellitus, chronic kidney disease.
Social Determinants of Health are factors that influence health outcomes, including employment status, household poverty-to-income ratio, food security, education level, access to healthcare, health insurance type, homeownership, and marital status, as defined by Healthy People 2030 and the World Health Organization. A cumulative score of unfavorable SDoH (ranging from 0 to 6 or more) was calculated for each participant, with 6 or more representing the most disadvantaged group.
Premature Atherosclerotic Cardiovascular Disease (ASCVD) refers to individuals who experienced an ASCVD event (such as coronary heart disease, angina, heart attack, or stroke) at age 55 or younger.

factors between men and women may explain this phenomenon. These structural differences suggest inherent sex disparities. Sex may be a complex socioeconomic and behavioral factor influencing premature cardiovascular outcomes. Additionally, women with ASCVD were more likely to report worse patient experiences, lower health-related quality of life, and poorer perceived health compared to men (Okunrintemi et al., 2018). In conclusion, sex remains a complex socioeconomic and behavioral factor influencing cardiovascular health outcomes.

This study has several important limitations. First, although we considered multiple covariates in our multivariate analysis to enhance validity, the observational nature of the study means it cannot fully account for all potential confounding factors. Second, several critical SDoH, such as living environment, regional economic level, and healthcare resources, were not measured and thus could not be included in the analysis. Third, the data on Premature ASCVD and SDoH were collected through self-reported questionnaires, which could introduce bias or error due to recall or reporting inaccuracies. To mitigate this, we performed sensitivity analyses excluding individuals who developed ASCVD after age 55, and the results remained robust. Lastly, the cross-sectional design of NHANES limits the ability to establish causality, so our findings are based on statistical associations rather than causal inferences. Therefore, future prospective studies are needed to determine the causal relationship between SDoH and Premature ASCVD risk, as well as to explore the underlying mechanisms.

5. Conclusion

This study demonstrates that unfavorable SDoH significantly increase the risk of developing Premature ASCVD, especially in individuals facing multiple unfavorable SDoH. Additionally, although women have a lower overall prevalence of Premature ASCVD compared to men, the cumulative effect of unfavorable SDoH results in a higher risk for women.

Ethics approval and consent to participate

The ethical approval of NHANES was granted by the US National Center for Health Statistics Research Ethics Review Board (Protocol No. 98-12, Protocol No. 2011-17, Continuation of Protocol No. 2011-17,

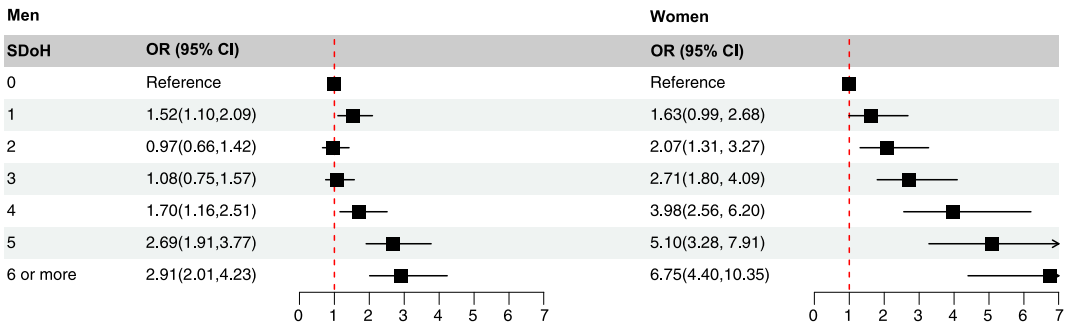

Fig. 2. Forest Plot of the Association Between Cumulative Unfavorable Social Determinants of Health and Premature Atherosclerotic Cardiovascular Disease by Sex in U.S. adults (2003–2018).

Protocol No. 2018-01).

Consent for publication

Not applicable.

Clinical trial number

Not applicable.

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CRediT authorship contribution statement

Chun Yang: Writing – review & editing, Supervision, Resources, Project administration, Funding acquisition, Conceptualization. **Na Zhang:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Software, Methodology, Formal analysis, Conceptualization. **Tiankuo Gao:** Writing – original draft, Visualization, Supervision, Conceptualization. **Yingxin Zhu:** Validation, Supervision, Conceptualization. **Chen Gong:** Supervision, Investigation, Conceptualization. **Mingyue Xu:** Supervision, Methodology, Conceptualization. **Cuicui Feng:** Supervision, Resources, Investigation, Data curation, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Chun Yang reports financial support was provided by National Natural Science Foundation of China. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2025.102967.

Data availability

All data are available as publicly accessible datasets through NHANES. It is open and publicly accessible through the following link; https://wwwn.cdc.gov/nchs/nhanes/index.htm.

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