Journal of the American Heart Association

ORIGINAL RESEARCH

Pathways From Socioeconomic Factors to Major Cardiovascular Events Among Postmenopausal Veteran and Nonveteran Women: Findings From the Women's Health Initiative

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BACKGROUND: Cardiovascular disease (CVD) remains a leading cause of death for women in the United States, with veterans being at potentially higher risk than their nonveteran counterparts due to accelerated aging and distinct biopsychosocial mechanisms. We examined pathways between selected indicators of socioeconomic status (SES) such as education, occupation, household income, and neighborhood SES and major CVD events through lifestyle and health characteristics among veteran and nonveteran postmenopausal women.

METHODS AND RESULTS: A total of 121 286 study-eligible WHI (Women's Health Initiative) participants (3091 veterans and 118 195 nonveterans) were prospectively followed for an average of 17 years, during which 16 108 major CVD events were documented. Using generalized structural equations modeling coupled with survival analysis techniques, we estimated the effects of SES on major CVD events through smoking, body mass index, comorbidities, cardiometabolic risk factors, and self-rated health, controlling for WHI component, region, age, race, ethnicity, marital status, and health care provider access. Among veterans, SES characteristics were indirectly related to major CVD events through body mass index, comorbidities, cardiometabolic risk factors, and self-rated health. Among nonveterans, lower education (β=0.2, P<0.0001), household income (β=+0.4, P<0.0001), and neighborhood SES (β=+0.2, P<0.0001) were positively related to major CVD events, and these relationships were partly mediated by body mass index, comorbidities, cardiometabolic risk factors, and self-rated health. Smoking played a mediating role only among nonveterans.

CONCLUSIONS: Nonveteran postmenopausal women exhibit more complex pathways between SES and major CVD events than their veteran counterparts, informing the design, conduct, and evaluation of preventive strategies targeting CVD by veteran status.

Key Words: cardiovascular disease ■ postmenopausal ■ socioeconomic status ■ veteran ■ women

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This article was sent to Monik C. Botero, SM, ScD, Associate Editor, for review by expert referees, editorial decision, and final disposition.

Supplemental Material is available at https://www.ahajournals.org/doi/suppl/10.1161/JAHA.124.037253

For Sources of Funding and Disclosures, see page 14.

JAHA is available at: www.ahajournals.org/journal/jaha

RESEARCH PERSPECTIVE

What Is New?

- This study followed >121 000 Women's Health Initiative participants for an average of 17 years, documenting >16 000 major cardiovascular disease (CVD) events. It examined the pathways between socioeconomic status and major CVD events among postmenopausal veteran and nonveteran women. The results suggest that socioeconomic status characteristics were associated with major CVD events only through body mass index, comorbidities, cardiometabolic risk factors, and self-rated health among veterans, whereas nonveterans showed more complex pathways linking education, household income, and neighborhood socioeconomic status to major CVD events.

What Question Should Be Addressed Next?

- Future research should be focused on the design, implementation, and evaluation of preventive strategies against major CVD events that are tailored to the needs of postmenopausal women by veteran status.

Nonstandard Abbreviations and Acronyms

GSEM	generalized structural equations modeling
HEI-2015	2015 Healthy Eating Index
NSES	Neighborhood socioeconomic status
VA	US Department of Veterans Affairs
WHI	Women's Health Initiative
WHI-CT	Women's Health Initiative Clinical Trial
WHI-OS	Women's Health Initiative Observational Study

Despite the decline in overall mortality rates, cardiovascular disease (CVD) remains the leading cause of death for women in the United States, claiming one life every minute and 19 seconds.[1–6] Based on 2015 to 2018 National Health and Nutrition Examination Survey data, women represented 48.1% of total CVD deaths in the United States, while men represented 51.9%.[7] Sex differences exist in physiological aspects and clinical presentations of CVD, and currently available risk stratification algorithms are less accurate for women, especially since women may exhibit atypical CVD risk factors, such as rheumatoid arthritis and depression, at a higher frequency than men.[6] Moreover, sex differences in CVD diagnosis and treatment are well-documented, with women undergoing fewer diagnostic tests and receiving less aggressive therapies.[5] Previous studies have also revealed sex disparities in CVD outcomes, with women experiencing more delayed care for emergent cardiac illnesses, higher in-hospital mortality following myocardial infarction, and less guideline-concordant care after stroke, as compared with men.[1]

More women are joining the US military than ever before, with the number of female veterans expected to exceed 2 million over the next few decades.[5] Research indicates that military service may have implications for increasing CVD, with military veterans exhibiting accelerated aging in the context of factors such as combat exposure, injury, and environmental contaminants.[3] Race and ethnicity represent fundamental social determinants of health that may underlie disparities in CVD mortality among veteran and nonveteran women. According to nationally representative data from the 2011 to 2014 American Community Survey, Black women represent 12.4% of the nonveteran population but compose 19.3% of veteran women in the United States, while, at the same time, other racial and ethnic groups are underrepresented among US veterans.[8] Socioeconomic status (SES), including income, education, occupation, as well as neighborhood socioeconomic characteristics as they relate to the built environment,[9–13] may also be important risk factors for CVD in the United States.[2,14–17] An intercorrelation between SES, psychosocial factors, and inflammation, potentially leading to the development of atherosclerosis and CVD, has been previously reported.[18] To date, few studies[19,20] have explored the putative role of SES in relation to CVD risk, while comparing veteran with nonveteran women in the United States. A better understanding of the biopsychosocial mechanisms underlying the relationships of SES indicators with CVD risks among veteran and nonveteran women is needed to inform public health interventions focused on risk/protective factors that are salient to women, in general, and women veterans, in particular.

To address this knowledge gap, we conducted a study using generalized structural equations modeling (GSEM) and survival analysis techniques with data from the WHI-CT (Women's Health Initiative Clinical Trial) and WHI-OS (Women's Health Initiative Observational Studies). First, we compared the risk of major CVD events among veteran and nonveteran postmenopausal women. Second, we examined the association of socioeconomic characteristics with risk of major CVD events by veteran status. Third, we constructed GSEM for lifestyle and health characteristics as mediators for relationships of socioeconomic characteristics with the risk of major CVD events by veteran status. We hypothesized that the risk of CVD events was higher among veteran women, that lower SES was associated with major CVD risk among veteran and nonveteran women, and that this relationship varied by veteran status and was partially mediated by lifestyle and health characteristics.

METHODS

Women's Health Initiative

The WHI (Women's Health Initiative) collected data on a sample of postmenopausal women, aged 50 to 79 years at baseline, who were recruited and enrolled between 1993 and 1998 at 40 geographically diverse clinical centers (24 states and the District of Columbia) in the United States. The WHI study design, eligibility criteria, recruitment methods, and measurement protocols are described elsewhere.[21–26] Briefly, WHI-CT (n=68 132) and WHI-OS (n=93 676) are 2 components of the WHI (n=161 808). Whereas the overlapping WHI-CT consisted of the Hormone Therapy Trials (n=27 347), the Calcium/Vitamin D Trial (n=36 282), and the Dietary Modification Trial (n=48 835), the WHI-OS evaluated causes of morbidity and mortality in postmenopausal women. The main WHI studies occurred between 1993 and 2005, and, of 150 076 participants who underwent active follow-up at the end of these studies, 76.9% participated in the Extension Study 1 (2005–2010) and 86.9% of those eligible participated in the Extension Study 2 (2010–2015).[27–32] Data collection protocols comprised self-administered questionnaires, in-person/telephone interviews, and clinical measurements that varied according to the WHI study component. All WHI participants completed the same assessments at their enrollment visit (1993–1998), covering demographics; general health; clinical and anthropometric characteristics; functional status; health care behaviors; reproductive, medical, and family history; personal habits; thoughts and feelings; therapeutic class of medication; and hormones, supplements, and dietary intake. Several of these characteristics were reassessed at follow-up. The WHI study received institutional review board approval with informed consent from all participating clinical centers, as well as the coordinating center's institutional review board and the National Institute of Health.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Design and Participants

We restricted our study population to WHI-CT and WHI-OS participants, with available data on veteran status, individual- and neighborhood-level socioeconomic characteristics, and demographic, lifestyle, and health characteristics, who had at least 12 months of follow-up until the first occurrence of a major cardiovascular event, censoring, or December 31, 2022, whichever came first. To avoid issues with reverse causality, WHI participants who experienced a major CVD event or were lost to follow-up within 12 months after enrollment were excluded from the study.

Measures

In addition to the WHI component (WHI-CT, WHI-OS), we identified demographic characteristics as potential confounders. Also, lifestyle and health characteristics were identified as potential confounders or mediators for hypothesized relationships. Further details are provided elsewhere.[33–35] An "unknown/not reported" category was created for race, ethnicity, occupation, and household income given the sensitive nature of these self-reported data and the expectation that a substantial proportion of women would fall into these categories.

Veteran Status

Veteran status was defined as a dichotomous variable based on a WHI participant's response to a self-reported questionnaire item ("Have you served in the US armed forces on active duty for a period of 180 days or more?") at enrollment (1993–1998). WHI participants responding affirmatively or negatively were classified as veterans (n=3719) or nonveterans (n=141 802), respectively. Those with missing data on veteran status (n=16 258) were excluded from the analytic sample.[25,26,36–44]

Demographic Characteristics

Several demographic characteristics collected at the enrollment visit (1993–1998) were evaluated as potential confounders of hypothesized relationships, including region of residence (Midwest, Northeast, South, West), age (in years), race (American Indian/Alaska Native, Asian, Native Hawaiian/other Pacific Islanders, Black, White, more than one race, unknown/not reported), ethnicity (Hispanic, non-Hispanic, unknown/not reported), and marital status (married/partnered, single, divorced, widowed).

Socioeconomic Characteristics

Individual-Level Socioeconomic Status

Three markers of individual-level socioeconomic status were examined at enrollment (1993–1998) and categorized by risk of major CVD event. These markers included education (less than high school, high school, some college, completed college or higher level), occupation (managerial/professional, technical/sales/administrative, service/labor, homemaker, other, not working/retired/disabled, unknown/not reported), and household income (<\$20 000, \$20 000–\$49 999, \$50 000–\$99 999, ≥\$100 000, unknown/not reported). High- and low-risk CVD groups were defined for education (less than a college degree versus a college degree or higher), occupation (unemployed [homemaker, not working, retired, disabled] versus other [managerial, professional, technical, sales, administrative, service, labor, other, unknown/not reported]) and income (<\$100 000 versus other [≥\$100 000, unknown/not reported]).

Neighborhood-Level Socioeconomic Status

The neighborhood SES (NSES) index is a composite measure of 6 census tract–level variables generated using confirmatory factor analysis from 12 theoretically relevant measures, including (1) percentage of adults older than 25 years with less than a high school education, (2) percentage of male unemployment, (3) percentage of households with income levels below the poverty line, (4) percentage of households receiving public assistance, (5) percentage of female-headed households with children, and (6) median household income.[23,45] These 6 census tract–level variables were generated using a standardized geocoding protocol whereby WHI participant addresses were linked to the 2000 Census Federal Information Processing Standards codes and census tract–level socioeconomic data.[23,46,47] Specifically, the NSES index was assigned to WHI participants based on their tract of residence at enrollment (1993–1998).[46] The NSES index values range between 0 and 100, with higher scores representing higher neighborhood-level SES.[45,48,49] After examining NSES as a continuous variable with and without polynomial terms and applying restricted natural splines as a flexible tool, we found a significant nonlinear relationship between NSES and major CVD events (Table S1). As such, NSES was alternatively defined in tertiles (first tertile [<75], second tertile [75 to <80], third tertile [≥80]), or as a dichotomized (low NSES [<80] versus other [≥80]) variable taking sample size and major CVD risk into account.

Lifestyle Characteristics

Several lifestyle characteristics collected at the enrollment visit (1993–1998) were evaluated as potential confounders or mediators of the hypothesized relationships, including smoking status (never smoker, past smoker, current smoker), alcohol consumption (nondrinker, former drinker, <1 drink per week, ≥1 drink per week), the 2015 Healthy Eating Index (HEI-2015),[50–52] and physical activity (metabolic equivalent-hours per week) scores. Using a WHI-specific scoring algorithm, the HEI-2015 total score was calculated as the sum of 13 component scores ranging between 0 and 100 from food frequency questionnaire data collected closest to an expected annual visit between 1993 and 2005, with higher HEI-2015 scores indicating closer conformance to the 2015 dietary guidance for Americans.[53]

Health Characteristics

Several health characteristics collected at the enrollment visit (1993–1998) were evaluated as potential confounders or mediators of the hypothesized relationships, including body mass index (BMI), comorbid conditions, cardiometabolic risk factors, self-rated health (excellent/very good/good, fair/poor), depressive symptoms, and current health care provider (yes, no). Trained staff collected anthropometric data, including weight (in kilograms) and height (in centimeters) at enrollment.[54] BMI was calculated as (weight in kilograms divided by height in meters squared) and further categorized as <25.0 kg/m^2 (underweight/normal weight); 25.0 to 29.9 kg/m^2 (overweight); and ≥30 kg/m^2 (obese). The number of comorbid conditions (0, 1 or 2, or 3+) was assessed based on self-report of physician-diagnosed hypertension, coronary artery disease, diabetes, congestive heath failure, stroke/transient ischemic attack, osteoporosis, Alzheimer disease, asthma, emphysema, or cancer, as previously described by WHI investigators.[45] Alternatively, the presence of cardiometabolic risk factors (obesity, hypertension, diabetes, dyslipidemia, CVD) was also examined using self-reported and physical examination data. History of CVD was defined in terms of previous coronary heart disease, angina, aortic aneurysm, carotid endarterectomy or angioplasty, atrial fibrillation, congestive heart failure, cardiac arrest, stroke, or transient ischemic attack. History of hypertension was defined as self-reported diagnosis of or treatment for hypertension or evidence of high blood pressure based on systolic and diastolic blood pressure measurements. History of diabetes was defined as physician-diagnosed diabetes or use of diabetes medications. History of hyperlipidemia was defined as using lipid-lowering medications or having been told of high cholesterol by a physician. A depressive symptoms screening algorithm developed using the 20-item Center for Epidemiological Studies Depression scale and National Institute of Mental Health's Diagnostic Interview Schedule, was adopted with scores ranging from 0 to 1 and a preestablished threshold of 0.06 consistent with greater burden of depressive symptoms.[25,55–58] The presence of a current health care provider at enrollment (1993–1998) was evaluated based on the following questionnaire item: "Do you have a clinic, doctor, nurse, or physician assistant who gives you your usual medical care?"

Major Cardiovascular Events

The outcome variable of interest was the time until first occurrence of a major cardiovascular event between enrollment (1993–1998) and December 31, 2022. Data sources for this outcome variable consisted of self-report, clinical record–adjudicated outcomes, and the National Death Index. Consistent with the 3-point definition,[59] a major CVD event was defined as a fatal or nonfatal myocardial infarction (clinical or silent), stroke (ischemic or hemorrhagic), in addition to specific underlying causes of "cardiovascular" death, namely, "possible coronary heart disease," "other cardiovascular," and "unknown cardiovascular" causes of death. This standard definition excludes cardiovascular morbidities not linked to myocardial infarction or stroke, as well as cardiovascular morbidity and mortality specifically linked to cardiovascular procedures.

Statistical Analysis

All statistical analyses were conducted using SAS version 9.4 (SAS Institute Inc) and Stata version 18 (StataCorp). Descriptive statistics are displayed as measures of central tendency and dispersion for continuous variables and frequencies with percentages for categorical variables. Bivariate associations were examined using independent samples *t* tests, 1-way ANOVA, the χ^2 test, Pearson correlation coefficient, or their nonparametric counterparts, as appropriate. Kaplan–Meier curves were constructed to examine cumulative incidence of major CVD events according to veteran status and socioeconomic characteristics. We also fit Cox proportional hazards models and calculated hazard ratios (HRs) with their 95% CIs, to examine associations of veteran status and socioeconomic characteristics with incidence of major CVD events, controlling for confounding variables. When examining the association of veteran status with incidence of major CVD events, we sequentially controlled for demographic, socioeconomic, lifestyle, and health characteristics as a priori confounders of the hypothesized relationship. When examining the association of each socioeconomic characteristic with incident major CVD events, we controlled for demographic characteristics as a priori confounders of hypothesized relationships, while stratifying according to veteran status. Two-way interaction terms were added to multivariable Cox regression models to evaluate whether the effect of education, occupation, household income, and NSES on incident major CVD events varied by veteran status. For each Cox regression model, the proportional hazards assumption was evaluated by examining Kaplan–Meier curves and tested using Schoenfeld residuals, and stratified analyses according to median follow-up time were performed when this assumption was violated. Sensitivity analyses were also performed whereby women with <2 years and <5 years of follow-up were excluded and cause-specific hazard models were constructed to account for competing risks from other causes of death. GSEM were constructed to evaluate total effects as well as pathways between socioeconomic characteristics and the incidence of major CVD events through selected lifestyle (ie, smoking [ever versus never]) and health (ie, z-transformed BMI [kg/m^2]), z-transformed number of comorbidities, cardiometabolic risk factors (yes versus no), and self-rated health (fair/poor versus excellent/very good/good) characteristics that met the criteria for mediation, before and after stratifying by veteran status, and controlling for confounders.

Assuming sequential ignorability with no unmeasured confounding between the exposure, mediator, and outcome variables, causal mediation analyses were performed using parametric survival models (Weibull GSEM), which are distinct from Cox models but optimal for causal mediation analyses in the context of survival analysis.[60] Within GSEM, time to first occurrence of a major CVD event was modeled as the outcome variable. GSEM models were used to test mediating pathways between exposure (SES) variables and the outcome (major CVD event) variable of interest. The total effects of SES variables were estimated using GSEM where only exogenous (WHI component, region of residence, age, race, ethnicity, marital status, and access to health care provider at baseline) variables were included with the outcome variable being time to first occurrence of a major CVD event. Direct effects represented the main pathway, whereas indirect effects were estimated by multiplying and adding effects from each exposure variable into the outcome of interest, and passing through each mediator.[61] Given sample size limitations, bootstrapped SEs for total and indirect effects were calculated in the overall sample and among nonveterans, but not among veterans. The percentage mediated, assuming controlled mediation effects, was calculated based on the ratio of indirect to total effects. Using the *ginvariant* option within the *gsem* Stata command, the likelihood ratio test was performed to compare GSEM models whereby all parameters were constrained to unconstrained GSEM models and all parameters were distinctly estimated for veterans and nonveterans. Given the large size of the overall study sample and small percentage of missing data on each covariate (0%–1.5%) and for all covariates (5%), complete case analyses were reported, whereby sensitivity analyses involving multiple imputations with chained equations (5 data sets and 100 iterations) yielded similar results as complete case analyses. Two-tailed statistical tests were assessed at an α level of 0.05.

RESULTS

Among 145 521 WHI participants with nonmissing data on veteran status, an "unknown/not reported" category was created for 2742 (1.88%) who did not report their occupation and 9607 (6.60%) who did not report their household income. Furthermore, 129 340 (88.9%) of 145 521 WHI participants with no missing data on veteran status also had no missing data on socioeconomic characteristics, with 144 585 having nonmissing data on education and 130 158 having nonmissing data on NSES. Of those, 122 811 (94.9%) had nonmissing data on demographic, lifestyle, and health characteristics. Of those, 1525 women (45 veteran and 1480 nonveteran) were followed up for <12 months, experienced a major CVD event, or had missing data on major CVD events within 12 months postenrollment, and were therefore excluded. The final analytic sample consisted of 121 286 women (3091 veterans and 118 195 nonveterans) with a follow-up time ≥12 months, yielding 16 108 major CVD events (560 veteran and 15 548 nonveteran). Of those, 4821 (126 veteran and 4695 nonveteran) had a myocardial infarction, 5559 (191 veteran and 5368 nonveteran) had a stroke, and 12 536 (477 veteran and 12 059 nonveteran) experienced a CVD-related death, whereas 105 178 (2531 veteran and 102 647 nonveteran) did not experience a major CVD event between follow-up time ≥12 months and December 31, 2022 (Figure S1). Of note, 29 656 women (987 veterans and 28 669 nonveterans) died from other causes besides a major CVD event between follow-up time ≥12 months and December 31, 2022. Significant differences in distribution by WHI component, region of residence, race, and ethnicity were observed between 121 286 WHI participants with nonmissing and 6391 WHI participants with missing data on covariates (Table S2). Similarly, significant differences in distribution by region of residence, race, and ethnicity were observed between 121 286 WHI participants in the analytic sample and 145 521 WHI participants with nonmissing data on veteran status (Table S3), with the incidence of major CVD events being slightly less in the analytic sample versus those with nonmissing data on veteran status (HR, 0.98 [95% CI, 0.96–0.99).

Table 1 presents demographic, socioeconomic, lifestyle, and health characteristics of women who were enrolled between 1993 and 1998 (mean±SD age, 63.4±7.2 years; 86.3% white and 94.9% non-Hispanic) by veteran status. Except for WHI component, NSES, BMI, cardiometabolic risk factors, self-rated health, depressive symptoms, and current health care provider, the distribution by these baseline characteristics differed significantly between veteran and nonveteran groups, with veterans being older and more frequently highly educated, White, non-Hispanic, single/divorced/widowed, not working/retired/disabled, ever-smokers, or consumers of alcohol. Although they had a greater number of comorbidities, veterans had better diet quality and physical activity than their nonveteran counterparts.

A total of 16 108 (560 of 3091 [18.1%] veteran and 15 548 of 118 195 [13.2%] nonveteran) women experienced a major CVD event over a mean±SD follow-up time of 16.98±8.14 years (range, 1–28 years) and a median of 18.43 years (interquartile range, 8.81–24.98 years). Based on examination of Kaplan–Meier curves (Figures S2 though S4) and the weak correlation between Schoenfeld residuals and follow-up time among women who experienced a major CVD event in the context of multivariable Cox regression models (Table S4), the proportional hazards assumption was not violated. However, given the large sample size, the proportional hazards assumption test was statistically significant (P<0.0001) for hypothesized relationships. Accordingly, we also presented multivariable Cox regression models for these relationships, after stratifying by median follow-up time.

Univariate analyses suggested that veterans were at higher risk for experiencing a major CVD event, with an unadjusted HR of 1.55 (95% CI, 1.43–1.69). However, this relationship became nonsignificant after sequentially controlling for demographic, socioeconomic, lifestyle, and health characteristics, suggesting that veteran women were not more likely to develop CVD as compared with their nonveteran counterparts, after adjusting for these characteristics (Table 2). Similar results were obtained with cause-specific hazard models, whereby a death from another cause was considered a competing risk (Table S5) and after exclusion of women with <2 years or <5 years of follow-up (Table S6). Stratified analyses by median follow-up time yielded similar results to the overall analysis (Table S7).

We examined HRs from Cox regression models to understand the relationship of socioeconomic characteristics with major CVD risk, resulting in the high-risk versus low-risk SES indicators to be evaluated in subsequent analyses (Table S8). Table 3 shows Cox regression models that adjusted for WHI component, region of residence, age, race, ethnicity, and marital status. These models suggest that SES indicators are not significantly related to major CVD events among veteran women. In contrast, among nonveteran women, having some college education or less, household income <$100 000, or NSES below the third tertile are associated with 13% to 35% greater risk for a major CVD event. Whereas interaction terms of occupation×veteran status (P=0.45) and veteran status × NSES (P=0.08) in adjusted models were not statistically significant, interaction term of education × veteran status (P=0.02) and household income×veteran status (P=0.03) in adjusted models were statistically

Table 1. Demographic, Socioeconomic, Lifestyle, and Health Characteristics by Veteran Status

	Total (N=121 286)	Veteran (n=3091)	Nonveteran (n=118 195)
	No. (%)	No. (%)	No. (%)
WHI component		*P*=0.09	
CT	48 375 (39.89)	1188 (38.43)	47 187 (39.92)
OS	72 911 (60.11)	1903 (61.57)	71 008 (60.08)
Region of residence		*P*<0.0001	
Midwest	28 833 (23.77)	520 (16.82)	28 313 (23.95)
Northeast	31 553 (26.02)	846 (27.37)	30 707 (25.98)
South	27 278 (22.49)	555 (17.96)	26 723 (22.61)
West	33 622 (27.72)	1170 (37.85)	32 452 (27.46)
Age, y		*P*<0.0001	
Mean±SD	63.38±7.17	67.08±7.89	63.28±7.12
50–54	15 111 (12.46)	270 (8.74)	14 841 (12.56)
55–59	23 686 (19.53)	375 (12.13)	23 311 (19.72)
60–64	28 356 (23.38)	469 (15.17)	27 887 (23.59)
65–69	27 064 (22.31)	440 (14.23)	26 624 (22.53)
70–74	19 020 (15.68)	957 (30.96)	18 063 (15.28)
75–79	8049 (6.64)	580 (18.76)	7469 (6.32)
Race		*P*<0.0001	
American Indian/Alaska Native	374 (0.31)	5 (0.16)	369 (0.31)
Asian	3299 (2.72)	33 (1.07)	3266 (2.76)
Native Hawaiian/other Pacific Islanders	116 (0.10)	4 (0.13)	112 (0.09)
Black	9336 (7.70)	203 (6.57)	9133 (7.73)
White	104 626 (86.26)	2757 (89.19)	101 869 (86.19)
More than one race	1461 (1.20)	48 (1.55)	1413 (1.20)
Unknown/not reported	2074 (1.71)	41 (1.33)	2033 (1.72)
Ethnicity		*P*<0.0001	
Hispanic	5184 (4.27)	86 (2.78)	5098 (4.31)
Non-Hispanic	115 131 (94.93)	2987 (96.64)	112 144 (94.88)
Unknown/not reported	971 (0.80)	18 (0.58)	953 (0.81)
Marital status		*P*<0.0001	
Married/partnered	76 442 (63.03)	1529 (49.47)	74 913 (63.38)
Single	5231 (4.31)	313 (10.13)	4918 (4.16)
Divorced	18 780 (15.48)	559 (18.08)	18 221 (15.42)
Widowed	20 833 (17.18)	690 (22.32)	20 143 (17.04)
Education		*P*<0.0001	
Less than high school	5905 (4.87)	47 (1.52)	5858 (4.96)
High school	21 092 (17.39)	323 (10.45)	20 769 (17.57)
Some college	45 610 (37.61)	1275 (41.25)	44 335 (37.51)
Completed college or higher level	48 679 (40.14)	1446 (46.78)	47 233 (39.96)
Occupation		*P*<0.0001	
Managerial/professional	21 979 (18.12)	411 (13.30)	21 568 (18.25)
Technical/sales/administrative	36 292 (29.92)	783 (25.33)	35 509 (30.04)
Service/labor	11 087 (9.14)	230 (7.44)	10 857 (9.19)
Homemaker	19 551 (16.12)	508 (16.43)	19 043 (16.11)
Other	7859 (6.48)	201 (6.50)	7658 (6.48)
Not working/retired/disabled	22 495 (18.55)	912 (29.51)	21 583 (18.26)
Unknown/not reported	2023 (1.67)	46 (1.49)	1977 (1.67)

(*Continued*)

Table 1. Continued

	Total (N=121 286)	Veteran (n=3091)	Nonveteran (n=118 195)
	No. (%)	No. (%)	No. (%)
Household income		*P*<0.0001	
<$20 000	18 103 (14.93)	512 (16.56)	17 591 (14.88)
$20 000–$49 999	50 959 (42.02)	1446 (46.78)	49 513 (41.89)
$50 000–$99 999	33 418 (27.55)	779 (25.20)	32 639 (27.61)
≥$100 000	11 129 (9.18)	202 (6.54)	10 927 (9.24)
Unknown/not reported	7677 (6.33)	152 (4.92)	7525 (6.37)
Neighborhood socioeconomic status		*P*=0.49	
Mean±SD	75.83±8.56	75.93±7.92	75.83±8.58
		P=0.12	
First tertile	45 368 (37.41)	1192 (38.56)	44 176 (37.38)
Second tertile	34 857 (28.74)	905 (29.28)	33 952 (28.73)
Third tertile	41 061 (33.85)	994 (32.16)	40 067 (33.90)
Smoking status		*P*<0.0001	
Never smoker	62 113 (51.21)	1383 (44.74)	60 730 (51.38)
Past smoker	51 003 (42.05)	1441 (46.62)	49 562 (41.93)
Current smoker	8170 (6.74)	267 (8.64)	7903 (6.69)
Alcohol consumption		*P*<0.0001	
Nondrinker	13 235 (10.91)	207 (6.70)	13 028 (11.02)
Former drinker	22 448 (18.51)	632 (20.45)	21 816 (18.46)
<1 drink per wk	39 971 (32.96)	1048 (33.90)	38 923 (32.93)
≥1 drinks per wk	45 632 (37.62)	1204 (38.95)	44 428 (37.59)
2015 Healthy Eating Index		*P*<0.0001	
	65.26±10.39	66.06±10.32	65.24 ± 10.39
Physical activity, metabolic equivalent-h/wk		*P*=0.0007	
Mean±SD	12.49±13.67	13.36±14.26	12.47 ± 13.65
Body mass index, kg/m^2		*P*=0.37	
Mean±SD	27.89±5.91	27.80±5.74	27.89±5.92
		P=0.10	
<25	43 295 (35.70)	1083 (35.04)	42 212 (35.71)
25 to <30	42 070 (34.69)	1127 (36.46)	40 943 (34.64)
≥30	35 921 (29.62)	881 (28.50)	35 040 (29.65)
Comorbid conditions		*P*<0.0001	
Mean±SD	0.87±0.97	1.04±1.06	0.87 ± 0.97
		P<0.0001	
0	51 869 (42.77)	1108 (35.85)	50 761 (42.95)
1 or 2	61 661 (50.84)	1692 (54.74)	59 969 (50.74)
≥3	7756 (6.39)	291 (9.41)	7465 (6.32)
Cardiometabolic risk factors		*P*=0.16	
Yes	35 921 (29.62)	881 (28.50)	35 040 (29.65)
No	85 365 (70.38)	2210 (71.50)	83 155 (70.35)
Self-rated health		*P*=0.66	
Excellent/very good/good	110 835 (91.38)	2818 (91.17)	108 017 (91.39)
Fair/poor	10 451 (8.62)	273 (8.83)	10 178 (8.61)
Depressive symptoms		*P*=0.17	
Mean±SD	1.49±2.10	1.41±2.02	1.49±2.10
>6	62 774 (51.76)	1562 (50.53)	61 212 (51.79)

(*Continued*)

Table 1. Continued

	Total (N=121 286)	Veteran (n=3091)	Nonveteran (n=118 195)
	No. (%)	No. (%)	No. (%)
Current health care provider		*P*=0.31	
Yes	114 225 (94.18)	2924 (94.60)	111 301 (94.17)
No	7061 (5.82)	167 (5.40)	6894 (5.83)

CT indicates Clinical Trials; OS, Observational Study; and WHI, Women's Health Initiative.

significant. Similar results were obtained with cause-specific hazard models, whereby a death from another cause was considered a competing risk (Table S5), as well as after excluding women with <2 years or <5 years of follow-up (Table S6). Stratified analyses by median follow-up time yielded similar results to the overall analysis, but also suggested that high-risk SES was associated with major CVD events among nonveterans after ≥18 years of follow-up (Table S9).

After examining bivariate relationships of demographic, lifestyle, and health characteristics with high-risk versus low-risk SES indicators (Table S10) and major CVD events (Table S11), we selected the key mediators from the conceptual framework described in Figure S5. Likelihood ratio tests for group invariance suggested that none of the GSEM estimates differed by veteran status. Accordingly, we performed GSEM to examine the pathway from each dichotomized SES indicator to major CVD event through ever-smoker status, which may influence BMI, number of comorbidities, cardiometabolic risk factors, and self-rated health, in both the overall sample (Table 4) and after stratifying by veteran status (Table 5). Of note, alcohol consumption, diet quality, physical activity, and depressive symptoms were not consistently related to SES indicators and major CVD event, and, therefore, did not meet the criteria for mediation between exposure and outcome variables. Consistent with Cox regression models, the total effects of socioeconomic characteristics were not significant for veterans, whereas the total effects of education, household income, and NSES were significant among nonveterans. Among veterans, education was associated with major CVD events only through BMI, comorbidities, cardiometabolic risk factors, and self-rated health, with no mediating effect for smoking history. Similarly, among veterans, BMI mediated the relationship between household income and CVD events, whereas BMI, cardiometabolic risk factors, and self-rated health mediated the relationship between NSES and CVD events, with no mediating effect of smoking history. Among nonveterans, SES indicators were associated with CVD events through BMI, comorbidities, cardiometabolic risk factors, and self-rated health, and smoking history partly mediated the relationships of education, household income, and NSES with major CVD events through comorbidities and self-rated health.

DISCUSSION

In this prospective cohort study, we followed 121 286 postmenopausal women, aged 50 to 79 years at enrollment (1993–1998), over an average of 17 years. Our results suggest that after controlling for demographic,

Table 2. Cox Proportional Hazards Models for Veteran Status (Yes vs No) in Relation to Incidence of Major Cardiovascular Events, Before and After Controlling for Demographic, Socioeconomic, Lifestyle, and Health Characteristics (N=121 286)

	Hazard Ratio	95% CI
Model 0: unadjusted	1.55	1.43–1.69
Model 1: demographic*	1.03	0.95–1.12
Model 2: demographic*+socioeconomic†	1.05	0.96–1.14
Model 3: demographic*+socioeconomic†+lifestyle‡	1.03	0.95–1.04
Model 4: demographic*+ socioeconomic†+lifestyle‡+health§	1.00	0.92–1.09

*Demographic characteristics include the Women's Health Initiative component (Clinical Trials, Observational Study), region of residence (Midwest, Northeast, South, West), age (50–54, 55–59, 60–64, 65–69, 70–74, 75–79 years), race (American Indian/Alaska Native, Asian, Native Hawaiian/other Pacific Islanders, Black, White, more than one race, unknown/not reported), ethnicity (Hispanic, non-Hispanic, unknown/not reported), and marital status (married/partnered, single, divorced, widowed).

†Socioeconomic characteristics include education (less than high school, high school, some college, completed college or higher level), occupation (managerial/professional, technical/sales/administrative, service/labor, homemaker, other, not working/retired/disabled, unknown/not reported), household income (< \$20 000, \$20 000–\$49 999, \$50 000–\$99 999, ≥\$100 000, unknown/not reported), and neighborhood socioeconomic status (tertiles).

‡Lifestyle characteristics include smoking status (never smoker, past smoker, current smoker), alcohol consumption (nondrinker, former drinker, <1 drink per week, ≥1 drink per week), the 2015 Healthy Eating Index, and physical activity (metabolic equivalent-hours per week) scores.

§Health characteristics include body mass index (<25.0 kg/m^2 [underweight/normal weight], 25.0–29.9 kg/m^2 [overweight], and ≥30 kg/m^2 [obese]), number of comorbid conditions (0, 1 or 2, 3+), cardiometabolic risk factors (yes, no), self-rated health (excellent/very good/good, fair/poor), depressive symptoms (≤6, >6), and current health care provider (yes, no).

Table 3. Cox Proportional Hazards Models for High-Risk Socioeconomic Groups in Relation to Incidence of Major Cardiovascular Events, Overall and by Veteran Status, Before and After Controlling for Demographic Characteristics

	Hazard Ratio (95% CI)		
	Overall (N=121 286)	Veteran (n=3091)	Nonveteran (n=118 195)
Unadjusted models			
Education: some college or less	1.41 (1.36–1.46)	1.04 (0.88–1.23)	1.43 (1.38–1.48)
Occupation: not working/retired/disabled/homemaker	1.44 (1.39–1.49)	1.59 (1.35–1.89)	1.43 (1.38–1.48)
Income: <$100 000	2.44 (2.27–2.62)	1.56 (1.08–2.24)	2.46 (2.29–2.65)
NSES: below the third tertile	1.35 (1.30–1.39)	1.04 (0.86–1.24)	1.36 (1.31–1.40)
Adjusted models[*,†]			
Education: some college or less	1.13 (1.09–1.16)	0.96 (0.81–1.14)	1.13 (1.09–1.17)
Occupation: not working/retired/disabled/homemaker	1.01 (0.98–1.04)	1.06 (0.89–1.26)	1.00 (0.97–1.04)
Income: <$100 000	1.34 (1.24–1.48)	1.04 (0.71–1.50)	1.35 (1.25–1.45)
NSES: below the third tertile	1.14 (1.10–1.18)	1.04 (0.87–1.25)	1.14 (1.10–1.18)

NSES indicates neighborhood socioeconomic status; and WHI, Women's Health Initiative.

*Adjusted for WHI component (Clinical Trials, Observational Study), region of residence (Midwest, Northeast, South, West), age (50–54, 55–59, 60–64, 65–69, 70–74, 75–79 years), race (American Indian/Alaska Native, Asian, Native Hawaiian/other Pacific Islanders, Black, White, more than one race, unknown/not reported), ethnicity (Hispanic, non-Hispanic, unknown/not reported), and marital status (married/partnered, single, divorced, widowed).

†Interaction terms of occupation × veteran status (*P*=0.45), and veteran status×NSES (*P*=0.08) in Cox regression models adjusted for WHI component, region, age (categorical), race, ethnicity, marital status, the socioeconomic characteristic, and veteran status were not statistically significant. However, the interaction term of education × veteran status (*P*=0.02) and household income × veteran status (*P*=0.03) in a Cox regression model adjusted for WHI component, region, age (categorical), race, ethnicity, marital status, household income, and veteran status were statistically significant.

socioeconomic, lifestyle, and health characteristics, there were no differences in CVD risk between veteran and nonveteran postmenopausal women. Among veterans, the total effects of socioeconomic characteristics on risk of major CVD events were not statistically significant, with socioeconomic characteristics associated with major CVD events only indirectly through BMI, comorbidities, cardiometabolic risk factors, and self-rated health. In contrast, among nonveterans, lower education, household income, and NSES were positively related to major CVD events, and these total effects were partly mediated by indirect effects of BMI (education: 20%; household income: 12.5%, NSES: 15%), comorbidities (education: 20%; household income: 12.5%, NSES: 15%), cardiometabolic risk factors (education: 15%; household income: 10%, NSES: 10%), and self-rated health (education: 15%; household income: 7.5%; NSES: 10%). Similarly, smoking history served as one of the mediators within pathways between SES indicators and major CVD events only among nonveterans.

The finding of a stronger relationship between SES and major CVD events and more complex pathways linking SES to major CVD events among nonveteran versus veteran women can be best interpreted through the lens of the marginalization-related diminished returns theory, whereby veteran women can be conceptualized as a marginalized group in a similar fashion to other minority groups defined based on race, ethnicity, sexual orientation, and immigrant status, and for whom SES exerts a weaker health effect compared with more mainstream groups.[62–66] For instance, the pathway between education and major CVD through BMI was found to be weaker for the marginalized veteran group compared with the more privileged nonveteran group. This finding that, compared with nonveterans, veteran women face additional barriers possibly linked to posttraumatic stress, stigma, and other forms of social disadvantage, which can diminish the protective effect of SES on their health, contributes to the body of evidence on marginalization-related diminished returns. It highlights veteran status, one of the least studied types of marginalization, as a key social determinant of health. Conversely, the double jeopardy hypothesis,[67–69] which posits that marginalized groups experience compounded negative effects from multiple sources of disadvantage, may not fully explain these findings. According to this hypothesis, we would expect a stronger relationship between SES and major CVD outcomes among veterans versus nonveterans, which is not supported by the data.

Female veterans in the United States represent a vulnerable population with unique cardiovascular care needs and disparities.[6,16,20,70,71] They may experience a higher CVD risk due to increased adverse childhood experiences, combat exposure, military sexual trauma, intimate partner violence, suboptimal CVD literacy, risky health behaviors, chronic medical conditions, mental health disorders (eg, depression, posttraumatic stress disorder), less regular exercise, lower social support, greater risk of homelessness, and poorer overall health, compared with civilians and male

Table 4. Structural Equations Models for Effects of Lifestyle and Health Characteristics on the Relationships Between Individual- and Neighborhood-Level Socioeconomic Status and Incidence of Major Cardiovascular Events in the Overall Study Sample, Controlling for Confounders (N=121 286)

	Education		Occupation		Household income		NSES	
	β (SE) *	*P* value	β (SE) *	*P* value	β (SE) *	*P* value	β (SE) *	*P* value
Total effect	+0.2 (0.02)	<0.0001	−0.03 (0.02)	0.19	+0.4 (0.05)	<0.0001	+0.2 (0.01)	<0.0001
Indirect effects								
SES→BMI→hazard	+0.04 (0.002)	<0.0001	−0.004 (0.001)	0.003	+0.05 (0.001)	<0.0001	+0.03 (0.002)	<0.0001
SES→number of comorbidities→hazard	+0.04 (0.002)	<0.0001	+0.005 (0.002)	0.03	+0.04 (0.004)	<0.0001	+0.03 (0.001)	<0.0001
SES→cardiometabolic risk factors→hazard	+0.03 (0.001)	<0.0001	−0.004 (0.001)	0.001	+0.04 (0.002)	<0.0001	+0.02 (0.001)	<0.0001
SES→self-rated health→hazard	+0.03 (0.002)	<0.0001	+0.004 (0.002)	0.002	+0.03 (0.002)	<0.0001	+0.02 (0.001)	<0.0001
SES→smoking→BMI→hazard	−0.00002 (0.00003)	0.59	0.00 (0.00)	0.99	−0.00006 (0.0001)	0.49	−0.00007 (0.0001)	0.56
SES→smoking→number of comorbidities→hazard	+0.0009 (0.0004)	0.02	+0.00004 (0.00009)	0.26	−0.003 (0.0004)	<0.0001	−0.002 (0.0003)	<0.0001
SES→smoking→cardiometabolic risk factors→hazard	−0.00006 (0.0002)	<0.0001	0.00 (0.00)	0.58	+0.0001 (0.0001)	0.36	+0.00008 (0.00004)	0.04
SES→smoking→self-rated health→hazard	+0.0003 (0.00008)	0.002	+0.00003 (0.00005)	0.60	−0.0009 (0.0002)	<0.0001	−0.0007 (0.0001)	<0.0001

BMI indicates body mass index; NSES, neighborhood socioeconomic status; SES, socioeconomic status; and WHI, Women's Health Initiative.

*Bootstrapped SEs are reported. Exogenous variables are defined as WHI component (Clinical Trial, Observational Study), region of residence (Midwest, Northeast, South, West), z-transformed age (years), race (American Indian/Alaska Native, Asian, Native Hawaiian/other Pacific Islanders, Black, White, more than one race, unknown/not reported), ethnicity (Hispanic, non-Hispanic, unknown/not reported), marital status (married/partnered, single, divorced, widowed), and current health care provider (yes, no). Exposure variables are defined as education (some college or less vs college degree or higher), occupation (unemployed [homemaker, not working, retired, disabled] vs other [managerial, professional, technical, sales, administrative, service, labor, other, unknown/not reported]), income (<\$100 000 vs other [≥\$100 000, unknown/not reported]), and NSES (low [<80] vs other [≥80]). Mediators are defined as smoking (ever vs never), z-transformed BMI (kg/m^2), z-transformed number of comorbidities, cardiometabolic risk factors (yes vs no), and self-rated health (fair/poor vs excellent/very good/good).

veterans.[1,5,6,14,15,20,72] Contrary to our findings, CVD risk factors were previously found to be more prevalent among female veterans than their civilian counterparts, with higher prevalence rates of obesity, obesity-related chronic conditions (eg, hypertension, diabetes, and hyperlipidemia), and smoking among veterans.[1] Compared with male veterans, female veterans often face disparities in CVD prevention, including lower likelihood of receiving nicotine replacement therapy and achieving adequate cholesterol control.[1] Whereas the majority of veterans receive their health care at other facilities, the US Department of Veterans Affairs (VA) has made significant progress in providing comprehensive and sex-specific health care over the past few decades, including the establishment of the VA Women's Health Services national program office in the early 1990s.[5] Regional and local clinics have improved women's primary care, outperforming private sector quality metrics and reducing VA disparities among the sexes.[5] However, gaps remain in diabetes, lipid control, and ischemic heart disease, with health literacy among female veterans remaining suboptimal.[5,6,16] In this study, we found that postmenopausal women in the WHI classified as veterans were 55% more likely to experience a major CVD event compared with their nonveteran counterparts. However, this relationship was confounded by demographic, socioeconomic, lifestyle, and health characteristics. Since nearly 50% of veteran women were70 years and older compared with only 22% of nonveteran women within this age range, it is plausible that age is the main driver for differences in major CVD risk between veteran and nonveteran women in the WHI. Further analyses suggest that the age-adjusted HR for the relationship between veteran status and major CVD risk was 1.04 (95% CI, 0.96–1.14).

While traditional CVD risk factors have been extensively investigated, socioeconomic characteristics at different levels of organization such as individual- and neighborhood-level SES, are established social determinants of health, and these may directly or indirectly influence cardiovascular health, but have received less attention.[4–6,15,70] For instance, lower educational attainment has been linked to higher CVD

Table 5. Structural Equations Models for Effects of Lifestyle and Health Characteristics on the Relationships Between Individual- and Neighborhood-Level Socioeconomic Status and Incidence of Major Cardiovascular Events by Veteran Status, Controlling for Confounders (N=121 286)

	Education		Occupation		Household income		NSES	
	β (SE) *	*P* value	β (SE) *	*P* value	β (SE) *	*P* value	β (SE) *	*P* value
Veterans (n=3091)								
Total effect	+0.03 (0.09)	0.69	+0.04 (0.09)	0.61	+0.04 (0.2)	0.82	+0.08 (0.09)	0.38
Indirect effects								
SES→BMI→hazard	+0.04 (0.01)	0.001	+0.002 (0.007)	0.81	+0.031 (0.02)	0.050	+0.03 (0.01)	0.002
SES→number of comorbidities→hazard	+0.03 (0.01)	0.03	+0.0008 (0.01)	0.95	−0.002 (0.02)	0.92	+0.009 (0.01)	0.44
SES→cardiometabolic risk factors→hazard	+0.03 (0.009)	0.002	−0.005 (0.007)	0.45	+0.03 (0.01)	0.060	+0.03 (0.009)	0.003
SES→self-rated health→hazard	+0.02 (0.008)	0.02	+0.009 (0.007)	0.22	+0.02 (0.01)	0.10	+0.02 (0.008)	0.04
SES→smoking→BMI→hazard	+0.00007 (0.0004)	0.88	+0.00004 (0.0002)	0.85	+0.00006 (0.0004)	0.85	+0.00006 (0.0003)	0.85
SES→smoking→number of comorbidities→hazard	+0.002 (0.002)	0.39	+0.0006 (0.002)	0.76	+0.001 (0.004)	0.97	+0.001 (0.002)	0.55
SES→smoking→cardiometabolic risk factors→hazard	+0.0001 (0.0004)	0.76	+0.00006 (0.0002)	0.81	+0.0001 (0.0004)	0.82	+0.0001 (0.0004)	0.76
SES→smoking→self-rated health→hazard	+0.0002 (0.0005)	0.72	+0.00006 (0.0002)	0.80	+0.0001 (0.0005)	0.81	+0.0001 (0.0004)	0.74
Nonveterans (n=118 195)								
Total effect	+0.2 (0.02)	<0.0001	−0.03 (0.02)	0.08	+0.4 (0.02)	<0.0001	+0.2 (0.02)	<0.0001
Indirect effects								
SES→BMI→hazard	+0.04 (0.002)	<0.0001	−0.004 (0.002)	0.02	+0.05 (0.002)	<0.0001	+0.03 (0.001)	<0.0001
SES→number of comorbidities→hazard	+0.04 (0.002)	<0.0001	+0.005 (0.002)	0.02	+0.05 (0.002)	<0.0001	+0.03 (0.002)	<0.0001
SES→cardiometabolic risk factors→hazard	+0.03 (0.002)	<0.0001	−0.0037 (0.0006)	<0.0001	+0.04 (0.002)	<0.0001	+0.02 (0.002)	<0.0001
SES→self-rated health→hazard	+0.03 (0.001)	<0.0001	+0.0004 (0.001)	<0.0001	+0.03 (0.001)	<0.0001	+0.02 (0.001)	<0.0001
SES→smoking→BMI→hazard	−0.00002 (0.00004)	0.67	0.0 (0.0)	0.96	+0.00006 (0.0001)	0.28	−0.00007 (0.0001)	0.48
SES→smoking→number of comorbidities→hazard	+0.0009 (0.0002)	<0.0001	+0.00004 (0.0004)	0.91	−0.003 (0.0005)	<0.0001	−0.002 (0.0002)	<0.0001
SES→smoking→cardiometabolic risk factors→hazard	−0.00007 (0.00003)	0.04	0.00 (0.00)	0.88	+0.0001 (0.0001)	0.07	+0.00008 (0.00009)	0.35
SES→smoking→self-rated health→hazard	+0.0003 (0.0001)	0.01	+0.00001 (0.00005)	0.82	−0.0009 (0.0001)	<0.0001	−0.0008 (0.0002)	<0.0001

BMI indicates body mass index; NSES, neighborhood socioeconomic status; SES, socioeconomic status; and WHI, Women's Health Initiative.

*Bootstrapped SEs are reported for the nonveteran group only. Exogenous variables are defined as WHI component (Clinical Trial, Observational Study), region of residence (Midwest, Northeast, South, West), z-transformed age (years), race (American Indian/Alaska Native, Asian, Native Hawaiian/other Pacific Islanders, Black, White, more than one race, unknown/not reported), ethnicity (Hispanic, non-Hispanic, unknown/not reported), marital status (married/partnered, single, divorced, widowed), and current health care provider (yes, no). Exposure variables are defined as education (some college or less vs college degree or higher), occupation (unemployed [homemaker, not working, retired, disabled] vs other [managerial, professional, technical, sales, administrative, service, labor, other, unknown/not reported]), income (<$100 000 vs other [≥$100 000, unknown/not reported]), and NSES (low [<80] vs other [≥80]). Mediators are defined as smoking (ever vs never), z-transformed BMI (kg/m^2), z-transformed number of comorbidities, cardiometabolic risk factors (yes vs no), and self-rated health (fair/poor vs excellent/very good/good).

risks and was associated with increased all-cause and CVD mortality rates, potentially through lower health literacy, more risky health behaviors, and a greater need for health care services.[1,3–6,16,20] In contrast, higher educational attainment and income can lead to better access to health care services and lower mortality rates, whereas racial and ethnic minorities may experience socioeconomic challenges in obtaining higher education, insurance, and access to health care.[4,14,16,70,71,73–76] Although the simultaneous examination of the NSES index with individual-level SES characteristics has the potential for Berkson measurement error, NSES differs from education, occupation, and income, because of its relationship to the built environment, which can impact CVD risk through resource distribution, physical activity, and general well-being. At a broader level, CVD mortality rates for nonelderly adults in the United States have remained stagnant over the past decade. This could be explained by economic trends, especially with rising income inequality, income fluctuation, and job instability, and the decline in social cohesiveness.[2,76–78] This study identified education, household income, and NSES as being more strongly related to major CVD events than occupation. It also highlighted a more salient role for socioeconomic characteristics in major CVD events among nonveterans versus veterans. It is important to recognize that veterans may have unique protective factors such as access to health care and case management supports through the VA.[79,80] There may be heterogeneity within the group of women veterans according to their level of access to VA health care services,[81] necessitating further evaluation. Although a question regarding health insurance was asked of WHI participants at enrollment, it cannot be used to ascertain their lifetime access to VA health care services. Therefore, in-depth studies are needed that can explain why SES is more relevant to major CVD events among nonveteran versus veteran women, and how SES can potentially influence smoking, BMI, comorbidities, cardiovascular risk factors, and self-rated health, as mediators for major CVD events.

It is worth noting that this study examined depression as the only psychosocial factor that can mediate the effect of SES indicators on major CVD events, whereas previous WHI studies found that traits such as dispositional optimism and cynical hostility, which are related to SES but independent from depression, may be linked to incident CVD, all-cause, and CVD- and cancer-related mortality risks.[82] These trait-like attitudes, which are formed early in life and are crucial for stress response, social interactions, and health behaviors, should be taken into consideration in future WHI studies of veteran versus nonveteran populations. Future studies should also explore alternatives to NSES, including urban–rural residence based on the Rural–Urban Commuting Areas system, which considers population density and how closely a community is linked socioeconomically to larger urban centers, as well as food security, which incorporates functional status and the HEI as another NSES component for CVD risk. Finally, future studies should explore the complex interrelationships among key mediators within pathways between SES indicators and CVD risk, especially since self-rated health may be considered as an outcome of BMI, comorbidities, and cardiometabolic risk factors.

This study has several strengths, including its comprehensive data collection at enrollment, which enables easy assessment of associations and accounting for confounders. It also offers an acceptable generalizability to postmenopausal women from diverse geographical areas in the United States, although racial and ethnic minorities within the WHI have higher levels of education and income and may experience fewer psychosocial adversities when compared with the general US population.[83] Our study also has several limitations. First, we performed secondary data analyses using a subsample of the original WHI participants, which could potentially result in selection bias. Second, information bias may have occurred because many of the exposure, mediator, covariate, and outcome measurements were self-reported. Similarly, most variables were assessed at the enrollment visit (1993–1998), and despite a long-term follow-up of 17 years, on average, heterogeneities among different components of the WHI study precluded us from defining time-varying exposures, mediators, and covariates. Furthermore, SES indicators assessed at the time of WHI enrollment do not necessarily coincide with many early life exposures that may also influence CVD outcomes. Since the WHI study collected data on household income as an ordinal variable and household size was not provided within the baseline questionnaire, we were not able to calculate an SES measure that combines household income with size and composition of the household. Although posttraumatic stress disorder may be a more relevant mediator between SES and major CVD events among veterans, depressive symptoms were evaluated as a proxy for mental health disorders. Third, residual confounding due to unmeasured or inadequately measured confounders remains a concern for observational study designs. Of note, a causal relationship between socioeconomic characteristics and major CVD events through the mediation of lifestyle and health characteristics can only be established in the context of an experimental design. Fourth, veteran status is a complex issue due to various factors such as being deployed to war zones, having psychiatric conditions, receiving health care at VA facilities, as well as eligibility for disability benefits and other opportunities not afforded to nonveterans. Veterans may also inaccurately report their household income because of concerns over eligibility for VA benefits. Fifth, the role of chance in analyses stratified by veteran status cannot be ruled out, given that the number of veterans is considerably less than that of nonveterans. Larger samples are also needed to further stratify analyses by branch of military service and history of CVD. Finally, participants in the WHI were volunteer postmenopausal women at clinical centers, restricting our ability to generalize study findings to younger women of diverse racial and ethnic background. Specifically, Black race is an important confounder that may underlie the greater CVD risk among female veterans. In the United States, CVD is overrepresented among racial and ethnic minorities,[84–86] and Black women are overrepresented within the veteran population.[8] In fact, Black women represent 12.4% of the nonveteran but 19.3% of the veteran female population in the United States,[8] while Black nonveteran (7.7%) and veteran (6.6%) women are underrepresented in the WHI. As such, these study findings may not generalize to a more racially diverse population of female veterans, potentially biasing CVD morbidity and mortality risks to the null. In addition, these results may not generalize to military veterans in other countries besides the United States.

In conclusion, a stronger link exists between SES and major CVD events among nonveteran versus veteran postmenopausal women. Furthermore, nonveteran postmenopausal women exhibited more complex pathways between socioeconomic characteristics and major CVD events through lifestyle and health characteristics than their veteran counterparts. These findings inform the future design, conduct, and evaluation of preventive strategies that target CVD risk according to veteran status. This study expands the marginalization-related diminished returns literature and is among the first to highlight the importance of considering the unique barriers faced by veteran women as a marginalized group, when examining the relationship between SES and CVD outcomes. The findings underscore the need for tailored interventions that address these barriers and help mitigate the diminished returns of SES in improving health for veteran women as a marginalized population.

ARTICLE INFORMATION

Received June 26, 2024; accepted October 15, 2024.

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Acknowledgments

The article was supported in part by the Intramural Research Program of the National Institute on Aging in Baltimore, Maryland. The views expressed in this paper are those of the authors and do not reflect the official policy or position of the Department of the Navy, the Uniformed Services University of the Health Sciences, the Department of Defense, the Department of Veterans Affairs, the National Institutes of Health, or the US government. The authors thank the WHI investigators and staff for their dedication and the study participants for making the program possible. A listing of WHI investigators can be found at https://www-whi-org.s3.us-west-2.amazonaws.com/wp-content/uploads/WHI-Investigator-Short-List.pdf. The sponsors did not play a role in the study design, collection, analysis, and interpretation of data; in the writing of the report; or in the decision to submit the article for publication.

Sources of Funding

The WHI program is funded by the National Heart, Lung, and Blood Institute, National Institutes of Health, and the US Department of Health and Human Services through 75N92021D00001, 75N92021D00002, 75N92021D00003, 75N92021D00004, 75N92021D00005.

Disclosures

None.

Supplemental Material

Data S1
Tables S1-S11
Figures S1-S5

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