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Neighborhood Socioeconomic Status and Cognitive Function in Women

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Abstract

Objectives—We examined whether neighborhood socioeconomic status (NSES) was associated with cognitive functioning in older US women, and whether this was explained by associations between NSES and vascular, health behavior, and psychosocial factors.

Methods—Women ages 65–81 (N=7,479) free of dementia enrolled in the Women’s Health Initiative Memory Study. Linear mixed models examined the cross-sectional association between an NSES index (0–100) and log_e-transformed cognitive functioning scores. A base model adjusted for age, race/ethnicity, education, income, marital status, and hysterectomy. Three groups of potential confounders were examined in separate models: vascular, health behavior, and psychosocial factors.

Results—Living in a neighborhood with a one-unit higher NSES value was associated with 0.022 standard deviations higher cognitive function ($p=0.02$). The association was attenuated but still marginally significant ($p<0.10$) after adjustment for confounders and, based on interaction tests, stronger among younger and non-white women.

Conclusions—The socioeconomic status of a woman’s neighborhood may influence cognitive function. This relationship is only partially explained by vascular, health behavior, or psychosocial factors. Future research will examine the longitudinal relationships between NSES, cognitive impairment and cognitive decline.

Keywords

neighborhood socioeconomic status; cognitive function; women

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INTRODUCTION

A growing body of research suggests that the characteristics of neighborhoods in which individuals live may influence risk for poor self-rated health, cardiovascular disease, and mortality, above and beyond individual-level characteristics (1–15). The proposed mechanisms by which lower quality neighborhoods may influence poor physical health include exposure to chronic stressors and pollutants in the environment; increased access to alcohol and cigarette outlets; barriers to physical activity; reduced social support, networks, and cohesion; and reduced access to high quality health and social services. Three recent studies have linked lower neighborhood socioeconomic status (NSES) with lower cognitive function in UK adults older than 52 years (16), US adults older than 70 years living in urban areas (17), and Mexican Americans older than 65 living in five southwestern states (18). However, the mechanisms underlying this relationship are not well understood. Extensive epidemiological research has linked NSES to vascular-related conditions (4, 19–22), poor health behaviors (23–25), and greater psychosocial stress (26–30). Incidentally, these factors also have well-established linkages with brain health such that individuals who have vascular-related conditions (31, 32), engage in lower physical activity, smoking and excessive alcohol intake (33–35), and have greater symptoms of depression or lower social support (36–38) experience increased risk for poor cognitive function. No studies to date have addressed whether these conditions may explain the relationship between NSES and cognitive function.

Prior studies indicate that neighborhood environments may influence poor cognitive function above and beyond individual-level demographic characteristics such as age, race/ethnicity, educational attainment and income (16, 17, 39, 40). Demographic subgroups may be especially vulnerable to NSES' effects on cognitive function. Poor neighborhood environments may differentially affect older adults because they spend more time in their neighborhoods (41) and may have less access to social, financial, or health services, and have accumulated greater exposures to stressors or pollutants. Non-white older adults who live in lower SES neighborhoods may face discrimination or other stressors which may confer greater vulnerability to NSES effects on cognitive function. Wight and colleagues (17) examined individual- and neighborhood-level educational interaction among US adults. However, no U.S. study to date has addressed whether other individual-level demographic factors modify, or confer vulnerability to NSES using an index consisting of important measures of socioeconomic status beyond education alone.

The purpose of this study was to examine whether an NSES index was related to cognitive function in a large, geographically and demographically diverse cohort of older U.S. women with rich data on a sensitive measure of global cognitive function and a comprehensive set of clinical, behavioral and psychosocial confounders. We tested whether the relationship between NSES and cognitive function was explained by risk and protective factors for poor cognitive function that have also been linked with NSES, and whether certain subgroups were more vulnerable to lower NSES.

METHODS

Data Sources

The Women's Health Initiative Memory Study (WHIMS) was an ancillary study to the Women's Health Initiative hormone therapy trials (42), two large, randomized, double-blind, placebo-controlled, clinical trials to assess the relative effect of 0.625 mg/day of conjugated equine estrogen alone (E trial) or in combination with 2.5 mg/day of continuous medroxyprogesterone acetate (E+P trial) on the incidence of dementia and level of cognitive functioning in postmenopausal women. The study design, eligibility criteria and recruitment

procedures of WHIMS have been described previously (43, 44). Briefly, 7,479 women from 39 sites who were at least 65 years of age and free of dementia were enrolled in WHIMS (4,532 in the E + P and 2,947 in the E trial) between May 1996 and December 1999. We geocoded addresses of WHIMS women at enrollment to the census tract and linked them with Census data on census tract-level NSES.

Study Sample

We excluded 1,342 women from the total sample (17.9 percent of 7,479): those living outside of Metropolitan Statistical Areas (MSAs; 797) which precluded us from accounting for geographic clustering, and those with missing, foreign, or military addresses, or with geocoded census tracts that were missing NSES values (545). A total of 6,137 women were included in the analyses. Women who were excluded from the analytic sample were slightly younger, less educated, and less wealthy. They were also more likely to be married, have more social support and social integration, be less depressed, and drink and smoke less (all χ^2 p-values <0.05).

Dependent Variable: Cognitive Function

The Modified Mini-Mental State Examination (3MSE; (45)) measured cognitive functioning at baseline. The 3MSE is a well-established measure of global cognitive function with good reliability, and high sensitivity and specificity for detecting cognitive impairment and dementia in general and in WHIMS (46, 47). 3MSE assessments were administered by trained and certified technicians who were masked to treatment group and other outcomes. Administration times averaged 10–12 minutes. Total 3MSE score was a sum of 15 items and ranged 0–100; higher scores reflected better cognitive functioning. Test items measured temporal and spatial orientation, immediate and delayed recall, executive function (control and management of other cognitive processes), naming, verbal fluency, abstract reasoning, praxis, writing, and visuo-constructional abilities. Due to the skewed distribution towards higher 3MSE scores, a negative logarithmic transformation was applied [$-\log_e(102-3\text{MSE score})$] to yield a more normal distribution. Higher transformed scores indicated higher cognitive functioning. We then computed z-scores from this index to express it in standard deviation units.

Independent Variables: Neighborhood Socioeconomic Status

NSES was assessed at the census tract level using data from the 2000 Census. NSES is an index of six census tract variables including: percent of adults older than 25 with education less than high school; percent male unemployment; percent of households with income below the poverty line; percent of households receiving public assistance; percent of households with children headed by a female; and median household income. The composite measure was identified through confirmatory factor analysis and demonstrated in prior studies to be an important neighborhood-level predictor of health outcomes (19). The NSES index was scaled to range 0–100 for U.S. census tracts; higher scores indicated more affluent tracts. To obtain the NSES value for each woman at baseline, which occurred between 1996 and 1999, we derived intercensal estimates using either geometric or linear interpolation based on the 1990 census tract definitions. Since some census tract boundaries changed between 1990 and 2000, we created a mapping between the 1990 and 2000 Censuses using the 1990/2000 Census Tract Relationship File to facilitate the interpolation.

Independent Variables: Individual-level Covariates

Individual-level demographic and lifestyle variables were measured at baseline by self-report (44). To examine potential factors influencing the relationship between NSES and cognitive function, we considered three groups of confounders that have been previously

linked with NSES or cognitive function. Vascular factors included non-fatal coronary heart disease (myocardial infarction, angina, and coronary revascularization), diabetes, stroke, or hypertension, as assessed by self-reported history, measured blood pressures, and current medication use. Health behaviors included the number of alcoholic drinks per day, smoking status, and physical activity (episodes per week of moderate activity lasting 20 or more minutes). Psychosocial factors included depressive symptoms, social support, and social integration as psychosocial confounders. Depressive symptoms were measured using a validated algorithm of an 8-item screening instrument (48) that incorporated 6 items from the Center for Epidemiological Studies Depression Scale (49) and 2 items from the Diagnostic Interview Scale (50). The total score ranged 0–1; higher scores indicated more depressive symptoms. Social support was measured by nine items selected from the Medical Outcomes Study (51). These assessed perceived availability of emotional/informational support, tangible support, affectionate support, and positive social interaction (sum = 9–45). Social integration was an average of two items that measured how often a woman went to a religious service or meetings of clubs, lodges, or parent groups during the past month. Both items ranged 1 (not at all) to 6 (every day).

Statistical Analysis

We examined the cross-sectional association between NSES and transformed 3MSE scores at baseline. We used a linear mixed model with random effects to account for clustering by MSA. Exploratory analyses did not indicate that clustering by census tract improved model fit, whereas MSA-level clustering did. The model building strategy first examined the unadjusted relationship between NSES and 3MSE. Model 1 adjusted for basic demographic covariates that were significantly associated with NSES or cognitive function in bivariate regressions (median centered age, race/ethnicity, educational attainment, household income, and marital status). Hysterectomy status was included as a covariate because it distinguishes between women who were randomized to the E versus E+P trial. A cutpoint of less than \$10,000 categorized household income because this appeared to define the strongest differences.

We then examined whether adjustment for three separate sets of confounders (Models 2–4) partially explained the association between NSES and 3MSE in Model 1. Model 2 included covariates from Model 1 and the vascular factors defined above. Model 3 included covariates from Model 1 and health behaviors. Model 4 included Model 1 covariates and psychosocial factors. Tests of interactions assessed the consistency of associations for subgroups of age (<70 versus ≥70), race (whites versus non-whites), household income (<\$10,000 versus ≥\$10,000), or educational status (high school versus college). Individual-level covariates for race/ethnicity, education, income, and marital status were missing in 6.7 percent of cases. Single imputation was used to impute missing values using IVEware (52). Supporting analyses, limited to women with complete data, were conducted to assess the sensitivity of findings to imputation.

RESULTS

Baseline descriptive characteristics

The baseline, raw mean 3MSE score was 95.1 for the 6,137 women in the analytic sample (Table 1). Approximately 87% of women were white, 7% were black, 3% were Hispanic and 3% were of another race or ethnicity. Approximately 92% had a high school degree or higher, 51% were married, and 39% had a hysterectomy. The mean NSES value across individual women in the sample was 75.4. Figure 1 illustrates the distribution of raw 3MSE scores by quartile of NSES where quartile cut-points are defined by the distribution of NSES in the WHIMS sample.

Cross-sectional association between NSES and cognitive function

Table 2 displays coefficients and standard errors for the cross-sectional association between NSES and transformed 3MSE score. Without any covariate adjustment, living in a neighborhood with a one-unit higher NSES value (median NSES for the WHIMS sample=77; range 25–96) was significantly associated with a 0.0235 standard deviations higher level of cognitive functioning ($p<0.001$). The intraclass correlation was 0.052. Once basic covariates were included (Model 1), this relationship remained significant (standardized $\beta=0.0037$; $p=0.02$). Adjustment for vascular factors (Model 2) attenuated the strength of the relationship slightly (standardized $\beta=0.0034$; $p=0.03$). Adjustment for health behavior factors (Model 3) or psychosocial factors (Model 4) also attenuated the relationship (standardized $\beta=0.0028$; $p=0.07$ and standardized $\beta=0.0028$; $p=0.08$, respectively). Coronary heart disease ($p=0.06$) in Model 2, alcohol intake ($p<0.001$) in Model 3 and depressive symptoms ($p=0.03$) in Model 4 were the only significant predictors of cognitive function after adjustment for NSES.

Differences in NSES-3MSE Relationship Across Demographic Factors

With minimal covariate adjustment (Model 1), the interaction between NSES and age was significant at $p=0.05$ and with race was marginally statistically significant ($p=0.07$). As portrayed in Figure 2, the fitted slopes were greater for younger versus older women and for non-white versus white women. Adjustment for vascular, health behavior, and psychosocial factors in Models 2–4 did not materially change these results. There was no evidence that relationships varied among subgroups defined by household income and education ($p>0.10$). Sensitivity analyses among only women who had complete, non-imputed data yielded similar results for the analyses among the full sample. Stratified analyses were similar, although the only difference was that education-stratified analyses among the reduced sample without imputed data revealed a stronger association between higher NSES and higher cognitive function among women with higher education ($p<0.05$).

DISCUSSION

This study of a national sample of older U.S. women provides consistent evidence that living in a neighborhood with higher NSES is associated with higher cognitive functioning, above and beyond individual-level demographic characteristics such as age, race/ethnicity, income, education, and marital status. This is the largest U.S.-based study to examine the cross-sectional relationship between area-level socioeconomic composition and cognitive function, and to explore potential underlying mechanisms as well as vulnerability to NSES across age, race, income, and education.

We hypothesized that the relationship between higher NSES and higher cognitive function in women would be explained by the association between NSES and vascular factors, health behavior, and psychosocial factors. These factors only partially explained the relationship between NSES and cognitive function, as indicated by the slightly smaller magnitudes of regression parameters. In particular, the results for the overall sample indicated that adjustment for health behavior and psychosocial factors resulted in the greatest relative reduction in the association between NSES and cognitive function. However, accounting for the three groups of confounders did not completely explain the relationship suggesting that there may be other factors that have not been accounted for. These may include better access to high-quality health services, cognitive activity, or intake of foods high in antioxidants that have been shown to be protective against poor cognitive function (53–56).

These findings corroborate prior research on NSES and cognitive function. Lang and colleagues (16) found that higher neighborhood socioeconomic deprivation was cross-

sectionally related to lower cognitive functioning. Further adjustment for systolic blood pressure, stroke, and depression did not account for the association between neighborhood deprivation and cognitive function. Accounting for perceived access to medical resources or stores and local shops also did not account for the association. Wight and colleagues (17) found that lower neighborhood-level education was cross-sectionally associated with lower cognitive performance, even after adjustment for demographic factors, depressive symptoms, and chronic health conditions. While these studies were nationally representative of U.K. adults 52 and older (16) or U.S. adults older than 70 (17), our study adds to the literature by including rural, in addition to urban or suburban areas, and also by measuring cognitive functioning using the 3MSE which is more sensitive to detecting cognitive impairment than tests used in those studies (57, 58).

We hypothesized that the relationship between higher NSES and higher cognitive function would be more pronounced for non-white and older women, and women with lower individual SES. However, stratified analyses and models with interaction terms indicated that higher NSES was protective for younger and non-white women. Individual-level income and education did not modify the effects of NSES. Lang and colleagues (16) found that neighborhood deprivation's association with poor cognition was more pronounced among older men and women. Our findings, which can also be interpreted as an association between lower NSES and lower cognitive function for younger and non-white women, conflict with the findings of Lang and colleagues. Our results do not support prior literature that suggests older individuals are more vulnerable to lower NSES neighborhood effects due to a longer duration of exposure to poor or declining neighborhood conditions, greater acquired biological and psychological and cognitive vulnerability, general declines in physical function that may limit their mobility to areas outside of their neighborhood, and greater reliance on local health and social resources (41, 59). It is unclear why older women in WHIMS were not as vulnerable to effects of living in a lower SES neighborhood; it may be that older women in WHIMS were exposed to unmeasured factors accumulated over the lifetime which may have overwhelmed the effects of NSES on cognition. Additionally, survivorship bias may play a role if women living in lower SES neighborhoods have worse cognitive function and experience higher mortality rates than those with better cognitive function. Both of these hypotheses should be examined further. Nonetheless, our findings suggest that it may not be too early to intervene in women younger than age 70 to mitigate the effects of lower NSES on risk for lower cognitive function. Discrepant findings may be due to the fact that Lang and colleagues (16) may have included women with dementia. In addition, the variability of NSES in the WHIMS sample was greater in the younger age group compared to the older age group, which may have promoted our ability to detect a relationship among the younger age group. Because the WHIMS does not have data on duration of current residence, we cannot rule out the possibility that older women may have been more likely to move recently, and therefore live in a neighborhood with a different NSES than the neighborhoods they spent most of their lives in. This bias would be most relevant if NSES has a more acute effect. However, research indicates that neighborhoods are slow to change over time, and the differences in neighborhoods that individuals live in do not change drastically over the life course (3, 60, 61).

This study is the first to report differences in the relationship between NSES and cognitive function by race. Our results concur with our hypothesis that non-whites may be more vulnerable to NSES effects compared to whites due to greater susceptibility to the effects of stressors, or have lower access to social, psychosocial, and economic resources. It is possible that the ability to observe this association was facilitated by the larger variance in NSES values among non-whites compared to whites. While Wight and colleagues (17) found that the effect of living in a neighborhood with lower educational attainment on cognitive performance was modified by individual-level education, we did not find significant effect

modification by education, although we did find a stronger effect among those with higher education in sensitivity analyses that excluded imputed data. Women excluded from the analytic sample were less educated suggesting that the association among women with lower education may be more sensitive to missing data.

Our data are drawn from non-demented volunteers who were eligible for a trial of postmenopausal hormone therapy, yet we still observed a robust association between NSES and 3MSE after adjustment for vascular factors, and a reduced association after adjustment for health behavior and psychosocial factors. Without covariate adjustment, a two standard deviation difference in NSES (i.e. 17 units) was associated with an approximately 0.4 standard deviation difference (17×0.0235) in our measure of cognitive function. Covariate adjustment for potential confounders in Models 1–4 attenuated this relationship so that a two standard deviation NSES differences was associated with 0.04 to 0.06 (17×0.0022 and 17×0.0037 , respectively) standard deviation differences in cognitive function. To provide some context for comparison purposes, the WHIMS trials found assignment to conjugated equine estrogen therapy without or with medroxyprogesterone acetate was associated with decrements in cognitive function of 0.08 to 0.09 standard deviations, respectively, over the course of the trials (62), and these relatively small mean differences were associated with significant increases in dementia and brain atrophy (43, 63, 64).

This study has a number of important strengths. First, this is the largest U.S. study of contextual-level socioeconomic status on cognitive function. Second, our primary outcome measure, the 3MSE, is a widely used measure of global cognitive function and screening tool of dementia that covers a wider range of cognitive domains (65), difficulty of items, and sensitivity to cognitive impairment compared to other tests of global cognitive function (45). Third, the WHIMS encompasses a demographically and geographically diverse sample of women living in 35 states and rural, mixed, and urban areas (3%, 76%, 21%, respectively, of all sample tracts), lending further support for a contextual-level effect on cognitive function in the U.S. Although we excluded women living outside MSAs, some MSAs include rural and mixed rural-urban census tracts. Our study also expands upon one other U.S.-based national study (17) by including women younger than 70 years. Fourth, we examined a comprehensive and multi-faceted index of socioeconomic status which builds on prior literature (17, 39) that has focused on education or income, or classes of neighborhoods (barrio, transitional, or suburban). Lastly, we considered a relatively large number of confounders to examine potential mechanistic pathways. Inclusion of these confounders indicated that higher NSES was independently and consistently associated with cognitive functioning, even after accounting for important demographic, vascular, health behavior, and psychosocial confounders.

Despite these strengths, we note several limitations of these analyses. We examined cross-sectional associations between NSES, cognitive function, and confounding variables measured at baseline. Thus, any causal relationships or indication of mediation resulting from the adjustment for vascular, health behavior, and psychosocial covariates, and examination of the reduction of main effects (66) must be interpreted with caution. The WHIMS is not a population-based sample and included mostly well-educated women who had volunteered and were eligible for a clinical trial of postmenopausal hormone therapy, and probably had substantial interest in their health. It also required participants to have plans to stay in their current geographic area so these results may not be generalizable to other populations, including men. The generalizability of the sample may have been further restricted by missing NSES data or information on MSAs, limiting it to 82% of the entire WHIMS cohort. In addition, we cannot rule out the potential for residual confounding or selection effects such that individuals with similar characteristics beyond those we accounted for may systematically choose to live in similar neighborhoods.

Poor cognitive function in late life has been linked with steeper declines in cognitive function over time, which increases the risk of dementia such as Alzheimer's disease (67, 68). Our analyses suggest that policies that aim to bolster higher NSES, or early public health interventions that target modifiable risk factors such as poor health behaviors and facilitate social support and integration among women in lower SES neighborhoods, may also provide some protection against the harmful effects of NSES on poor cognitive function. In particular, the relationship between living in a lower SES neighborhood and moderate alcohol intake or more depressive symptoms indicates that these may be key intermediate factors to intervene on for individuals living in high-risk neighborhoods. Stratified analyses showing differential effects by age and race indicate that targeted interventions among non-white women or women younger than 70 may help mitigate the harmful effects of lower NSES. Future research should examine the longitudinal relationship between living in a lower SES neighborhood and risk for steeper cognitive declines and risk for subclinical syndromes that increase risk for dementia such as mild cognitive impairment.

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Figure 1.
Box Plot Graphs of Raw Modified Mini-Mental Examination Score (3MSE) by
Neighborhood Socioeconomic Status (NSES) Quartile.

Figure 2. NSES and Global Cognitive Function: Linear Regression Parameter Estimates (Margin of Error) for Overall Sample, and Stratified by Individual-level Age and Race
 Notes: Global cognitive function is measured by the Modified Mini-Mental Examination Score (3MSE); NSES=Census tract-level neighborhood socioeconomic status; White = non-Hispanic Caucasian; Global cognitive function is scaled in standard deviation units of $[-\log_e(102-3\text{MSE score})]$.
 Model 1 adjusts for basic covariates (centered-median age, race/ethnicity, educational attainment, household income, marital status, and hysterectomy status)

Table 1

Baseline Sample Characteristics (N = 6,137)

Variable	Mean (SD) or n (%)
3MSE score	95.1 (4.4)
Individual-level characteristics	
Age	70.2 (3.9)
Race/ethnicity	
Non-Hispanic White	5337 (87%)
Non-Hispanic Black	429 (7%)
Hispanic	157 (2.6%)
Other	214 (3.5%)
Educational attainment	
Less than high school	472 (7.7%)
High school graduate	1358 (22.1%)
Some college	2426 (39.5%)
College degree or higher	1881 (30.7%)
Household income	
Less than \$10,000	354 (5.8%)
\$10,000 to \$19,999	1176 (19.2%)
\$20,000 to \$34,999	1889 (30.8%)
\$35,000 to \$49,999	1282 (20.9%)
\$50,000 to \$74,999	915 (14.9%)
\$75,000 to \$99,999	305 (5%)
\$100,000 to \$149,999	150 (2.4%)
\$150,000 or more	66 (1.1%)
Marital status	
Never married	218 (3.6%)
Divorced or separated	781 (12.7%)
Widowed	1930 (31.4%)
Marriage-like relationship	52 (0.8%)
Married	3156 (51.4%)
Hysterectomy status	
No	3744 (61%)
Yes	2393 (39%)
Vascular factors	
History of or current coronary heart disease	588 (9.6%)
History of or current stroke	103 (1.7%)
History of or current diabetes	518 (8.4%)
History of or current hypertension	3289 (53.6%)
Health behavior factors	
Alcohol intake	

Variable	Mean (SD) or n (%)
No intake	2729 (44.5%)
< 1 drink/day	2735 (44.6%)
1 or more drinks / day	673 (11%)
Smoking Status	
Never smoked	3170 (51.7%)
Past smoker	2501 (40.8%)
Current smoker	466 (7.6%)
Physical activity	
No activity	1095 (17.8%)
Some activity of limited duration, frequency, or intensity	2752 (44.8%)
2 to 3 times/week [†]	981 (16%)
4 times/week [†]	1293 (21.1%)
Psychosocial factors	
Depressive symptoms	0.03 (0.1)
Social support	35.5 (7.9)
Social integration	2.6 (1.1)
NSES[‡]	75.4 (8.5)

[†] Moderate or strenuous activity 20 minutes duration

[‡] Across all WHIMS census tracts

Notes: 3MSE=Modified Mini-Mental Examination Score; NSES=Census tract-level neighborhood socioeconomic status

Table 2

Standardized Linear Regression Parameter Estimates (SE) for the Association Between Neighborhood Socioeconomic Status (NSES) and Global Cognitive Function

	Standardized β (SE)
Unadjusted	0.0235 (0.0015) ***
Model 1	0.0037 (0.0017) **
Model 2	0.0034 (0.0017) **
Model 3	0.0028 (0.0017) *
Model 4	0.0028 (0.0017) *

Notes: Global cognitive function is measured by the Modified Mini-Mental Examination Score; Global cognitive function is scaled in standard deviation units of $[-\log_e(102-3\text{MSE score})]$; Neighborhood socioeconomic status is measured at the census tract-level.

Model 1 adjusts for basic covariates (centered-median age, race/ethnicity, educational attainment, household income, marital status, and hysterectomy status)

Model 2 includes basic covariates + vascular factors (history of or current coronary heart disease, diabetes, stroke, and hypertension)

Model 3 includes basic covariates + behavior factors (alcohol intake, smoking status, and physical activity)

Model 4 includes basic covariates + psychosocial factors (depressive symptoms, social support, and social integration)

* $p < 0.10$;

** $p < 0.05$;

*** $p < 0.01$