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Original Contribution

Do Neighborhood Socioeconomic Deprivation and Low Social Cohesion Predict Coronary Calcification?

The CARDIA Study

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Growing evidence suggests that neighborhood characteristics may influence the risk of coronary heart disease. No studies have yet explored associations of neighborhood attributes with subclinical atherosclerosis in younger adult populations. Using data on 2,974 adults (1,699 women, 1,275 men) aged 32–50 years in 2000 from the Coronary Artery Disease Risk Development in Young Adults (CARDIA) Study and 2000 US Census block-group-level data, the authors estimated multivariable-adjusted associations of neighborhood socioeconomic deprivation and perceived neighborhood cohesion with odds of coronary artery calcification (CAC) 5 years later. Among women, the quartiles of highest neighborhood deprivation and lowest cohesion were associated with higher odds of CAC after adjustment for individual-level demographic and socioeconomic factors (for deprivation, odds ratio = 2.49, 95% confidence interval: 1.22, 5.08 (*P* for trend = 0.03); for cohesion, odds ratio = 1.87, 95% confidence interval: 1.10, 3.16 (*P* for trend = 0.02)). Associations changed only slightly after adjustment for behavioral, psychosocial, and biologic factors. Among men, neither neighborhood deprivation nor cohesion was related to CAC. However, among men in deprived neighborhoods, low cohesion predicted higher CAC odds (for interaction between neighborhood deprivation and cohesion, *P* = 0.03). This study provides evidence on associations of neighborhood deprivation and cohesion with CAC in younger, asymptomatic adults. Neighborhood attributes may contribute to subclinical atherosclerosis.

atherosclerosis; coronary disease; residence characteristics; risk factors; social environment

Abbreviations: CAC, coronary artery calcification; CARDIA, Coronary Artery Disease Risk Development in Young Adults; CHD, coronary heart disease; CI, confidence interval; OR, odds ratio; SEP, socioeconomic position.

Growing evidence suggests that neighborhood socioeconomic context may influence the risk of coronary heart disease (CHD) (1–6). Neighborhood socioeconomic position (SEP), reflecting the relative social and economic position of neighborhoods, may be closely linked to a variety of material/physical amenities and resources relevant to CHD risk (7). For instance, the local availability and quality of nutritious foods and green spaces plausibly contribute to CHD behavioral risk factors (8–12).

Aside from the material/physical environment, an attribute of the neighborhood social environment that may potentially shape CHD risk is social cohesion, defined as the presence of strong social bonds, including interpersonal trust (13). Posited mechanisms for health effects include diffusion of knowledge about health-related behaviors (e.g., dietary practices), maintenance of healthy behaviors through informal social control, generation of psychosocial processes including social support, and greater collective efficacy in improving local amenities and services (13). Social cohesion (or the related concept of social capital) at the state and community levels has predicted wide-ranging health outcomes, including obesity (14), self-rated health (15, 16), smoking (17), depression (18), and CHD incidence (19).

While researchers have explored the associations between neighborhood socioeconomic deprivation, social cohesion/capital, and individual health endpoints, few investigators

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have studied these neighborhood attributes in relation to coronary artery calcification (CAC), a marker for underlying CHD; to our knowledge, no investigators have done so in younger adult populations. Prospective analyses of asymptomatic adults have shown CAC to predict CHD (20–22).

The relations between neighborhood deprivation, cohesion, and individual CAC may vary by gender and race/ethnicity, as findings for related endpoints suggest. For instance, several studies have found stronger associations of neighborhood characteristics with CHD outcomes in women than in men (3, 5, 23) and in whites than in blacks (24). Neighborhood deprivation and low social cohesion may further act synergistically to affect health (25).

We used data from a population-based sample of younger adults to investigate associations of neighborhood deprivation and low perceived neighborhood cohesion with CAC. We hypothesized that higher deprivation and lower cohesion would each be associated with higher CAC prevalence. We looked for heterogeneous associations by gender (hypothesizing stronger associations in women) and race/ethnicity (positing stronger associations in whites) and explored whether associations of neighborhood cohesion with CAC were modified by neighborhood deprivation. We also investigated the extent to which psychosocial, behavioral, and biologic factors could explain the neighborhood associations.

MATERIALS AND METHODS

Study population

The Coronary Artery Disease Risk Development in Young Adults (CARDIA) Study is a prospective cohort study exploring predictors of the development of CHD risk factors in young adults (26). At the initial examination in 1985, the cohort consisted of 5,115 black and white men and women aged 18–30 years living in 4 US urban areas: Birmingham, Alabama; Chicago, Illinois; Minneapolis, Minnesota; and Oakland, California. Baseline response rates were 36.2% in Birmingham, 50.3% in Chicago, 58.7% in Minneapolis, and 65.0% in Oakland (26). In each area, the recruitment goal was to enroll adults in approximately equal numbers of blacks and whites, women and men, persons aged <25 years and ≥25 years, and persons with a high school education or less and persons with more than a high school education. Compared with eligible persons who did not participate at baseline, study subjects were more likely to be white, male, older, and more educated (26). The baseline examination included measures of established and putative CHD risk factors. Follow-up examinations took place in 1987, 1990, 1992, 1995, 2000, and 2005.

Outcome variable

CAC in the main coronary arteries (left main, left circumflex, left anterior descending, and right) was assessed at the 2005 examination using 2 computed tomography scans taken 1–2 minutes apart (3-mm slice thickness for electron-beam computed tomography and 2.5-mm slice thickness for multidetector computed tomography). A cardiovascular radiologist scored the scans with imaging software. A blinded expert adjudicated each scan set with at least 1 nonzero score and a random sample of scan sets. For scan sets with only 1 nonzero score judged to be artifactual, the score was set to zero. In 2000, there was high interreader agreement based on a similar adjudication process; 2 reviewers agreed in 91% of cases (95% of concordant scan sets, 82% of discordant scan sets).

The study outcome was a dichotomous variable corresponding to the presence or absence of CAC in 2005.

Predictor variables

Participants' residential addresses in 1995 were linked to 2000 US Census variables, including aggregate income, education, and occupational data, at the Census block-group level (as proxies for neighborhoods, with each containing 1,000 residents on average). Neighborhood characteristics in 2000 were examined in relation to CAC in 2005 to incorporate a plausible lag period for hypothesized effects of neighborhood characteristics. Prospective analyses with follow-up periods of less than a decade have found significant relations between higher neighborhood deprivation and CHD incidence (3, 5, 23). We used 6 block-group-level variables corresponding to dimensions of income/wealth (log of median household income, log of median value of housing units, and percentage of households receiving interest/dividend/net rental income), education (percentage of adults aged ≥25 years who had completed high school, percentage of adults aged ≥25 years who had completed college), and occupation (percentage of employed persons aged ≥16 years in executive/managerial/professional specialty occupations). For each variable, we derived a standardized z score. Neighborhood SEP scores were calculated by taking the mean value across all z scores, with lower scores indicating lower neighborhood SEP and higher socioeconomic deprivation (3).

Perceived neighborhood cohesion was measured in the 2000 CARDIA follow-up questionnaire as the individual's mean score on a 5-point Likert scale using the following 5 items (the last 2 items being reverse-coded): "People around here are willing to help their neighbors," "this is a close-knit neighborhood," "people in this neighborhood can be trusted," "people in this neighborhood generally don't get along with each other," and "people in this neighborhood do not share the same values." This scale has exhibited acceptable internal consistency reliability (27, 28).

Covariates

Data on individual-level covariates were gathered from the 2000 CARDIA examination and consisted of age, gender, race/ethnicity, income, education, health-care access (i.e., having a usual source of medical care), and study site. Neighborhood-level covariates and potential confounders consisted of the percentage black, immigrant concentration (mean of standardized percentages of Hispanics and foreign-born residents), and residential stability (mean of standardized percentages of persons living in the same house over

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Table 1. Individual- and Neighborhood-Level Demographic and Socioeconomic Characteristics of Participants in 2000 and the Presence of Coronary Artery Calcification in 2005, by Sex, Coronary Artery Disease Risk Development in Young Adults (CARDIA) Study[a,b]

	Women	Men
Individual characteristics ($n = 2{,}974$)		
No. of participants	1,699	1,275
Coronary artery calcification in 2005, %		
Yes	10.8	28.9
No	89.2	71.1
Perceived neighborhood cohesion[c]	3.7	3.6
Mean age, years	45.3 (3.7)	45.3 (3.6)
Race/ethnicity, %		
Black	48.6	41.2
White	51.4	58.8
Marital status, %		
Married/cohabitating	52.6	57.8
Divorced/separated/widowed	18.2	12.2
Never married	18.8	19.8
Other/missing data	10.4	10.2
Educational attainment, %		
High school or less	17.5	22.0
Some college/college	52.2	48.1
Graduate school	20.3	20.1
Unspecified/missing data	9.9	9.9
Annual household income ($US), %		
<16,000	8.5	6.2
16,000–34,999	15.2	12.2
35,000–49,999	14.4	13.6
50,000–74,999	20.7	18.2
75,000–99,999	12.0	15.4
≥100,000	18.4	23.5
Unspecified/missing data	10.9	10.9
Access to health care[d], %		
Yes	87.2	81.8
No	2.9	8.2
Unspecified/missing data	9.9	10.0

Table continues

the past 5 years and owner-occupied housing). These data were derived from the 2000 US Census.

Potential mediators

The following psychosocial, behavioral, and biologic factors measured in 2005 were explored as potential mediators of the associations of neighborhood characteristics with CAC: *psychosocial factors*—depression (depressive symptom scores of 0–100 on the Center for Epidemiologic Studies Depression Scale (29)); *behavioral factors*—physical activity (weighted average of the intensity of moderate and vigorous physical activity over the past year, in metabolic equivalents (30)) and smoking (number of cigarettes smoked per day); *biologic factors*—systolic/diastolic blood pressure (≥120/80 mm Hg), serum low density lipoprotein cholesterol (≥130 mg/dL), serum high density lipoprotein cholesterol (<40 mg/dL), fasting blood glucose (≥110 mg/dL), and body mass index (weight (kg)/height (m)^2; ≥30). The biologic factors have previously predicted CAC (31).

Statistical methods

We used multivariable logistic regression models to estimate the associations between higher neighborhood socioeconomic deprivation (equivalent to lower neighborhood SEP) and the odds of CAC and between lower perceived

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Table 1. Continued

	Women	Men
Study center, %		
Minneapolis, Minnesota	25.3	28.5
Birmingham, Alabama	22.1	24.5
Chicago, Illinois	22.7	22.8
Oakland, California	29.8	24.2
Neighborhood characteristics (n = 2,185)		
No. of distinct neighborhoods	1,237	948
Socioeconomic deprivation		
Median household income, 1,000 $US	52.8 (27.9)	52.6 (26.1)
Median house value, 1,000 $US	189.1 (146.1)	188.1 (139.4)
Mean % of households receiving interest, dividend, or rental income	37.9 (20.1)	39.1 (19.3)
Mean % of adults (aged ≥25 years) with high school education or more	83.1 (14.1)	85.3 (12.4)
Mean % of adults (aged ≥25 years) with college education or more	39.3 (22.9)	41.4 (21.8)
Mean % of persons aged ≥16 years employed in executive, managerial, or professional occupations	38.9 (18.4)	39.9 (17.6)
Mean % black	25.5 (33.1)	21.0 (30.2)
Mean % immigrant		
Hispanic	8.9 (13.5)	8.1 (12.0)
Foreign-born	12.1 (12.5)	11.9 (12.0)
Residential stability		
Mean % living in same household during the past 5 years	53.9 (15.3)	52.8 (15.8)
Mean % living in owner-occupied housing	62.8 (27.3)	61.8 (27.5)

[a] For continuous variables, mean values (with standard deviations in parentheses) are displayed. For categorical variables, the percentage of the sample (women or men) in each category is shown.
[b] Data on individual-level characteristics (except for coronary artery calcification) were collected in 2000. The presence of coronary artery calcification was ascertained in 2005. Data on neighborhood characteristics were derived from the 2000 US Census (with addresses ascertained in 1995).
[c] Range of scores was 1–5 in both women and men; higher values indicate higher perceived neighborhood cohesion.
[d] Defined as having a usual source of medical care.

neighborhood cohesion and the odds of CAC. Given the overall average of 1.4 participants per neighborhood and the small intraclass correlation (~0), multilevel models/methods to account for within-neighborhood correlations were not applied. Findings from the multivariable regression models are reported.

In all models, the highest levels of neighborhood SEP and cohesion served as the reference categories. An indicator variable was used to code for missing values on cohesion (comprising approximately 10% of observations in each of women and men). To test for trend, we modeled quartiles of higher neighborhood deprivation/lower cohesion (after excluding missing values) as an ordinal variable and noted the associated P value.

To assess the presence of mediation, we looked for attenuation in the odds ratio estimates for neighborhood deprivation/low cohesion after each set of risk factors was added to the respective model.

All reported findings are stratified by gender. A stronger positive association was observed between higher neighborhood deprivation and CAC in women than in men. In the gender-combined model, cross-product terms corresponding to the interactions between the higher quartiles of neighborhood deprivation and gender were jointly significant ($P = 0.001$). No significant interactions were observed between race/ethnicity and neighborhood SEP or cohesion; in models stratified by race/ethnicity, similar but less precise point estimates were observed for blacks and whites. Therefore, our reported results are stratified by gender and adjusted for race/ethnicity.

We further tested for effect modification of the association between low neighborhood cohesion and CAC by

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neighborhood deprivation (dichotomized using the median neighborhood SEP score) in both women and men.

In supplementary analyses, we repeated the main analyses for participants who were living in the same homes in 1995 and 2000. In addition, to check the robustness of our findings, we employed multiple imputation methods to impute missing values for CAC and cohesion (by creating multiply imputed data sets using logistic regression and combining the results) (32). We also repeated the main analyses using linear regression, modeling the outcome as continuous (logarithm of CAC score plus 1).

RESULTS

Addresses in 1995 for 3,320 of the 3,549 study participants (93.5%) seen at the 2005 CARDIA examination were linked to 2000 US Census block-group-level variables. Exclusion of participants with missing CAC values in 2005 yielded a total sample of 2,974 persons (1,699 women and 1,275 men, of whom 184 and 369 had CAC, respectively) in 2,185 neighborhoods (Table 1). Approximately two-thirds of women (63%) and men (64%) lived in the same homes in 1995 and 2000.

The mean age of the overall sample in 2000 was 45.3 years (range, 32–50 years); 57.1% were female, 54.6% were white, and 45.4% were African-American. Women were more likely to be African-American and to report lower income and education, although gender differences by income and education were not large. There were no substantial differences in neighborhood characteristics between men and women. CAC prevalence was substantially lower in women (10.9% in women vs. 28.9% in men). A comparison of the 2005 and 1985 baseline samples of women and men (by race/ethnicity, income, and education) suggested greater selective attrition in men.

Internal consistency reliability estimates for the neighborhood SEP and cohesion measures were high (Cronbach's α values were 0.94 and 0.82, respectively). In the overall sample, neighborhood SEP scores were strongly inversely correlated with the percentage of black residents ($r = -0.63$), weakly inversely correlated with the percentage of immigrants ($r = -0.13$), and positively correlated with residential stability ($r = 0.21$). Higher neighborhood SEP and residential stability were positively correlated with neighborhood cohesion ($r = 0.26$ and $r = 0.17$, respectively). Being female, being white, having a higher income, being widowed, divorced, or separated, and never being married were also related to higher cohesion.

In women (Table 2), the highest quartile of neighborhood deprivation was associated with 2.49 times' higher odds of CAC, controlling for covariates and perceived neighborhood cohesion (P for trend = 0.03; model 2). Persons in the quartile corresponding to the lowest level of cohesion had 1.87 times' higher adjusted odds of CAC than persons in the quartile of highest cohesion (P for trend = 0.02; model 2). Associations of neighborhood deprivation and cohesion with CAC were very similar before and after adjustment for individual sociodemographic and socioeconomic characteristics (compare model 1 with model 2). Additional adjustment for physical activity and smoking slightly attenuated associations with neighborhood deprivation (model 3), and separate adjustment for Center for Epidemiologic Studies Depression Scale score slightly attenuated associations with cohesion (model 4), although both main effects remained statistically significant. Adjustment for biologic factors (model 5) also resulted in minor changes. When all potential risk-factor mediators were added, the neighborhood associations remained but were no longer statistically significant for deprivation (for quartile of highest deprivation, odds ratio (OR) = 2.02, 95% confidence interval (CI): 0.95, 4.32 (P for trend = 0.16); for quartile of lowest cohesion, OR = 1.80, 95% CI: 1.02, 3.16 (P for trend = 0.04)).

Neighborhood deprivation was not associated with CAC in men (Table 3). Men in quartiles 2, 3, and 4 of neighborhood cohesion (indicating lower levels of cohesion) had higher CAC odds than those in the lowest quartile, but confidence intervals were wide and only the estimate for quartile 2 was statistically significant; there was no dose-response trend. These estimates were largely unchanged after adjustment for individual-level risk factors.

Table 4 shows associations of neighborhood cohesion with CAC for men in deprived and nondeprived neighborhoods separately. The interaction between neighborhood deprivation and cohesion was statistically significant ($P = 0.03$). In deprived neighborhoods, all 3 lower quartiles of cohesion were associated with higher odds of CAC in comparison with the highest quartile, with a marginally statistically significant trend ($P = 0.07$). No association between social cohesion and CAC was seen in men in nondeprived neighborhoods (model 1). For women, lower cohesion predicted higher odds in both deprived and nondeprived neighborhoods, although associations were significant only in nondeprived neighborhoods (data not shown; for interaction between neighborhood deprivation and cohesion, $P = 0.34$).

After restricting the main analyses to persons living in the same homes in 1995 and 2000, neighborhood deprivation associations adjusted for demographic/socioeconomic covariates and neighborhood cohesion became stronger in women (for quartile of highest deprivation, OR = 3.93, 95% CI: 1.52, 10.13) and were relatively unchanged in men.

In multiple imputation analyses, odds ratio point estimates for neighborhood deprivation and cohesion differed by less than 10% in comparison with corresponding estimates from models without imputation.

With the logarithm of (CAC score + 1) as the outcome, we observed qualitatively similar patterns. For example, in women, the highest quartile of neighborhood deprivation was associated with a 26% higher CAC score ($P = 0.02$); the lowest level of cohesion was associated with a 14% higher CAC score ($P = 0.08$).

DISCUSSION

We found independent, graded associations of higher neighborhood deprivation and lower social cohesion with the presence of CAC 5 years later in women. No associations were observed in men overall. However, low social cohesion was associated with higher odds of CAC among

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Table 2. Odds Ratios for Coronary Artery Calcification Among Women in 2005 Associated With Neighborhood- and Individual-level Characteristics in 2000 ($n = 1{,}699$), Coronary Artery Disease Risk Development in Young Adults (CARDIA) Study

	Model 1		Model 2		Model 3		Model 4		Model 5	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Neighborhood-level predictors										
Quartile of socioeconomic deprivation[a]										
2	1.89*	1.13, 3.18	1.81*	1.06, 3.11	1.80*	1.05, 3.09	1.75*	1.01, 3.01	1.74	0.99, 3.04
3	1.47	0.83, 2.60	1.44	0.79, 2.63	1.38	0.75, 2.53	1.29	0.70, 2.38	1.45	0.78, 2.70
4	2.46*	1.26, 4.82	2.49*	1.22, 5.08	2.39*	1.17, 4.91	2.22*	1.07, 4.58	2.43*	1.16, 5.09
P for trend	0.02		0.03		0.046		0.08		0.04	
Quartile of low perceived neighborhood cohesion[a]										
2	1.25	0.74, 2.11	1.24	0.73, 2.11	1.23	0.72, 2.09	1.18	0.68, 2.02	1.30	0.76, 2.24
3	1.56	0.96, 2.55	1.47	0.89, 2.43	1.44	0.87, 2.40	1.43	0.86, 2.38	1.53	0.91, 2.58
4	1.84*	1.11, 3.07	1.87*	1.10, 3.16	1.77*	1.03, 3.02	1.89*	1.11, 3.22	1.83*	1.06, 3.17
P for trend	0.01		0.02		0.04		0.02		0.03	
Individual-level potential mediators										
Center for Epidemiologic Studies Depression Scale score[b]					1.10	0.94, 1.28				
Intensity of physical activity[b,c]							0.88	0.74, 1.06		
Smoking, cigarettes/day[b]							1.37**	1.21, 1.55		
Blood pressure (≥120/80 mm Hg)									1.84**	1.30, 2.60
Low density lipoprotein cholesterol (≥130 mg/dL)									1.49*	1.04, 2.15
High density lipoprotein cholesterol (<40 mg/dL)									2.24**	1.37, 3.65
Fasting glucose concentration (≥110 mg/dL)									1.30	0.79, 2.14
Body mass index[d] (≥30)									1.20	0.85, 1.72

* $P < 0.05$; ** $P < 0.01$.

Abbreviations: CI, confidence interval; OR, odds ratio.

[a] Quartile 1 for deprivation (reference category) corresponds to the quartile with the least socioeconomically deprived (i.e., "richest") neighborhoods. Quartile 1 for cohesion (reference category) contains the persons with the highest perceived level of neighborhood cohesion. In all models, results were also adjusted for the neighborhood percentage black, percentage immigrant, and residential stability and for individual age, race/ethnicity, marital status, educational attainment, household income, access to health care, and study center—except for model 1 (results were adjusted for neighborhood characteristics and study center only).

[b] Odds ratios correspond to a 1-standard-deviation change in the risk factor.

[c] Weighted average of the intensity of moderate and vigorous physical activity over the past year, in metabolic equivalents (30).

[d] Weight (kg)/height (m)^2.

men living in poorer neighborhoods, although no clear dose-response was found.

A key strength of our analysis was the investigation of an established marker of subclinical atherosclerosis in young adults. This helped us to avoid biases that may occur in cross-sectional analyses of prevalent clinical outcomes when clinical symptomatic disease influences residential location. Moreover, the investigation of CAC in a young adult sample allows the detection of associations with very early disease, long before it becomes symptomatic. Thus, our analyses demonstrated that, particularly in women, neighborhood characteristics predict the presence of very early disease.

Our finding that neighborhood characteristics predict very early CHD agrees with past studies of neighborhood deprivation and subclinical atherosclerosis (33–36). To our knowledge, this study is among the first to document this relation in younger adults, and represents the first US study of these characteristics and coronary calcification. Our findings are also consistent with the magnitude of associations between neighborhood deprivation and CHD incidence/mortality documented in prospective studies (3, 5, 36). They add

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Table 3. Odds Ratios for Coronary Artery Calcification Among Men in 2005 Associated With Neighborhood- and Individual-level Characteristics in 2000 ($n = 1,275$), Coronary Artery Disease Risk Development in Young Adults (CARDIA) Study

	Model 1		Model 2		Model 3		Model 4		Model 5	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Neighborhood-level predictors										
Quartile of socioeconomic deprivation[a]										
2	0.71	0.49, 1.03	0.75	0.51, 1.10	0.77	0.52, 1.14	0.74	0.50, 1.10	0.73	0.49, 1.10
3	0.88	0.59, 1.30	1.00	0.65, 1.54	0.96	0.62, 1.48	0.99	0.64, 1.52	0.94	0.60, 1.47
4	1.04	0.62, 1.76	1.18	0.67, 2.10	1.19	0.67, 2.13	1.13	0.63, 2.02	1.20	0.66, 2.18
P for trend	0.85		0.47		0.56		0.57		0.53	
Quartile of low perceived neighborhood cohesion[a]										
2	1.55*	1.05, 2.28	1.54*	1.03, 2.30	1.52*	1.01, 2.29	1.54*	1.03, 2.30	1.61*	1.06, 2.46
3	1.32	0.91, 1.92	1.46	0.98, 2.16	1.54*	1.03, 2.29	1.46	0.98, 2.16	1.46	0.97, 2.21
4	1.35	0.91, 2.01	1.45	0.94, 2.22	1.49	0.96, 2.31	1.48	0.96, 2.27	1.48	0.95, 2.32
P for trend	0.24		0.14		0.09		0.12		0.15	
Individual-level potential mediators										
Center for Epidemiologic Studies Depression Scale score[b]					1.13	0.99, 1.29				
Intensity of physical activity[b,c]							1.01	0.88, 1.15		
Smoking, cigarettes/day[b]							1.10	0.97, 1.25		
Blood pressure (≥120/80 mm Hg)									1.32	1.00, 1.74
Low density lipoprotein cholesterol (≥130 mg/dL)									1.49*	1.12, 1.98
High density lipoprotein cholesterol (<40 mg/dL)									1.06	0.79, 1.44
Fasting glucose concentration (≥110 mg/dL)									1.15	0.78, 1.69
Body mass index[d] (≥30)									1.58*	1.16, 2.14

* $P < 0.05$.

Abbreviations: CI, confidence interval; OR, odds ratio.

[a] Quartile 1 for deprivation (reference category) corresponds to the quartile with the least socioeconomically deprived (i.e., "richest") neighborhoods. Quartile 1 for cohesion (reference category) contains the persons with the highest perceived level of neighborhood cohesion. In all models, results were also adjusted for the neighborhood percentage black, percentage immigrant, and residential stability and for individual age, race/ethnicity, marital status, educational attainment, household income, access to health care, and study center—except for model 1 (results were adjusted for neighborhood characteristics and study center only).

[b] Odds ratios correspond to a 1-standard-deviation change in the risk factor.

[c] Weighted average of the intensity of moderate and vigorous physical activity over the past year, in metabolic equivalents (30).

[d] Weight (kg)/height (m)^2.

substantially to the limited existing research on the relation between social cohesion/capital and CHD, which is largely confined to ecologic studies and non-US studies that used single-item measures of social cohesion/capital (37, 38). The present study advances the literature by showing that social cohesion predicts subclinical atherosclerosis, even in a relatively young adult sample.

We estimated neighborhood characteristics 5 years before CAC assessment, making the temporal relation in our data compatible with causation. Strengths of our analysis include the use of a demographically and socioeconomically diverse sample. Furthermore, we adjusted for multiple neighborhood- and individual-level potential confounders and predictors of CAC, which should have limited residual confounding.

In several prospective studies of neighborhood deprivation and CHD incidence and mortality, researchers have found stronger associations in women than in men (3, 5, 23). Similar differences have been observed in analyses of subclinical carotid artery intima-media wall thickness (34, 36). In a German study of neighborhood deprivation and coronary calcification, Dragano et al. (35) found a less clear pattern, although they primarily used the neighborhood

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Table 4. Odds Ratios for Coronary Artery Calcification Among Men in 2005 Associated with Perceived Neighborhood Cohesion in 2000, According to Residence in a Deprived Neighborhood, Coronary Artery Disease Risk Development in Young Adults (CARDIA) Study

	Model 1		Model 2		Model 3		Model 4	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Living in a socioeconomically deprived neighborhood ($n = 668$)[a]								
Neighborhood-level predictors								
Quartile of low perceived neighborhood cohesion								
2	3.66**	1.77, 7.55	3.35**	1.61, 6.95	3.68**	1.78, 7.62	4.46**	2.01, 9.91
3	3.29**	1.62, 6.67	3.32**	1.63, 6.74	3.32**	1.63, 6.74	3.77**	1.73, 8.24
4	3.02**	1.46, 6.25	2.89**	1.38, 6.04	3.08**	1.48, 6.42	3.77**	1.69, 8.43
P for trend	0.07		0.06		0.06		0.04	
Individual-level potential mediators								
CES-D score[b]			1.10	0.91, 1.34				
Intensity of physical activity[b,c]					0.97	0.80, 1.17		
Smoking, cigarettes/day[b]					1.12	0.96, 1.32		
Blood pressure (≥120/80 mm Hg)							1.30	0.87, 1.94
LDL cholesterol (≥130 mg/dL)							1.31	0.86, 2.00
HDL cholesterol (<40 mg/dL)							1.26	0.82, 1.94
Fasting glucose concentration (≥110 mg/dL)							1.23	0.73, 2.09
Body mass index[d] (≥30)							1.39	0.90, 2.14
Not living in a socioeconomically deprived neighborhood ($n = 607$)[a]								
Neighborhood-level predictors								
Quartile of low perceived neighborhood cohesion								
2	0.97	0.57, 1.65	0.98	0.57, 1.68	0.97	0.57, 1.65	0.99	0.57, 1.72
3	0.97	0.57, 1.65	1.00	0.59, 1.71	0.98	0.57, 1.66	1.00	0.58, 1.74
4	1.04	0.57, 1.90	1.14	0.61, 2.10	1.06	0.58, 1.96	0.95	0.50, 1.80
P for trend	0.84		0.65		0.80		0.98	
Individual-level potential mediators								
CES-D score[b]			1.18	0.97, 1.42				
Intensity of physical activity[b]					1.01	0.82, 1.24		
Smoking, cigarettes/day[b]					1.10	0.86, 1.40		
Blood pressure (≥120/80 mm Hg)							1.29	0.85, 1.94
LDL cholesterol (≥130 mg/dL)							1.61*	1.07, 2.42
HDL cholesterol (<40 mg/dL)							0.90	0.57, 1.42
Fasting glucose concentration (≥110 mg/dL)							1.05	0.57, 1.94
Body mass index (≥30)							1.96**	1.24, 3.10

* $P < 0.05$; ** $P < 0.01$.

Abbreviations: CES-D, Center for Epidemiologic Studies Depression Scale; CI, confidence interval; HDL, high density lipoprotein; LDL, low density lipoprotein; OR, odds ratio.

[a] Quartile 1 for cohesion (reference category) contains the persons with the highest perceived level of neighborhood cohesion. In all models, results were also adjusted for the neighborhood percentage black, percentage immigrant, and residential stability and for individual age, race/ethnicity, marital status, educational attainment, household income, access to health care, and study center.

[b] Odds ratios correspond to a 1-standard-deviation change in the risk factor.

[c] Weighted average of the intensity of moderate and vigorous physical activity over the past year, in metabolic equivalents (30).

[d] Weight (kg)/height (m)^2.

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unemployment rate as the measure of neighborhood SEP. Empirical evidence also suggests that dietary factors, physical activity, and smoking behaviors are more responsive to neighborhood socioeconomic environments in women than in men (39, 40). These gender differences could result from gender differences in health-related behavioral responses to neighborhood perceptions (e.g., varying perceptions of crime/physical safety contributing to differential levels of physical activity). Furthermore, the gender discrepancies could be due to differences in the degree and type of neighborhood exposures, which in turn may be shaped by domestic and work-related gender roles. For example, women may be less likely to be employed full-time and may plausibly spend greater proportions of time in the neighborhood due to child care and domestic chores. Conversely, men may be more likely to work full-time and to be exposed to psychosocial stressors in the workplace, some of which may be linked to CHD incidence (e.g., job strain) (41, 42). In a supplementary exploratory analysis, employment status modified the estimated effects of neighborhood deprivation in women (in the full-time stratum, highest-quartile OR = 1.12, 95% CI: 0.44, 2.82; in the non-full-time stratum, highest-quartile OR = 7.15, 95% CI: 1.49, 34.4 (P for interaction = 0.02)). No effect modification was seen in men, although the sample size in the non-full-time stratum was limited ($n = 161$) (data not shown).

Our study suggested only partial mediation of neighborhood effects by risk factors, at best. There were suggestions of modest mediation of neighborhood deprivation effects by behavioral factors (i.e., smoking, physical activity) and of social cohesion effects by depression. Evidence of mediation by biologic factors was also limited. While previous studies have similarly found limited evidence of mediation by modifiable risk factors (3), our ability to examine mediation may have been compromised by measurement error, the timing of measures, and the particular potential mediators considered. In addition, while we hypothesized these sets of risk factors primarily as potential mediators, our study design could not allow us to distinguish mediation from confounding. A fuller account of mediating pathways would require data different from those available to us (including longitudinal assessments of mediators and assessments of confounders of the mediator-CAC relations).

Lower neighborhood cohesion predicted higher CAC prevalence among men in poorer (but not richer) neighborhoods. Plausibly, resources available in richer neighborhoods (e.g., abundant green spaces for leisure) may buffer the adverse effects of low cohesion on CAC. The similar associations observed for the 3 lowest quartiles versus the highest quartile might reflect a threshold effect. We lack a clear explanation for why this effect modification was observed in men only, and replication in other studies is needed. We did not find that high family income versus low family income had a similar modifying effect on the associations for low cohesion in men (data not shown), suggesting that individual income was not driving the observed interaction.

Previous studies, including the Whitehall studies, have found graded associations between individual SEP and CHD which persist after controlling for behavioral and biologic risk factors (43). The persistence of this gradient across places and time periods suggesting multiple pathways to disease has characterized individual SEP as a ''fundamental cause'' of health and disease (44). To the extent that neighborhood SEP and cohesion may mobilize and shape more proximal specific neighborhood dimensions (such as access to healthy foods and recreation (45, 46) or neighborhood sources of stress) over time, which may in turn shape individual-level risk factors, neighborhood SEP and cohesion may be considered contextual ''fundamental causes'' of health (44, 47). Therefore, explaining the associations between these key neighborhood attributes and disease according to selected risk factors may be particularly challenging. Nevertheless, in future work, investigators should attempt to carefully elucidate the specific pathways through which these distal causes may operate in order to identify promising interventions for CHD prevention. Furthermore, corresponding to these factors as ''fundamental causes,'' more fundamental approaches (e.g., mixed-income housing initiatives) to reduce gaps in neighborhood SEP and social capital should be explored for their potential to reduce CHD inequalities.

Our study had several limitations. First, participants' residential addresses were ascertained in 1995 and characterized on the basis of 2000 US Census data. Some study participants had moved into other neighborhoods by the time of CAC assessment in 2005. If the relevant exposure time frame for the development of CAC is between neighborhood assessment and CAC assessment, misclassification related to residential mobility subsequent to the 1995 assessment could have led to underestimation of the true associations. On the basis of information corresponding to residence in 1995 and 2000, we did in fact observe stronger associations for neighborhood deprivation among women who did not move. However, if neighborhood of residence assessed in 1995 is a reliable proxy for prior (life-course) exposures related to CAC development, subsequent residential mobility may not have introduced substantial bias. Second, despite the diverse characteristics of the cohort at inception, both nonresponse and cohort attrition may have limited the generalizability of the findings to younger-to-middle-aged US adult urban populations. Third, because of insufficient numbers of participants per neighborhood, perceived neighborhood cohesion was modeled at the individual level, not the neighborhood level. Unadjusted individual-level characteristics (such as affective states) may have influenced such perceptions while also determining CAC, resulting in residual confounding.

In summary, this study offers novel evidence on the associations of neighborhood deprivation and low cohesion with CAC in younger, asymptomatic adults. The associations appear to be relatively uniformly present in women, whereas in men the adverse effects of low cohesion seem confined to those living in deprived neighborhoods. Future investigations should build on these findings, including gender differences and mediating pathways, to better elucidate the contextual and individual-level determinants of CHD and thereby optimize the design of effective prevention strategies.

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