Community Socioeconomic Status is Associated With Circulating Interleukin-6 and C-Reactive Protein

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Objective: To examine the association of both individual and community socioeconomic status (SES) with inflammatory mediators relevant to cardiovascular pathophysiology, i.e., interleukin (IL)-6 and C-reactive protein (CRP), in a midlife community sample. Growing evidence suggests that socioeconomic attributes of both individuals and communities confer risk for cardiovascular morbidity and mortality. **Methods:** Subjects were 851 men and women, 30 to 54 years of age (Caucasian = 77%, African-American = 23%). Individual SES was indexed by a composite of educational attainment and family income, and community SES was indexed by corresponding indicators derived from US Census data for participants' census tracts of residence. Plasma concentrations of IL-6 and CRP were determined from blood samples. **Results:** Regression analyses adjusting for age, sex, and race showed individual SES to be associated inversely with IL-6 ($B = -0.126$, $p < .01$), and community SES to be associated inversely with both IL-6 and CRP ($B = -0.144$, $p < .01$, $B = -0.097$, $p < .01$, respectively). The relationship of community SES with IL-6, but not CRP, persisted on multivariable adjustment for both lifestyle risk factors (smoking, alcohol consumption, sleep, exercise, body mass index) and individual SES (IL-6: $B = -0.084$, $p < .05$; CRP: $B = -0.047$, $p > .10$). After adjustment for lifestyle factors, however, individual SES was no longer associated with IL-6. **Conclusions:** Independent of personal income or educational attainment, midlife adults living in less advantaged neighborhoods exhibit higher levels of circulating proinflammatory markers than residents of more affluent areas. This association may help explain the increased risk of atherosclerotic cardiovascular morbidity and mortality conferred by low community-level SES. **Key words:** community socioeconomic status, SES, IL-6, CRP, inflammation.

SES = socioeconomic status; **CRP** = C-reactive protein; **IL-6** = interleukin-6; **BMI** = body mass index; **ICC** = intraclass correlation coefficient.

INTRODUCTION

Inflammation is now recognized as playing a key role in the pathogenesis of atherosclerotic cardiovascular disease (1). Two circulating markers of inflammation, C-reactive protein (CRP) and interleukin (IL)-6, have emerged as predictors of future cardiovascular pathology and mortality in epidemiologic studies of midlife healthy men (2,3) and women (4), postmenopausal women (5), and older adults (6). Interestingly, levels of these peripheral proinflammatory mediators also covary inversely with the individuals' socioeconomic status (SES)—another known risk factor for cardiovascular disease (7–9). These associations with SES indicators are robust with respect to circulating levels of CRP (10–17), but less consistent among studies reporting variation in IL-6 (15,17–22). Inconsistent findings may result from the differential consideration of health practices, such as smoking, physical activity, and body mass, that covary with individual SES and are related to activation of innate inflammatory pathways (15,18).

Recent evidence suggests that social inequalities germane to cardiovascular risk are not fully captured by personal socioeconomic indices, such as income and educational attainment, but extend independently to qualities of individuals' communities of residence (23,24). Measures of community SES often include area rates of unemployment and poverty, distribution of educational attainment, costs of housing, rates of vehicle or home ownership, or median household income, as typically assessed at the level of census tracts, postal districts, or electoral wards. To the extent that socioeconomic variation is associated with inflammation, it is possible that the socioeconomic characteristics of communities contribute to variability in circulating levels of inflammatory mediators. To date, limited research has investigated this hypothesis. A recent epidemiologic study showed peripheral CRP levels to covary inversely with community SES in the United States (25). However, this relationship did not withstand cardiovascular disease risk factor adjustment. In regard to IL-6, elevated levels have been shown among urban slum dwellers when compared with middle class residents in India (26). The purpose of the present study was to further examine associations of individual and community measures of SES with the inflammatory mediators, IL-6 and CRP, among a diverse community sample of relatively healthy midlife volunteers.

METHODS

Participants

This investigation was based on data derived from 1081 adults (49.3% male; 77% European American, 23% African-American) who participated in the University of Pittsburgh Adult Health and Behavior (AHAB) project between 2001 and 2005. The AHAB registry is a compendium of behavioral and biological measurements on midlife community volunteers who were recruited, via mass-mail solicitation, from Southwestern Pennsylvania (principally Allegheny County). Registry data include sociodemographic measurements; indices of personality and temperament; psychiatric history and symptomatology; aspects of social and cognitive functioning (e.g., cognitive abilities, memory, and executive processes); health-impairing attributes of habit and lifestyle; biological measurements germane to cardiovascular, autonomic,

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metabolic, endocrine, immune, and central nervous system functioning; and deoxyribonucleic acid (DNA) for the study of genetic variation associated with registry phenotypes (27–31). Exclusions from AHAB participation included age <30 or >54 years; a reported history of atherosclerotic cardiovascular disease, chronic kidney or liver disease; cancer treatment in the preceding year; and major neurological disorders, schizophrenia or other psychotic illness. Other exclusions included pregnancy and the use of insulin, glucocorticoid, antiarrhythmic, psychotropic, or prescription weight loss medications. Data collection occurred over multiple laboratory sessions, and informed consent was obtained in accordance with approved protocol and guidelines of the University of Pittsburgh Institutional Review Board.

Because AHAB exclusions did not include common acute illnesses, such as recent colds or allergies, data of participants having circulating IL-6 levels of >10 pg/ml or CRP levels of >10 mg/L were not included in the current analyses. Overall, 230 subjects were excluded due to elevated inflammatory markers or absence of an identifiable census tract (e.g., an address coded by P.O. number), yielding a final sample of 851 individuals. This sample included 424 men and 427 women; 77% of participants were European American and 23% were African-American. These subjects did not differ in age, income, education, sex, or ethnic distribution from AHAB participants who were excluded from the present analyses due to elevated inflammatory markers or unknown census tract.

Procedure

Before arrival at the laboratory, participants were asked to fast for 8 hours and avoid exercise for 12 hours, alcohol for 24 hours, and nicotine for 1 hour. All sessions were scheduled in the morning. On arrival at the laboratory, the project nurse completed a medical history and medication use interview, obtained measurements of height and weight for the determination of body mass index (BMI), and drew a 40-mL blood sample in citrate treated tubes. A portion of the blood sample was spun down and plasma was collected and stored at −80°C until batched analysis of IL-6 and CRP levels.

Measures

Socioeconomic Status

Individual SES

Participants were asked to report their years of education, highest level of academic attainment, and current annual (pretax) family income. Subjects were well educated on average, with a mean ± standard deviation of 15.3 ± 2.8 years of schooling. Nonetheless, levels of educational attainment varied appreciably among study participants, with 5% lacking a high school diploma (coded 1), 19% having completed high school or technical training only (coded 2), 24% with some college (coded 3), 34% with a Bachelor's degree (coded 4), 15% with Master's degree (coded 5), and 4% with PhD or doctoral-level professional degree (coded 6). Family income also varied substantially across participants, within the following ranges: (coded 1—$15,000 (13.5%); coded 2—$15,000 to $24,999 (9.1%); coded 3—$25,000 to $34,999 (11/6%); coded 4—$35,000 to $49,999 (15.7%); coded 5—$50,000 to $64,999 (15.8%); coded 6—$65,000 to $80,000 (12.7%); and coded 7—>$80,000 (21.6%). An index of individual-level SES was calculated by standardizing the distributions of educational achievement (highest level attained) and bracketed range of family income across subjects, averaging the resulting Z scores for each individual, and restandardizing the resulting distribution (0 ± 1). For four subjects lacking income data, individual SES was determined from educational attainment alone.

Community SES

Participants' home addresses were used to identify their census tracts of residence based on the 2000 US Census (http://www.census.gov/main/www/cen2000.html). Census tracts are geographical areas established to reflect a relatively homogeneous group of approximately 4000 people (range = 2500–8000) and 1500 housing units (range = 1000–3000). For each of the 285 identified tracts, we extracted census data pertaining to the population distributions of educational attainment and household income. Following the work of Gump, Matthews, and Raikkonen (32), a single measure of tract-level educational status was calculated by the formula:

$$\{[1 \times (\text{number of adults [>25 years] reporting less than completed high school education/number of adults in the census tract})] + [2 \times (\text{number of adults with a high school diploma or equivalent [or technical training]/number of adults in the census tract})] + \cdots + [6 \times (\text{number of adults reporting professional or doctoral degrees/number of adults in the census tract})]\}.$$

The six categories of highest completed schooling used to derive our tract-level index of education were the same as those used to categorize educational attainment at the individual level. A corresponding index of tract-level income status was calculated by the same formula, but substituting for level of education the number of households having incomes within the same bracketed ranges used to categorize personal family income and, in the denominator, the number of households (rather than individuals) in the census tract. Due to a minor difference in income ranges reported in AHAB and the census database, the highest range of household income was defined as household income of >$75K at the tract level and >$80K at the individual level.

A single measure of community SES was then calculated as the average of standardized scores for the census-derived education and income variables. As with individual SES, this continuous index of community SES—where higher values reflect more advantaged communities—was then restandardized (0 ± 1). Illustrating the variability of community SES in this sample, the mean values of several census indicators for the upper and lower quartiles of the distribution of community SES were: $61,260 and $22,465 in median household income; 5.5% and 26.4% of households living below the federally designated poverty level; 3.1% and 11.8% of the workforce unemployed; and 53.4% and 10.9% of adults >25 years having a college education. Across subjects, community SES correlated significantly with individual SES ($r_{849} = 0.52$, $p < .0001$) as well as with its two components, educational attainment ($r_{849} = 0.41$, $p < .0001$) and current annual income ($r_{845} = 0.45$, $p < .0001$), indicating that participants with lower incomes and less education tended also to live in less advantaged communities. Nevertheless, variability in the economic and material circumstances of the census tracts represented here could be accounted for only partially by overlapping variation in individual SES.

IL-6

IL-6 levels were determined using a high sensitivity quantitative sandwich enzyme immunoassay kit (R&D Systems, Minneapolis, Minnesota) according to manufacturer's directions. The assay standard range is from 0.156 to 10 pg/ml. IL-6 levels were extrapolated from a standard curve with linear regression from a log-linear curve. All samples were run in duplicate and the average coefficient of variation (CV) between samples was 5%. Reciprocal transformation was applied to normalize raw score distributions of the IL-6 values.

CRP

CRP was measured using the BNII nephelometer from Dade Behring utilizing a particle enhanced immunonephelometric assay. In this procedure, polystyrene particles are coated with monoclonal antibodies to CRP, which, in the presence of antigen agglutinate cause an increase in the intensity of scattered light. The increase in scattered light is proportional to the amount of CRP in the sample. The assay range is 0.175 to 1100 mg/L. Intra-assay CVs range from 2.3% to 4.4% and inter-assay CVs range from 2.1% to 5.7%. Final CRP values were normalized by reciprocal transformation.

Additional Variables

A number of variables were assessed that might explain associations between SES and inflammation. These variables included age, sex, race, BMI, smoking status, alcohol use, sleep volume, and physical activity. Smoking

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TABLE 1. Bivariate Correlations with Covariates, CRP, IL-6, and Community SES (n = 851)

Characteristic	Total Sample Mean ± SD	CRP r	IL-6 r	Comm SES r
Age (years)	44.9 ± 6.5	−.035	.036	0.114[a]
Gender (% male)	49.8	.057[c]	−.080[b,c]	−0.009[c]
Race (% black)	23	.094[a,c]	.162[a,c]	−0.411[a,c]
BMI (kg/m$^{2)}$	27.5 ± 5.7	.484[a]	.306[a]	−0.128[a]
Smoking (% current)	18	.055[c]	.206[a,c]	−0.226[a,c]
Exercise (kilocalories)	2407 ± 1836	−.120[a]	−.149[a]	0.147[a]
Alcohol (drinks/week)	0.97 ± 0.96	−.049	.039	0.059
Sleep (hours/week)	47.7 ± 7.5	−.046	−.093[a]	0.086[b]
SES				
Individual	0 ± 1	−.120[b]	−.182[a]	0.520[a]
Community	0 ± 1	−.142[a]	−.201[a]	

Individual and community socioeconomic status (Comm SES) indices are expressed as z scores (mean ± standard deviation (SD) = 0 ± 1). Race coded 0 = White, 1 = Black. IL = interleukin; BMI = body mass index; smoking status (0 = not current, 1 = current); correlations were conducted on the transformed C-reactive protein (CRP), IL-6, alcohol, and exercise variables, but signs were reversed in the table for ease of interpretation.

[a] $p < .01$.

[b] $p < .05$.

[c] Point biserial correlation.

status was defined by participant's self-report as being a current cigarette smoker versus all other categories of tobacco use (ex-smoker, nonsmoker, other forms of tobacco use). Alcohol use was expressed as drinks/week and estimated from a subject's report of the number of alcoholic drinks consumed over the previous 4 weeks. Sleep volume was calculated from a participant's reported average hours of sleep during the 7 nights before study participation (hours of sleep = (average hours/week night × 5) + (average hours/weekend night × 2)). Physical activity was measured using the Paffenbarger Physical Activity Questionnaire, which estimates kilocalories expended per week (33). The distributions of physical activity scores and number of alcoholic drinks/week were normalized by square root and natural log transformations, respectively.

Data Analysis

Ordinary Least Squares (OLS) regression analysis was used to determine whether community and individual SES accounted for significant variability in IL-6 and CRP levels. Subjects in this sample were nested in census tracts, which raises concerns about data dependence. The median number of subjects per census to tract was 3, reflecting low levels of nesting. Still, we examined the level of data dependence by obtaining intraclass correlations (ICC), which assess the degree of clustering or nonindependence in the IL-6 and CRP data. The ICC for IL-6 was 0.009 and for CRP was 0.000, indicating low levels of data dependence within census tract. Based on the modest degree of nesting and the low levels of dependence within census tracts, multilevel hierarchical modeling was not feasible or indicated (34). Analyses were conducted using OLS regression in SPSS version 14.0 (SPSS Inc., Chicago, Illinois). For the initial analyses, age, sex, and race were entered in the first step of the equation, followed by either individual or community SES. Secondary analyses were then conducted to examine whether community and individual SES were associated with IL-6 and CRP independently of BMI and health practices. Here, demographic characteristics were entered in step 1; BMI, smoking, exercise, alcohol and sleep in step 2; and the SES parameter in step 3 of the regression equation. In a final model, we explored whether community SES accounted for variability in IL-6 or CRP above that explained by individual SES and other risk factors by entering demographic characteristics in step 1, BMI and health behaviors in step 2, individual SES in step 3, and community SES in step 4. Finally, we examined whether socioeconomic indicators might predict levels of inflammatory markers in interaction with the participant's race; as none of the interaction terms proved significant (all $p > .10$), these analyses are not reported here.

RESULTS

Bivariate correlations describing the associations of subject characteristics with community SES and with IL-6 and CRP levels are presented in Table 1. For convenience, the signs of correlations involving reciprocally transformed measurements of IL-6 and CRP are reversed (as in all subsequent test statistics), so that positive (and negative) coefficients are interpreted as such. Consistent with prior literature, higher levels of IL-6 were associated with female sex, African-American race, higher BMI, current smoking, higher alcohol consumption, fewer hours of sleep/week, and less physical activity. Similarly, higher CRP was associated with African-American race, higher BMI, and less physical activity. Neither CRP nor IL-6 covaried with age, nor was CRP associated with sex, smoking status, alcohol use, or sleep duration.

Circulating levels of IL-6 and CRP covaried inversely with both individual and community SES (Table 1). In initial regression analyses controlling for age, sex, and race (Table 2), individual SES continued to predict IL-6 ($F_{4,846} = 11.38$, $B = -0.126$, $p < .01$), but not CRP ($F_{4,846} = 3.14$, $B = -0.052$, $p = .17$). Similarly adjusted regression models showed that community SES predicted both IL-6 ($F_{4,846} = 12.13$, $B = -0.144$, $p < .01$) and CRP ($F_{4,846} = 4.34$, $B = -0.097$, $p < .01$). Regarding the latter associations, then, study participants living in less advantaged census tracts showed higher plasma concentrations of the two inflammatory markers than did residents of more affluent neighborhoods. In a further regression analysis, community SES was entered as a predictor after demographic covariates and individual SES, and again, our area-level socioeconomic index explained significant variability in both IL-6 ($B = -0.111$, $p < .01$) and CRP ($B = -0.091$, $p < .05$) concentrations. In a separate analysis reversing the order of entry of SES variables, individual SES continued to predict IL-6 ($B = -0.079$, $p = .05$)

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TABLE 2. Hierarchical Linear Regressions Showing the Contributions of Age, Sex, Race, and Individual and Community SES to the Prediction of Reciprocally Transformed IL-6 and CRP.[a]

Regression	ΔR^2	B	b (SE)	*p*		ΔR^2	B	b (SE)	*p*
IL-6					C-Reactive Protein				
Step 1: $F_{3,847} = 10.91$	0.037			.00	Step 1: $F_{3,847} = 3.55$	0.012			.01
Age		0.055	0.001 (0.001)	.11	Age		−0.029	−0.001 (0.001)	.39
Gender		−0.091	−0.028 (0.010)	.01	Gender		0.054	0.024 (0.015)	.12
Race		0.089	0.046 (0.018)	.001	Race	0.089	0.046 (0.018)	0.01	
Step 2: $F_{4,846} = 11.38$	0.013				Step 2: $F_{4,846} = 3.14$	0.002			
Individual SES		−0.126	−0.020 (0.006)	.00	Individual SES		−0.052	−0.011 (0.008)	.17
Step 1: see above					Step 1: see above				
Step 2: F=12.13	0.017				Step 2: $F_{4,846} = 4.34$	0.008			.00
Community SES		−0.144	−0.022 (0.006)	.00	Community SES		−0.097	−0.021 (0.008)	

IL = interleukin; CRP = C-reactive protein; SE = standard error; SES = socioeconomic status.
[a] Signs have been reversed for interpretation.

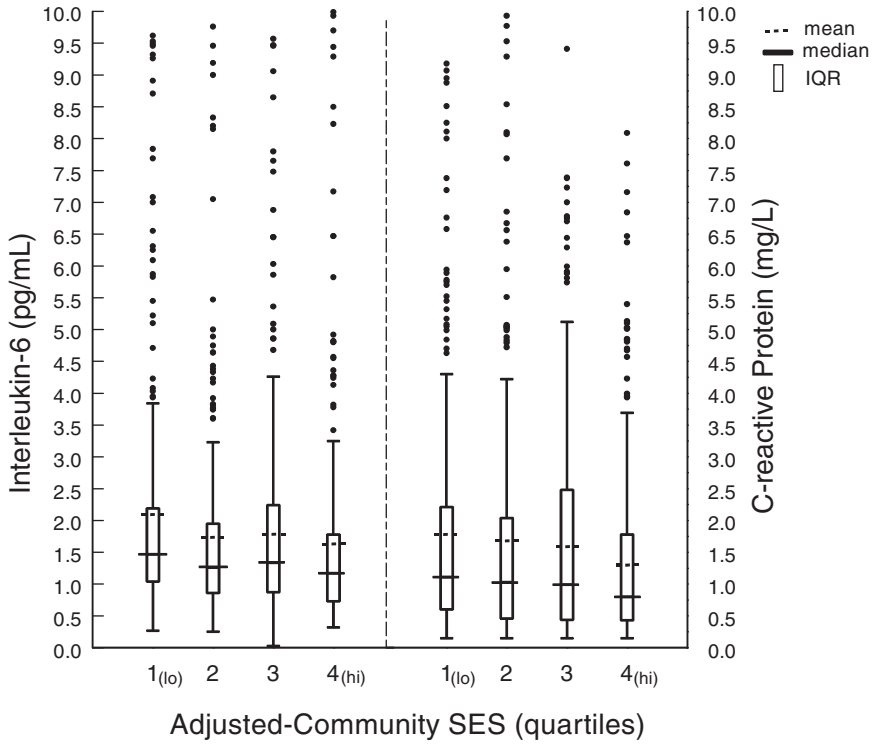

Figure 1. Distributions (box-plots) of the untransformed values of interleukin-6 and C-reactive protein (left and right panels, respectively) depicted for quartiles of age-, sex-, and race-adjusted community SES. IQR = interquartile range; SES = socioeconomic status.

when adjusted for both demographic covariates and community SES. Thus, the association of community SES with these two inflammatory markers was not attributable to correlated variation in personal socioeconomic indicators, and individual SES predicted IL-6 levels independently of community SES.

To examine the possibility that the community-level associations reported here might have emerged only in the context of the data transformation required to satisfy parametric assumptions of normality, box-plots of untransformed IL-6 and CRP measurements are reported in Figure 1. The values depicted here are partitioned by quartiles of the distribution of subjects' community "scores" (adjusted for correlated variation in age, sex, and race). For both cytokines, median values among subjects comprising the lowest quartile of community SES were greater than those of the highest quartile, and nonparametric statistic (Mann-Whitney U) corroborated end-quartile differences (IL-6: $Z = 3.7$, $p < .001$; CRP: $Z = 3.0$, $p < .003$). The Spearman rank-order correlation of community SES (adjusted for age, sex, and race) with untransformed inflammatory markers was likewise significant, across all subjects, for both IL-6 (rho $= -0.129$, $p < .001$) and CRP (rho $= -0.093$, $p < .007$). (For comparison, Pearson correlations between the adjusted community variable and reciprocally transformed IL-6 and CRP values (signs reversed) were virtually identical [IL-6: $r = -0.130$, $p < .001$; CRP: $r = -0.088$, $p < .05$]).

Finally, analyses were conducted to determine whether health practices could account for associations of either indi-

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TABLE 3. Contribution of Standard Covariates, Health Behaviors, and Both Individual and Community SES to the Prediction of Reciprocally Transformed IL-6 in Separate Hierarchical Regressions.[a]

Regression	ΔR^2	B	b (SE)	*p*		ΔR^2	B	b (SE)	*p*
IL-6					C-Reactive Protein				
Step 1: $F_{3,847} = 10.91$	0.037			.00	Step 1: $F_{3,847} = 3.55$	0.012			.01
Age		0.055	0.001 (0.001)	.11	Age		−0.029	−0.001 (0.001)	.39
Gender		−0.091	−0.028 (0.010)	.01	Gender		0.054	0.024 (0.015)	.12
Race		0.172	0.063 (0.012)	.00	Race		0.089	0.046 (0.018)	.01
Step 2: $F_{8,842} = 19.41$	0.119			.00	Step 2: $F_{8,842} = 35.29$	0.119			.00
BMI		0.285	0.008 (0.001)	.00	BMI		0.492	0.019 (0.001)	.00
Alcohol		0.043	0.007 (0.006)	.18	Alcohol		0.020	0.005 (0.007)	.53
Smoking		0.172	0.069 (0.014)	.00	Smoking		0.070	0.040 (0.019)	.03
Sleep		−0.049	−0.001 (0.001)	.17	Sleep		−0.020	−0.001 (0.001)	.51
Exercise		−0.078	−0.001 (0.000)	.04	Exercise		−0.025	0.000 (0.000)	.42
Step 3: $F_{9,841} = 17.51$	0.002			.15	Step 3: $F_{9,841} = 31.67$	0.002			.16
Individual SES		−0.053	−0.008 (0.006)	.15	Community SES		−0.047	−0.010 (0.007)	.16
Steps 1 and 2: see above									
Step 3: $F_{9,841} = 18.12$	0.007								
Community SES		−0.092	−0.014 (0.005)	0.01					

IL = interleukin; SE = standard error; BMI = body mass index; SES = socioeconomic status.
[a] Signs of regression coefficients have been reversed for ease in interpretation.

TABLE 4. Contribution of Standard Covariates as well as Health Behaviors to the Prediction of Reciprocally Transformed IL-6 in the Final Model of a Series of Hierarchical Regressions.[a]

Regression	R^2	B	b (SE)	*p*
IL-6				
$F_{10,840} = 16.32$	0.163			.00
Age		0.061	0.001 (0.001)	.06
Gender		0.034	−0.010 (0.011)	.32
Race		0.031	−0.011 (0.014)	.41
BMI		0.279	0.008 (0.001)	.00
Alcohol		0.046	0.007 (0.005)	.18
Smoking		0.157	0.063 (0.014)	.00
Sleep		−0.045	−0.001 (0.001)	.17
Exercise		−0.070	−0.001 (0.000)	.04
Individual SES		−0.019	−0.003 (0.006)	.62
Community SES		−0.084	−0.013 (0.006)	.03

IL = interleukin; SE = standard error; BMI = body mass index; SES = socioeconomic status.
[a] Signs of regression coefficients have been reversed for ease in interpretation.

vidual or community SES with markers of inflammation (Tables 3 and 4). As expected, after controlling for age, sex and race, higher BMI ($B = 0.285$, $p < .01$), current smoking ($B = 0.172$, $p < .01$), and less physical activity ($B = -0.078$, $p < .05$) were associated with higher IL-6 levels. Similarly, higher BMI ($B = 0.492$, $p < .01$) and current smoking status ($B = 0.040$, $p < .05$) predicted higher CRP levels independently of demographic characteristics. Interestingly, individual SES was no longer associated with IL-6 when entered into regression after demographic covariates and BMI and health behaviors ($B = -0.053$, $p > .10$). Community SES, on the other hand, remained a significant, independent predictor of IL-6 ($B = -0.084$, $p < .05$), but not CRP ($B = -0.047$, $p > .10$.), with age, sex, race, BMI, smoking status, alcohol use, sleep volume, and physical activity in the model. When entered after demographic covariates, BMI and health behaviors, and individual SES in a final regression analysis, community SES continued to predict IL-6 ($B = -0.084$, $p < .05$).

DISCUSSION

The present study provides initial evidence for an association between an area-based measure of socioeconomic inequalities and circulating markers of inflammation in a relatively healthy, midlife community sample. Consistent with evidence that socioeconomic attributes of communities confer risk for preclinical atherosclerosis (35–37) and predict cardiovascular morbidity and mortality (38–40), our findings show that, when compared with residents of more advantaged communities, individuals living in census tracts of lower income and less education have higher levels of circulating CRP and IL-6. These associations were independent of individual-level SES and of demographic risk factors (age, sex, and race). Further, participants from disadvantaged communities had higher IL-6 even after accounting for lifestyle-related risk factors, including BMI, smoking, alcohol consumption, physical activity, and sleep. The current results are consistent with recently published evidence that levels of CRP covary inversely with unadjusted community SES (25), extending these findings to include IL-6 as well. Thus, our findings also support prior observations that IL-6 concentrations are elevated in "slum dwellers" when compared with the urban middle class in India (26). Taken together, these findings raise the possibility that relationships between community SES and increased vulnerability to cardiovascular disease could be mediated, in part, through inflammatory pathways.

The mechanisms through which socioeconomic attributes of communities may affect systemic inflammation are unclear. Younger individuals in the sample were more likely to live in

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less advantaged communities than older individuals. This raises the possibility that community SES is a marker of accumulated wealth, which may be a more stable and global socioeconomic determinant than indicators of current income and educational attainment. However, given that controlling for age, education, and income did not attenuate the relationship between community status and inflammatory mediators, it is likely that other mechanisms are also involved. A growing literature suggests that community SES provides a measure of exposure to environmental factors promoting risk-related behaviors (e.g., fast food restaurants or lack of healthy food options) or differential access to health resources (e.g., medical facilities or places to exercise) (41), which may be related to susceptibility to inflammation. It is also likely that other aspects of less advantaged neighborhoods, such as crowding, noise, unemployment, crime, and pollution contribute to chronic stress, which has been related to an upregulation of innate inflammatory processes through endocrine pathways involving the hypothalamic-pituitary-adrenal axis or activation of the sympathetic nervous system (42,43).

In addition to examining community SES, the current study also contributes to an understanding of relationships between individual SES and inflammatory mediators. Consistent with the extant literature (16,19), we found an inverse association between individual SES and plasma IL-6 that was explained by behavioral factors, including BMI, smoking status, and physical activity. A large literature supports an association between lower individual SES and poor health practices, with higher rates of smoking and obesity and lower levels of physical activity than among persons of higher SES (44). Furthermore, these health practices have been associated with higher levels of peripheral proinflammatory mediators (45,46). The current findings support a particularly strong relationship between BMI and plasma levels of IL-6 and CRP, which may be explained by the production and release of IL-6 by adipocytes (47). In sum, behavioral covariates of individual SES may provide a pathway linking lower SES to increased systemic inflammation.

In regard to CRP, we found no significant relationship between individual SES and levels of CRP after adjusting for demographic characteristics. Although not all findings are consistent (19), the current results contrast with increasing evidence of an inverse relationship between individual SES and plasma CRP (10–16). One possible explanation for our failure to replicate this effect is our recruitment of a younger and healthier sample than in many other studies (11,12,15). It has also been suggested that the presence of subclinical infections among individuals lower in SES may account for relationships between individual SES and inflammatory mediators (19). In this regard, we excluded individuals with levels of IL-6 or CRP in the range associated with acute infection, decreasing the likelihood that this confounder influenced our findings. Finally, it is possible that the range of individual SES represented in this sample was limited in comparison with other studies. As 61% of our participants were college educated, the entire sample averaged over 15 years of schooling. It is possible that a clearer relationship of individual SES with inflammatory mediators would be seen across a broader spectrum of socioeconomic variation, including a greater representation of individuals from the lowest strata of socioeconomic position.

There are a number of limitations of the current study. First, its cross-sectional design precludes causal interpretation. Alternative explanations for our results include the possibility that inflammatory mediators and neighborhood of residence are independently related to a third factor, such as personality, cognitive ability, or general health. Another limitation is the single assessment of IL-6 and CRP. Although evidence suggests that levels of these inflammatory mediators are relatively stable over extended periods (48), a more reliable indicator of chronic interindividual variability would be derived from multiple assessments over time. In the future, longitudinal investigations are indicated beginning in early adulthood and tracking the influence of more proximal neighborhood characteristics, such as chronic stress and access to health resources, on inflammatory mediators to better elucidate how communities may affect the health of individuals.

Despite these shortcomings, our findings provide initial evidence that sociodemographic characteristics of communities are associated with markers of inflammation thought to play a role in the pathogenesis of cardiovascular and other inflammatory diseases. Furthermore, these relationships are independent of demographic characteristics, measured health practices, and socioeconomic attributes of individuals, raising the possibility that inflammatory mechanisms mediate relationships between neighborhood qualities and vulnerability to cardiovascular disease. Further investigation of this potential pathway is warranted.

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