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Cumulative Socioeconomic Status Across the Life Course and Subclinical Atherosclerosis

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PURPOSE: The purpose of this study is to investigate the relationship between individual-level and neighborhood-level socioeconomic status (SES) across the life course and subclinical atherosclerosis.
METHODS: Participants from the Atherosclerosis Risk in Communities Study (n = 12,332) were queried about individual-level SES and residential addresses across the life course. Individual-level measures were scored and summed to obtain a summary score (I-CumSES), whereas residential addresses were geocoded and linked to census data to obtain a summary neighborhood *z* score (N-CumSES) to evaluate the association of SES with intima-media thickness (IMT) and peripheral arterial disease (PAD).
RESULTS: A 1-SD lower I-CumSES was associated with greater mean IMT in each race–sex group and greater odds of PAD in white men (odds ratio [OR], 1.28; 95% confidence interval [CI], 0.99–1.64), white women (OR, 1.18; 95% CI, 1.02–1.36), and black women (OR, 1.33; 95% CI, 1.00–1.76). Compared with the highest tertile of N-CumSES, the lowest tertile was associated with greater mean IMT among whites, but was not associated with PAD for whites or blacks. When I-CumSES and N-CumSES were considered simultaneously, associations remained for only I-CumSES and were attenuated after adjustment for cardiovascular disease (CVD) risk factors.
CONCLUSIONS: Lower cumulative individual-level SES across the life course was associated with a greater burden of subclinical atherosclerosis, and this association was mediated in part by CVD risk factors.
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INTRODUCTION

The inverse association between socioeconomic status (SES) and cardiovascular disease (CVD) is well established in the literature (1, 2), although the association between SES and subclinical atherosclerosis is less consistent. Lower education, income, and occupation were associated with increased intima-media thickness (IMT) (3, 4) and progression of IMT (5), but also weak or no associations were reported for SES and IMT (6). Findings for peripheral arterial disease (PAD) also varied, with one study reporting an association between low SES and PAD (7) and another study reporting no association between SES and PAD for women and a weak association for men (8).

These prior studies used contemporaneous measures of SES, whereas few studies investigated the association between SES across the life course and subclinical atherosclerosis. In one study, subclinical carotid artery stenosis was associated with low paternal and adult occupational status for women (9), whereas another study reported socioeconomic position at birth was associated inversely with IMT for women (10). Still other studies investigated the association between neighborhood SES and subclinical disease, with one study reporting an association between low neighborhood-level SES during older adulthood and prevalent subclinical atherosclerosis (11) and another study reporting no association between a disadvantaged neighborhood environment during childhood and IMT (10).

Given the early origins of subclinical atherosclerosis and its association with a greater prevalence of CVD risk factors and cardiovascular events (12–17), better understanding of the social and economic context for the development of an individual's burden of atherosclerosis would offer important opportunities for prevention. Thus, this study investigated whether lower cumulative individual-level SES across the

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Selected Abbreviations and Acronyms

ARIC = Atherosclerosis Risk in Communities Study
SES = socioeconomic status
LC-SES = Life Course, Social Context and Cardiovascular Disease Study
CVD = cardiovascular disease
SBP = systolic blood pressure
I-CumSES = individual-level cumulative socioeconomic status
N-CumSES = neighborhood-level cumulative socioeconomic status
ABI = ankle–brachial index
IMT = intima-media thickness
PAD = peripheral arterial disease
OR = odds ratio
CI = confidence interval

life course and lower cumulative neighborhood-level SES across the life course were associated with greater subclinical atherosclerosis in a middle-aged cohort of black and white men and women.

METHODS

Study Population

The Atherosclerosis Risk in Communities (ARIC) Study is a prospective study of the etiology and progression of atherosclerosis and its clinical sequelae in four communities in the United States. It included 15,792 men and women aged 45 to 64 years at the baseline examination, sampled from residents of Forsyth County, NC; Jackson, MI; northwest suburbs of Minneapolis, MN; and Washington County, MD. Participants provided written informed consent and were interviewed and examined at baseline (1987 to 1989) and again at three triennial visits. Participants also were interviewed annually by telephone to assess changes in health and vital status and obtain information about hospitalizations. Details about the design of the ARIC Study were published (18, 19).

As an ancillary study to ARIC, the Life Course Socioeconomic Status, Social Context and Cardiovascular Disease (LC-SES) Study was designed to evaluate mechanisms explanatory of the association of historic and contemporary SES with CVD. In 2001 to 2002, ARIC participants were queried about their parental SES, individual SES, and places of residence during childhood and young adulthood (N = 12,716). Childhood residential data were linked with county-level census data, the smallest geographic unit for which census data were available at that time. Adulthood residential data were geocoded and linked with tract-level census data corresponding to the nearest census year in which the participant reported their residential address at ages 30, 40, and 50 years. In a quality-control study to assess the match rate, repeatability, and accuracy of commercial geocoding, repeatability of geocodes for a subsample of LC-SES participants was high ($\kappa = 0.90$) (20).

Because of small sample size and the majority of black participants being at a single site, participants who were not white or black (n = 35) and black participants in Minnesota, Maryland, and North Carolina (n = 349) were excluded. Subsequent analyses excluded participants who reported being unemployed or retired at age 30 years (n = 181), as well as participants with missing IMT (n = 752), ankle–brachial index (ABI) greater than 1.5 (n = 57), or missing ABI (n = 415) for outcome-specific analyses. Because subclinical atherosclerosis is the outcome, participants with prevalent coronary heart disease at baseline (n= 418) also were excluded. Thus, sample sizes were 10,981 and 11,261 for IMT and ABI, respectively.

Cumulative SES

Two cumulative SES scores were created: individual-level cumulative SES (I-CumSES) and neighborhood-level cumulative SES (N-CumSES). The I-CumSES score was created by summing the values for each of the four SES variables in each life epoch (Table 1). Minimum and maximum scores for each life epoch were 0 and 5, respectively. Thus, the range of values for I-CumSES score was 0 to 15, with higher values reflecting greater individual-level SES.

In prior factor analysis, six neighborhood-level SES indicators were identified (21) and used to represent neighborhood SES for older adulthood. Because of changes in variable definitions and availability across censuses, similar variables were used during young adulthood and childhood (Table 2). Because this study assesses neighborhood-level SES across several decades, during which the meaning of absolute levels of census variables changed, and black participants were from a single site with a history of segregation practices that led to lower neighborhood SES, race-specific z scores were obtained for each census variable and summed to obtain a summary z score for N-CumSES. Greater summary z score values reflect higher neighborhood-level SES.

Measurement of Subclinical Atherosclerosis

The markers of subclinical atherosclerosis investigated were IMT and PAD from the baseline examination. For IMT, the extracranial carotid arteries were measured bilaterally at three segments, the distal common carotid artery, carotid bifurcation, and internal carotid artery, by using high-resolution B-mode ultrasonography. Trained sonographers identified optimal angles to scan and record three 1-cm segments of the right and left carotid artery (22) and recordings were sent to a central site for reading (23, 24). Quality assurance procedures were in place for scanning and reading throughout the study (23, 25). High-resolution B-mode ultrasonography has good repeatability in the ARIC Study: 0.77, 0.73, and 0.70 for mean carotid far-wall IMT at the

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TABLE 1. Variables used in the creation of individual-level cumulative socioeconomic status score

Life Epoch	Variable	Value
Childhood (age 10 years)	Parental education[a]	<8th grade = 0 8th grade = 1 >8th grade = 2
	Parental occupation[b]	Manual = 0 Nonmanual = 1
	Parental occupational role	No managerial role = 0 Managerial role = 1
	Parental home ownership	Rent home or other = 0 Own home = 1
Young adulthood (age 30 years)	Education	<High school = 0 High school graduate = 1 >High school = 2
	Occupation	Manual = 0 Nonmanual = 1
	Occupational role	No managerial role = 0 Managerial role = 1
	Home ownership	Rent home or other = 0 Own home = 1
Older adulthood (age 45–64 years)	Income	<$25,000 = 0 $25–34,999 = 1 ≥$35,000 = 2
	Occupation	Manual = 0 Nonmanual = 1
	Occupational role	No managerial role = 0 Managerial role = 1
	Home ownership	Rent home or other = 0 Own home = 1

If the occupation reported was homemaker, occupation-related variables (occupation and occupation role) for that period were not used and score was determined by using the remaining variables for that period.
[a]Parental education was determined by the highest education of the mother or father if both were in household or the education of the single caretaker if both parents were not in the household.
[b]Parental occupation was determined by father's occupation unless there was not a father in the household, in which case, the mother's occupation was used.

carotid bifurcation and internal and common carotid arteries, respectively (26).

Resting ankle and brachial systolic blood pressures (SBPs) were measured by trained technicians following a standardized protocol to obtain the ABI, the ratio of ankle SBP to brachial SBP (27). To assess ankle SBP, the participant was in the prone position and a blood pressure cuff was wrapped around the participant's lower leg using a contour method to obtain automated readings using the Dinamap 1846 SX (Critikon Corporation, Tampa, FL). Use of the contour method and Dinamap 1846 SX was shown to have greater measurement precision compared with other methods (28). Readings of ankle SBP approximately 5 to 8 minutes apart were performed immediately before and after ultrasound scanning of the popliteal artery. The last ankle SBP was used to calculate ABI. To assess brachial SBP, the cuff was wrapped around the participant's arm during the ultrasound scanning of the carotid artery and measurements were performed repeatedly approximately 5 minutes apart, with the first brachial SBP used in the calculation of ABI. PAD is defined as an ABI less than 0.9, whereas no PAD is defined as an ABI of 0.9 or greater.

Measurement of Covariates

Demographic characteristics (age, race, sex, and study center) and other covariates were assessed at baseline. Body mass index was determined by using objectively assessed weight and height measurements (kilograms per square meter). Sitting blood pressure was measured three times after a 5-minute rest and determined by the average of the last two measurements. Type 2 diabetes was determined as a fasting blood glucose level greater than 126 mg/dL, nonfasting blood glucose level greater than 200 mg/dL, use of hypoglycemic medications, or self-reported physician diagnosis. High-density lipoprotein cholesterol was measured by using the Warnick method (29), and low-density lipoprotein cholesterol level was calculated by using the Friedewald formula (30) at a central laboratory. Physical activity was assessed by using the Baecke questionnaire (31). Smoking status (current, former, or never) and pack-years (average number of cigarettes smoked per day times number of years smoked) were self-reported.

Statistical Analysis

Because of retrospective ascertainment of residential addresses and individual-level SES from prior decades, several variables had missing data. The amount of missing data for most individual-level SES measures was minimal (<10%), whereas the amount of missing data for neighborhood-level SES measures varied because of the availability of census data for earlier periods. To address this issue, data were multiply imputed by obtaining a series of possible data points from a set number of trials and using an algorithm to obtain a single estimate for the missing data point, taking into account within- and between-variance of the imputation (32–34). STATA (StataCorp, College Station, TX) was used to perform the multiple imputation with 10 iterations and five imputations based on a Gibbs sampling method called multivariate imputation by chained equations (35, 36). SAS, version 9.1 (SAS Institute, Cary, NC), procedure MIANALYZE was used to combine the estimates and incorporate between- and within-imputation variance to obtain appropriate summary estimates and confidence intervals (CIs).

Prevalence estimates and means for traditional CVD risk factors and measures of subclinical atherosclerosis were age adjusted by using an adjusted proportions and means macro (37). Linear regression was used to assess the association of I-CumSES and N-CumSES with IMT. Logistic regression was used to assess the association of I-CumSES and N-CumSES with PAD.

TABLE 2. Variables used in the creation of neighborhood-level cumulative socioeconomic status score

Life Epoch	Census Variable
Childhood (age 10 years)	% Adults with ≥ 4 years of high school
	% Adults with ≥ 4 years of college
	Median value of owner-occupied dwelling (log)
	% Dwellings occupied by owner
	% Adults in managerial/professional occupations
Young adulthood (age 30 years)	% Adults with ≥ 4 years of high school
	% Adults with ≥ 4 years of college
	Mean family income (log)
	Mean value of owner-occupied dwelling (log)
	% Dwellings occupied by owner
	% Adults in managerial/professional occupations
Older adulthood (age 45–64 years)	% Adults with ≥ 4 years of high school
	% Adults with ≥ 4 years of college
	Median household income (log)
	Median value of owner-occupied dwelling (log)
	% Households with other income, rent, etc
	% Dwellings occupied by owner
	% Adults in managerial/professional occupations

Models were fit to estimate the effect of I-CumSES and N-CumSES separately and jointly. I-CumSES was standardized to a race-specific mean of 0 and SD of 1. A 1-SD decrease in I-CumSES corresponds to approximately three exposures to lower SES across the life course, which could reflect any combination of three exposures to lower SES at any point during the life course, i.e., parents not owning their home and the participant not owning a home during young adulthood and older adulthood would equal three exposures to lower SES, as would the participant having a manual occupation, nonsupervisory occupational role, and not owning a home during young adulthood. N-CumSES was divided into race-specific tertiles based on the summary z score. Analyses were performed adjusted for age and study center (whites only) and CVD risk factors (i.e., smoking, pack-years, SBP, use of antihypertensive medications, family history of coronary heart disease, High-density lipoprotein level, low-density lipoprotein level, body mass index, and physical activity). Because of differences in cumulative SES by race and because most women reported homemaking as an occupation at least once during the life course, analyses were stratified by race and sex.

RESULTS

Participant characteristics are listed in Table 3. Approximately 42% of participants were white women, 35% were white men, 15% were black women, and 8% were black men. Average participant age at baseline was 53 years. White participants consistently reported higher individual-level SES than black participants. Notably, less than 5% of black participants, but more than 25% of white participants, reported a parent/guardian in a nonmanual occupation during childhood. Also, more white men reported completing high school, having a nonmanual occupation, and having a managerial occupation role compared with the other groups during young adulthood. For older-adulthood SES, more men than women and more whites than blacks reported an annual income greater than $35,000. Mean SBP and prevalence of diabetes were greater among blacks than whites, whereas a family history of coronary heart disease was higher among men than women. For subclinical atherosclerosis, mean IMT was greater among men than women, whereas PAD prevalence was greater among women than men.

Various combinations of individual-level SES variables arose for creation of the I-CumSES score, with the more frequent combinations similar within race groups (data not shown). Home ownership during older adulthood only was the most frequent pattern for black men (3.8%) and black women (4.4%), followed by home ownership during young adulthood plus home ownership during older adulthood at 3.2% and 4.2%, respectively. Interestingly, 3.4% of black women and 2.6% of black men were not in a higher SES stratum in any life epoch. For white participants, the more frequent combinations reflected higher SES for education, occupation, occupational role, and home ownership during childhood, young adulthood, and older adulthood for white men (6.2%) and white women (3.7%). Only 0.2% of white men and 0.3% of white women were not in a higher SES stratum in any life epoch.

Parameter estimates and 95% CIs for the association between SES and mean IMT are listed in Table 4. In analyses of I-CumSES only, lower SES was associated with greater mean IMT for each race–sex group after adjustment for age. In analyses of N-CumSES only, the lowest tertile of SES was associated with greater mean IMT compared with the highest tertile, although this difference was statistically significant for only white women after adjustment for age. When both I-CumSES and N-CumSES were evaluated simultaneously, lower I-CumSES was associated with greater mean IMT after adjustment for age for each race–sex group, whereas the lower tertiles of N-CumSES were not associated with greater mean IMT. Previous work in the ARIC Study showed an average annual change in mean common carotid IMT of 7.4 to 9.1 μm (38), which is of similar magnitude to the cross-sectional differences in mean IMT noted in this study for I-CumSES.

Odds ratios (ORs) and 95% CIs for the association between SES and PAD are listed in Table 5. In analysis of I-CumSES only, lower SES was associated with greater odds of PAD after adjustment for age for white men (OR, 1.28; 95% CI, 0.99–1.64), white women (OR, 1.18; 95% CI, 1.02–1.36), and black women (OR, 1.33; 95% CI,

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TABLE 3. Participant characteristics from the Atherosclerosis Risk in Communities Study, 2001 to 2002

	White		Black	
Variable	Men (n = 4284)	Women (n = 5170)	Men (n = 1002)	Women (n = 1876)
Mean age at ARIC baseline, years	54.2	53.7	52.8	52.6
Childhood SES: individual				
Parental education > high school (%)	46.6	43.7	19.4	21.1
Parental nonmanual occupation (%)	28.8	27.0	4.9	3.6
Parental managerial occupation role (%)	42.6	41.5	28.0	24.4
Parents owned home (%)	72.9	73.0	47.1	43.7
Childhood SES: neighborhood				
z Score median	−1.01	−1.01	−0.93	−1.13
Young adulthood SES: individual				
Education > high school (%)	45.2	34.0	33.9	31.6
Nonmanual occupation (%)	58.4	32.0	31.0	31.6
Managerial occupation role (%)	34.0	6.7	16.7	6.5
Owned home during young adulthood (%)	69.7	74.1	47.7	50.3
Young adulthood SES: neighborhood				
z Score median	−0.71	−0.72	−2.56	−2.56
Older adulthood SES: individual				
Annual income > $35,000 (%)	63.2	51.2	29.1	17.6
Nonmanual occupation (%)	60.2	62.7	34.5	37.3
Managerial occupation role (%)	57.2	24.5	32.4	18.7
Owned home during older adulthood (%)	93.6	92.3	82.7	81.2
Older adulthood SES: neighborhood				
z Score median	−0.52	−0.80	−0.71	−0.89
Cardiovascular disease risk factors[a]				
Current smoker (%)	21.2	22.2	32.2	20.2
Diabetes (%)	7.8	6.5	14.7	17.5
Mean systolic blood pressure, mm Hg	119.0	116.2	129.3	127.2
Mean body mass index, kg/m^2	27.4	26.6	28.0	30.9
Mean low-density lipoprotein cholesterol, mg/dL	139.4	134.6	138.7	139.0
Family history of coronary heart disease (%)	47.9	24.9	35.3	17.7
Subclinical atherosclerosis[a]				
Mean intima-media thickness, μm	753.0	663.0	750.0	699.0
Ankle–brachial index < 0.9 (%)	1.7	4.3	2.5	4.6

SES = socioeconomic status; ARIC = Atherosclerosis Risk in Communities Study.
[a]Age adjusted.

1.00–1.76). Evaluating only N-CumSES using the highest tertile of SES as the referent, participants in the lowest tertile had greater odds of PAD for each race–sex group, although these associations were not statistically significant. When both I-CumSES and N-CumSES were included in the analysis, odds of PAD increased as I-CumSES decreased for white men, white women, and black women, but these associations were not statistically significant and no consistent relationship for N-CumSES was noted.

DISCUSSION

Atherosclerosis is detectable very early in life (39, 40), develops gradually as a subclinical condition over the life course (41), and underlies manifest cardiovascular clinical events. Similarly, SES encompasses a host of social conditions and exposures that exert positive or adverse effects over the life course. Findings from this study suggest that cumulative SES across the life course is associated with greater mean IMT and greater prevalence of PAD.

Different associations of individual-level and neighborhood-level SES with subclinical atherosclerosis were apparent in this study. Both I-CumSES and the lowest tertile of N-CumSES were associated with greater IMT independently, but only I-CumSES remained associated after simultaneous inclusion of I-CumSES and N-CumSES. Lack of association between N-CumSES and subclinical atherosclerosis after adjustment for individual-level SES does not necessarily mean that neighborhood SES has no effect on the disease process. Instead, this may reflect difficulty capturing the varied aspects of neighborhood SES across the life course, particularly for the childhood period of these birth cohorts, for which only county-level data were available. Similar findings were reported in the Cardiovascular Health Study, in which low individual and neighborhood SES, assessed in later adulthood only, were associated independently with increased odds of subclinical atherosclerosis, but only the

TABLE 4. Association of individual-level and neighborhood-level cumulative socioeconomic status with intima-media thickness (μm), the Atherosclerosis Risk in Communities Study

		White		Black	
		Men	Women	Men	Women
Individual cumulative SES only					
Model 1	Individual cumulative SES score (decrease 1 SD)	10.9 (5.4–16.3)	9.7 (5.5–13.9)	13.9 (4.1–23.7)	7.3 (0.5–14.1)
Model 2	Individual cumulative SES score (decrease 1 SD)	6.0 (0.4–11.6)	2.1 (−2.1–6.4)	11.9 (2.0–21.8)	1.8 (−5.0–8.6)
Neighborhood cumulative SES only					
Model 3	Neighborhood cumulative *z* score lowest tertile	15.5 (−1.5–32.4)	12.8 (3.1–22.4)	17.1 (−9.7–44.0)	5.8 (−10.5–22.0)
	Neighborhood cumulative *z* score middle tertile	3.1 (−11.1–17.2)	4.4 (−5.7–14.6)	1.9 (−24.1–27.9)	7.8 (−11.1–26.8)
Model 4	Neighborhood cumulative *z* score lowest tertile	14.0 (−5.7–33.8)	11.3 (0.1–22.5)	9.9 (−15.9–35.6)	−2.5 (−18.6–13.6)
	Neighborhood cumulative *z* score middle tertile	5.0 (−10.4–20.5)	5.2 (−5.1–15.4)	3.8 (−21.1–28.8)	4.0 (−14.9–22.9)
Individual and neighborhood cumulative SES					
Model 5	Individual cumulative SES score (decrease 1 SD)	10.2 (3.6–16.7)	9.0 (4.4–13.6)	13.0 (2.6–23.5)	7.3 (0.2–14.3)
	Neighborhood cumulative *z* score lowest tertile	4.5 (−15.5–24.4)	4.0 (−6.5–14.6)	7.0 (−20.9–34.9)	1.3 (−15.6–18.1)
	Neighborhood cumulative *z* score middle tertile	−2.7 (−17.6–12.1)	0.2 (−10.2–10.6)	−3.2 (−28.9–22.5)	6.1 (−12.8–25.0)
Model 6	Individual cumulative SES score (decrease 1 SD)	4.9 (−1.4–11.1)	0.9 (−3.6–5.4)	11.7 (1.3–22.0)	2.2 (−4.8–9.2)
	Neighborhood cumulative *z* score lowest tertile	9.1 (−12.9–31.1)	10.5 (−1.2–22.3)	1.5 (−24.8–27.9)	−3.7 (−20.2–12.9)
	Neighborhood cumulative *z* score middle tertile	2.5 (−13.7–18.6)	4.8 (−5.6–15.3)	−0.7 (−25.5–24.1)	3.6 (−15.3–22.5)

Values expressed as regression coefficient (95% confidence interval). A SD decrease corresponds to approximately three exposures to lower SES across the life course. Models 1, 3, and 5 were adjusted for age. Models 2, 4, and 6 were adjusted for age, smoking status, pack-years, systolic blood pressure, use of antihypertensive medications, diabetes status, family history of coronary heart disease, high-density and low-density lipoprotein levels, body mass index, and physical activity.
SES = socioeconomic status.

association with low individual SES persisted when both were considered simultaneously (11).

Previous studies evaluating SES across the life course and subclinical atherosclerosis noted differing associations by sex. Low cumulative SES across the life course was associated with increased odds of carotid stenosis among women, but not men, in one study (9), whereas another reported that low social class at birth was associated with greater IMT among women, but not men (10). Conversely, our study found an inverse association of I-CumSES with IMT and PAD in both women and men, with the exception of PAD among black men under circumstances of limited power because of a small sample size and low prevalence of PAD. Interestingly, the strongest association between I-CumSES and IMT was among black men, which persisted after taking into account CVD risk factors and N-CumSES.

Similar to findings reported by other studies (3, 4, 11), adjustment for CVD risk factors in this study attenuated the association between SES and subclinical atherosclerosis. Potential causal pathways between SES and subclinical atherosclerosis prominently include CVD risk factors as possible mediators of this relationship, as well as various psychosocial factors (1). Efforts to discern direct and indirect effects by adjusting for downstream factors are based on stringent assumptions and are not recommended (42); therefore, we evaluated changes in parameter estimates to assess the potential mediating role of each CVD risk factor. None of the CVD risk factors was a strong or moderate mediator of the association between SES and PAD for blacks or whites. For the association between SES and IMT, no CVD risk factor was identified as a mediator for black men, whereas several moderate mediators emerged for black women and several strong or moderate mediators emerged for white men and women. Adjustment for causal intermediates would be expected to attenuate the association between SES and subclinical atherosclerosis, but our findings suggest that other factors also influence this association.

Several challenges were encountered in conducting this research. The LC-SES questionnaire was not administered until 2001 to 2002; therefore, baseline ARIC participants who were lost to follow-up or died before the LC-SES Study are not included in this study (N = 3076). Also, retrospective ascertainment of SES across the life course required participants to recall information about parental SES, young-adult SES, and their addresses during childhood and young adulthood. Participants generally were able to recall their individual-level SES, but had difficulty recalling complete historic addresses (i.e., street number and street name). Also, incomplete coverage of census tracts for earlier decades resulted in greater missing data for young-adulthood neighborhood SES (43). Although multiple imputation was used to address the missing data issue, limitations in recall of addresses and availability of only county-level information for childhood neighborhood SES may have limited our ability to detect effects of cumulative neighborhood-level SES.

This study is one of the first to evaluate individual-level and neighborhood-level SES measures from across the life course in a biracial cohort of older adults. Although SES data were limited for some epochs, inclusion of SES measures from multiple periods during the life course contributes

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TABLE 5. Association of individual-level and neighborhood-level cumulative socioeconomic status with peripheral arterial disease in the Atherosclerosis Risk in Communities Study

		White		Black	
		Men	Women	Men	Women
Individual cumulative SES only					
Model 1	Individual cumulative SES score (decrease 1 SD)	1.28 (0.99–1.64)	1.18 (1.02–1.36)	1.01 (0.67–1.54)	1.33 (1.00–1.76)
Model 2	Individual cumulative SES score (decrease 1 SD)	1.03 (0.79–1.35)	1.06 (0.91–1.23)	0.97 (0.62–1.53)	1.24 (0.92–1.66)
Neighborhood cumulative SES only					
Model 3	Neighborhood cumulative *z* score lowest tertile	1.45 (0.75–2.79)	1.36 (0.96–1.93)	2.66 (0.78–9.06)	1.18 (0.62–2.22)
	Neighborhood cumulative *z* score middle tertile	1.06 (0.47–2.42)	1.00 (0.68–1.48)	1.53 (0.31–7.58)	0.87 (0.41–1.87)
Model 4	Neighborhood cumulative *z* score lowest tertile	0.96 (0.40–2.27)	1.03 (0.66–1.60)	2.27 (0.59–8.80)	1.09 (0.57–2.09)
	Neighborhood cumulative *z* score middle tertile	0.91 (0.36–2.32)	0.86 (0.56–1.32)	1.54 (0.28–8.42)	0.83 (0.39–1.77)
Individual and neighborhood cumulative SES					
Model 5	Individual cumulative SES score (decrease 1 SD)	1.25 (0.94–1.66)	1.14 (0.98–1.34)	0.89 (0.57–1.38)	1.32 (0.97–1.80)
	Neighborhood cumulative *z* score lowest tertile	1.14 (0.54–2.40)	1.19 (0.81–1.76)	2.91 (0.80–10.65)	1.00 (0.50–2.00)
	Neighborhood cumulative *z* score middle tertile	0.93 (0.40–2.17)	0.94 (0.63–1.40)	1.60 (0.32–7.87)	0.81 (0.37–1.80)
Model 6	Individual cumulative SES score (decrease 1 SD)	1.04 (0.78–1.39)	1.06 (0.90–1.24)	0.88 (0.55–1.41)	1.23 (0.90–1.69)
	Neighborhood cumulative *z* score lowest tertile	0.92 (0.36–2.33)	0.98 (0.61–1.56)	2.49 (0.60–10.26)	0.99 (0.50–1.97)
	Neighborhood cumulative *z* score middle tertile	0.89 (0.34–2.30)	0.84 (0.54–1.30)	1.63 (0.30–8.91)	0.80 (0.37–1.74)

Values expressed as odds ratio (95% confidence interval). An SD decrease corresponds to approximately three exposures to lower SES across the life course. Models 1, 3, and 5 were adjusted for age. Models 2, 4, and 6 were adjusted for age, smoking status, pack-years, systolic blood pressure, use of antihypertensive medications, diabetes status, family history of coronary heart disease, high-density and low-density lipoprotein levels, body mass index, and physical activity.
SES = socioeconomic status.

to a growing body of research of the accumulated effects of SES on health. Our findings of greater subclinical atherosclerosis for those with lower individual-level SES across the life course are consistent with previous studies that reported associations between cumulative measures of SES and CVD (44). Because a limitation of cumulative measures of SES is that each variable from across the life course is weighted equally, we also examined the association of SES at the different life epochs with subclinical atherosclerosis. The young-adulthood period was associated more strongly with IMT and PAD than the childhood or older-adulthood periods, although magnitudes of life epoch associations were less than the cumulative measure, as expected. Although indications of greater susceptibility at particular life epochs are of considerable interest, cumulative SES is the focus of this study because the accumulation of advantage or disadvantage across the life course occurs parallel to the natural history of the development and progression of atherosclerosis.

Because CVD continues to be the leading cause of death in the United States, it is of particular interest to explore subclinical measures of atherosclerosis to identify avenues to prevent the development of vulnerable plaques and, ultimately, occurrence of clinical events. Atherosclerosis develops in young adulthood and progresses throughout life. Our finding that cumulative disadvantage across the life course is associated with a greater burden of subclinical atherosclerosis suggests a potential for targeted interventions beginning early in life and continuing through adulthood. Thus, research to examine the complex relationship between life-course SES, individual level and neighborhood level, and various measures of subclinical atherosclerosis seems warranted.

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REFERENCES

1. Kaplan GA, Keil JE. Socioeconomic factors and cardiovascular disease: A review of the literature. Circulation. 1993;88:1973–1998.
2. Liberatos P, Link BG, Kelsey JL. The measurement of social class in epidemiology. Epidemiol Rev. 1988;10:87–121.
3. Lynch J, Kaplan GA, Salonen R, Cohen RD, Salonen JT. Socioeconomic status and carotid atherosclerosis. Circulation. 1995;92:1786–1792.
4. Diez-Roux AV, Nieto FJ, Tyroler HA, Crum LD, Szklo M. Social inequalities and atherosclerosis. The Atherosclerosis Risk in Communities Study. Am J Epidemiol. 1995;141:960–972.
5. Lynch J, Kaplan GA, Salonen R, Salonen JT. Socioeconomic status and progression of carotid atherosclerosis. Prospective evidence from the Kuopio Ischemic Heart Disease Risk Factor Study. Arterioscler Thromb Vasc Biol. 1997;17:513–519.
6. Rosvall M, Ostergren PO, Hedblad B, Isacsson SO, Janzon L, Berglund G. Occupational status, educational level, and the prevalence of carotid atherosclerosis in a general population sample of middle-aged Swedish men and women: Results from the Malmo Diet and Cancer Study. Am J Epidemiol. 2000;152:334–346.
7. Rooks RN, Simonsick EM, Miles T, Newman A, Kritchevsky SB, Schulz R, et al. The association of race and socioeconomic status with cardiovascular disease indicators among older adults in the health, aging, and body composition study. J Gerontol B Psychol Sci Soc Sci. 2002;57(Suppl):S247–256.
8. Macintyre CCA, Carstairs VDL. Social factors. In: Fowkes FGR, ed. Epidemiology of Peripheral Vascular Disease. London: Springer-Verlag; 1991:197–206.

9. Rosvall M, Ostergren PO, Hedblad B, Isacsson SO, Janzon L, Berglund G. Life-course perspective on socioeconomic differences in carotid atherosclerosis. Arterioscler Thromb Vasc Biol. 2002;22:1704–1711.
10. Lamont D, Parker L, White M, Unwin N, Bennett SM, Cohen M, et al. Risk of cardiovascular disease measured by carotid intima-media thickness at age 49-51: Lifecourse study. BMJ. 2000;320:273–278.
11. Nordstrom CK, Diez Roux AV, Jackson SA, Gardin JM. The association of personal and neighborhood socioeconomic indicators with subclinical cardiovascular disease in an elderly cohort. The Cardiovascular Health Study. Soc Sci Med. 2004;59:2139–2147.
12. Salonen JT, Salonen R. Ultrasound B-mode imaging in observational studies of atherosclerotic progression. Circulation. 1993;87:II56–II65.
13. Bots ML, Hoes AW, Koudstaal PJ, Hofman A, Grobbee DE. Common carotid intima-media thickness and risk of stroke and myocardial infarction: The Rotterdam Study. Circulation. 1997;96:1432–1437.
14. Burke GL, Evans GW, Riley WA, Sharrett AR, Howard G, Barnes RW, et al. Arterial wall thickness is associated with prevalent cardiovascular disease in middle-aged adults. The Atherosclerosis Risk in Communities (ARIC) Study. Stroke. 1995;26:386–391.
15. O'Leary DH, Polak JF, Kronmal RA, Manolio TA, Burke GL, Wolfson SK Jr. Carotid-artery intima and media thickness as a risk factor for myocardial infarction and stroke in older adults. Cardiovascular Health Study Collaborative Research Group. N Engl J Med. 1999;340:14–22.
16. Chambless LE, Heiss G, Folsom AR, Rosamond W, Szklo M, Sharrett AR, et al. Association of coronary heart disease incidence with carotid arterial wall thickness and major risk factors: The Atherosclerosis Risk in Communities (ARIC) Study, 1987-1993. Am J Epidemiol. 1997;146:483–494.
17. Chambless LE, Folsom AR, Clegg LX, Sharrett AR, Shahar E, Nieto FJ, et al. Carotid wall thickness is predictive of incident clinical stroke: The Atherosclerosis Risk in Communities (ARIC) Study. Am J Epidemiol. 2000;151:478–487.
18. The ARIC Investigators. The Atherosclerosis Risk in Communities (ARIC) Study: Design and objectives. Am J Epidemiol. 1989;129:687–702.
19. Jackson R, Chambless LE, Yang K, Byrne T, Watson R, Folsom A, et al. Differences between respondents and nonrespondents in a multicenter community-based study vary by gender ethnicity. The Atherosclerosis Risk in Communities (ARIC) Study Investigators. J Clin Epidemiol. 1996;49:1441–1446.
20. Whitsel EA, Rose KM, Wood JL, Henley AC, Liao D, Heiss G. Accuracy and repeatability of commercial geocoding. Am J Epidemiol. 2004;160:1023–1029.
21. Diez-Roux AV, Kiefe CI, Jacobs DR Jr, Haan M, Jackson SA, Nieto FJ, et al. Area characteristics and individual-level socioeconomic position indicators in three population-based epidemiologic studies. Ann Epidemiol. 2001;11:395–405.
22. Bond MG, Barnes RW, Riley WA, Wilmoth SK, Chambless LE, Howard G, et al. High-resolution B-mode ultrasound scanning methods in the Atherosclerosis Risk in Communities Study (ARIC). The ARIC Study Group. J Neuroimaging. 1991;1:68–73.
23. National Heart, Lung and Blood Institute. Atherosclerosis Risk in Communities (ARIC) Study. Operations Manual, no. 6B: Ultrasound Assessment. Part A, Ultrasound reading, version 1.0. Chapel Hill, NC: ARIC Coordinating Center, School of Public Health, University of North Carolina at Chapel Hill; 1987.
24. Riley WA, Barnes RW, Bond MG, Evans G, Chambless LE, Heiss G. High-resolution B-mode ultrasound reading methods in the Atherosclerosis Risk in Communities (ARIC) cohort. The ARIC Study Group. J Neuroimaging. 1991;1:168–172.
25. National Heart, Lung and Blood Institute. Atherosclerosis Risk in Communities (ARIC) Study. Operations Manual, no. 6A: Ultrasound Assessment. Part A, Ultrasound Scanning, version 1.0. Chapel Hill, NC: ARIC Coordinating Center, School of Public Health, University of North Carolina at Chapel Hill; 1987.
26. Chambless LE, Zhong MM, Arnett D, Folsom AR, Riley WA, Heiss G. Variability in B-mode ultrasound measurements in the Atherosclerosis Risk in Communities (ARIC) Study. Ultrasound Med Biol. 1996;22:545–554.
27. National Heart, Lung and Blood Institute. Atherosclerosis Risk in Communities (ARIC) Study. Operations Manual, no. 11: Sitting Blood Pressure, version 1.0. Chapel Hill, NC: ARIC Coordinating Center, School of Public Health, University of North Carolina at Chapel Hill; 1987.
28. Mundt KA, Chambless LE, Burnham CB, Heiss G. Measuring ankle systolic blood pressure: Validation of the Dinamap 1846 SX. Angiology. 1992;43:555–566.
29. Warnick GR, Mayfield C, Benderson J, Chen JS, Albers JJ. HDL cholesterol quantitation by phosphotungstate-$Mg2^{+}$ and by dextran sulfate-$Mn2^{+}$-polyethylene glycol precipitation, both with enzymic cholesterol assay compared with the lipid research method. Am J Clin Pathol. 1982;78:718–723.
30. Friedewald WT, Levy RI, Fredrickson DS. Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. Clin Chem. 1972;18:499–502.
31. Baecke JA, Burema J, Frijters JE. A short questionnaire for the measurement of habitual physical activity in epidemiological studies. Am J Clin Nutr. 1982;36:936–942.
32. Raghunathan TE. What do we do with missing data? Some options for analysis of incomplete data. Annu Rev Public Health. 2004;25:99–117.
33. Schafer JL. Multiple imputation: A primer. Stat Methods Med Res. 1999;8:3–15.
34. Schafer JL, Graham JW. Missing data: Our view of the state of the art. Psychol Methods. 2002;7:147–177.
35. Royston P. Multiple imputation of missing values. STATA J. 2004;4:227–241.
36. Van Buuren S, Boshuizen HC, Knook DL. Multiple imputation of missing blood pressure covariates in survival analysis. Stat Med. 1999;18:681–694.
37. Zhao DY. Logistic regression adjustment of proportions and its macro procedure. The SAS Users Group International Conference (SUGI) 22. San Diego, CA: SAS Institute Inc., 1998:1045–1050.
38. Chambless LE, Folsom AR, Davis V, Sharrett R, Heiss G, Sorlie P, et al. Risk factors for progression of common carotid atherosclerosis: The Atherosclerosis Risk in Communities Study, 1987-1998. Am J Epidemiol. 2002;155:38–47.
39. Strong JP, Malcom GT, McMahan CA, Tracy RE, Newman WP III, Herderick EE, et al. Prevalence and extent of atherosclerosis in adolescents and young adults: Implications for prevention from the Pathobiological Determinants of Atherosclerosis in Youth Study. JAMA. 1999;281:727–735.
40. Stary HC. Evolution and progression of atherosclerotic lesions in coronary arteries of children and young adults. Arteriosclerosis. 1989;9:I19–II32.
41. Strong JP, McGill HC Jr. The natural history of coronary atherosclerosis. Am J Pathol. 1962;40:37–49.
42. Cole SR, Hernan MA. Fallibility in estimating direct effects. Int J Epidemiol. 2002;31:163–165.
43. Rose KM, Wood JL, Knowles S, Pollitt RA, Whitsel EA, Diez Roux AV, et al. Historical measures of social context in life course studies: Retrospective linkage of addresses to decennial censuses. Int J Health Geogr. 2004;3:27.
44. Pollitt RA, Rose KM, Kaufman JS. Evaluating the evidence for models of life course socioeconomic factors and cardiovascular outcomes: a systematic review. BMC Public Health. 2005;5:7.