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"Association of Socioeconomic Status with Inflammation Markers in Black and White Men and Women in the Coronary Artery Risk Development in Young Adults (CARDIA) Study"

Tara L. Gruenewald,
University of California, Los Angeles Los Angeles, CA UNITED STATES[Proxy]

Sheldon Cohen, PhD,
Carnegie Mellon University

Karen A Matthews, PhD,
University of Pittsburgh

Russell Tracy, and
University of Vermont

Teresa E Seeman, PhD
University of California, Los Angeles

Abstract

Inflammatory processes are implicated in a number of diseases for which there are known socioeconomic status (SES) disparities, including heart disease and diabetes. Growing evidence also suggests SES gradients in levels of peripheral blood markers of inflammation. However, we know little about potential gender and racial/ethnic differences in associations between SES and inflammation, despite the fact that the burden of inflammation-related diseases varies by gender and race. The present study examines SES (education and income) gradients in levels of two inflammatory biomarkers, C-reactive protein (CRP) and interleukin-6 (IL-6), in a biethnic (White and Black) sample of men and women (n = 3,549, aged 37-55 years) in the USA from the CARDIA Study. Health status, behavioral and psychosocial variables that may underlie SES differences in inflammatory biomarker levels were also examined. Age-adjusted CRP and IL-6 levels were inversely associated with education level in each race/gender group except Black males. Income gradients were also observed in each race/gender group for IL-6 and in White females and males for CRP. In general, differences in CRP and IL-6 levels between low and high SES groups were reduced in magnitude and significance with the addition of health status, behavioral, and psychosocial variables, although the impact of the addition of model covariates varied across race/gender groups and different SES-inflammation models. Overall, findings indicate SES gradients in levels of inflammation burden in middle-aged White and Black males and females.

Corresponding Author: tgruenewald@mednet.ucla.edu.

Keywords

USA; inflammation; C-reactive protein; interleukin-6; socioeconomic status (SES); gender; race/ethnicity; biomarkers; health inequalities

Introduction

The inverse association between socioeconomic status (SES) and morbidity and mortality is well documented by a long history of research. Lower SES, whether measured in terms of education, income, or occupational status, is associated with greater risk for the development of many diseases, more rapid disease progression, and decreased survival (see Adler, 1999; Adler et al., 1994; Kaplan & Keil, 1993, for reviews). The greater risk for adverse health outcomes in those of lower SES is not simply the product of those living in abject poverty experiencing poorer health, as variations in health outcomes are found as one moves across the SES gradient, with those of moderate SES levels faring better than those lower on the gradient, and those at higher levels having more favorable health outcomes than those in the middle of the gradient.

The consistent observation of SES gradients in health has led to the search for pathways through which social status may impact health, including biological mechanisms through which social characteristics and experiences may affect functioning and disease outcomes. One biological pathway that is gaining increasing interest in this search is subclinical inflammation, as inflammatory processes are thought to be involved in both the development and progression of a number of diseases for which there are known SES gradients. Peripheral blood levels of inflammatory biomarkers, such as interleukin-6 (IL-6), C-reactive protein (CRP) and fibrinogen, predict risk of the development of diabetes (Thorand et al., 2003) and CHD (Koenig et al., 1999; Mendall et al., 2000; Sesso, Wang, Buring, Ridker, & Gaziano, 2007), as well as all-cause and CHD-related mortality (e.g., Danesh, Collins, Appleby, & Peto, 1998; Tuomisto, Jousilahti, Sundvall, Pajunen, & Salomaa, 2006). Although whether these inflammatory markers play an etiological role in disease development or simply reflect the activity of Cother pathogenic factors is presently unknown (Casas, Shah, Hingorani, Danesh & Pepys, 2008).

A growing body of research also suggests SES variations in levels of inflammatory biomarkers. Early work in this area documented SES gradients in fibrinogen levels, with those of lower education, income and occupational class having higher fibrinogen levels (Brunner et al., 1997; Ishizaki, Martikainen, Nakagawa, & Marmot, 2000; Steptoe et al., 2003; Wamala et al., 1999; Wilson et al., 1993). More recent investigations have demonstrated similar associations of SES with CRP and IL-6 (Jousilahti, Salomaa, Rasi, Vahtera, & Palosuo, 2003; Kivimaki et al., 2005; Koster et al., 2006; Loucks et al., 2006; Owen, Poulton, Hay, Mohamed-Ali, & Steptoe, 2003; Rathmann et al., 2006). Taken together, these investigations suggest greater inflammation burden in those of lower SES.

There are a number of characteristics of associations between SES and inflammatory biomarkers that remain relatively unexplored, however. One issue is whether associations between SES and inflammatory biomarkers are similar across different sex and racial/ethnic groups. Women have been found to have higher levels of inflammation burden than men (Lakoski et al., 2006), but it is unclear whether socioeconomic indicators show differential relation to inflammatory markers in men and women. Some studies have found significant associations in one sex only (e.g., in women only: Rathmann et al., 2006), some have documented similar relationships in both sexes (e.g., Kivimaki et al., 2005; Owen et al., 2003), and others have investigated only one sex, usually males (e.g., Ishizaki et al., 2000; Jousilahti et al., 2003; Wilson et al., 1993). Studies of racial/ethnic differences in inflammation

biomarker levels generally find higher levels in African-Americans or Hispanics, as compared to other racial/ethnic groups (Matthews et al., 2005; Nazmi & Victora, 2007). Gender and race may also interact to affect inflammation burden; Black women have been found to have higher inflammation marker levels than White women, who in turn have higher levels than Black men, with White men having the lowest levels (Khera et al., 2005). Few studies have specifically examined potential racial/ethnic differences in SES-inflammation associations. Koster and colleagues (2006) reported similar SES-inflammation associations in older Black and White adults, while a study by Pollitt and associates (2007) indicated less consistent SES gradients in inflammation levels in middle-aged Blacks, as co mpared to Whites. Given both racial and sex disparities in inflammation-associated diseases, such as higher rates of CHD incidence and mortality in African-Americans, as compared to other racial/ethnic groups, and in men, as compared to women, in the U.S. (Cooper, 2001; Ho, Paultre, & Mosca, 2005), further examination of whether SES gradients in inflammatory biomarkers vary across race and gender groups may be informative in understanding the biological pathways through which the social environment impacts health in different demographic groups.

Another issue regards the pathways through which SES might impact inflammation burden. Three commonly hypothesized pathway domains are health status (e.g., health conditions, obesity), behavioral (e.g., smoking, physical activity), and psychosocial (e.g., stress, affective states) factors. Those of lower SES may experience elevations in inflammation levels due to a greater burden of diseases in which inflammatory processes play a role, as well as from greater obesity/body mass via synthesis of inflammation biomarkers from adipose tissue (Coppack, 2001). Variations in health behaviors, such as smoking, which is thought to raise inflammation levels (Frohlich, Sund, Lowel, Imhof, & Koenig, 2003), and physical activity, which is associated with lower levels of inflammation (see Kushner, Rzewnicki & Samols, 2006), may also account for SES variations in inflammation burden. Indeed, a number of previous investigations have documented that SES variations in inflammation burden are partially or completely accounted for by health status and behavioral variables (e.g., Jousilahti et al., 2003; Kivimaki et al., 2005; Koster et al., 2006; Owen et al., 2003; Rathmann et al., 2006). A growing body of research links psychosocial factors thought to be more prevalent in those of lower SES, such as chronic stressor experience, depressed affect, and lower levels of social integration and social support (Williams, 1990), to higher levels of inflammation burden (Loucks, Berkman, Gruenewald, & Seeman, 2005, 2006; Loucks, Sullivan, D'Agostino, Larson, Berkman & Benjamin, 2006; Ranjit et al., 2007), possibly through physiological stress mechanisms (Black, 2006). Different pathways might also underlie SES gradients in inflammation level in different gender and ethnic/racial groups, as SES has been shown to have differential association with biobehavioral variables, such as BMI and smoking, in different demographic groups (Diez-Roux, Merkin, Hannan, Jacobs & Kiefe, 2003; Lewis, Everson-Rose, Sternfeld, Karavolos, Wesley & Powell, 2005; Zhang & Wang, 2004).

The goals of the current investigation were to: (1) Examine potential SES gradients in peripheral blood levels of CRP and IL-6 in a biethnic (Black and White) sample of men and women in their 40's and 50's in the Coronary Artery Risk Development in Young Adults (CARDIA) Study, and (2) Determine the extent to which hypothesized SES gradients in inflammatory markers are accounted for by health status, behavioral and psychosocial factors known to vary by SES and which may affect inflammatory biomarker levels. The sampling design of the CARDIA study, with relatively large numbers of White females, Black females, White males, and Black males, allows us to examine whether associations between SES and inflammation biomarkers vary across these groups, and to examine potential variations across the groups in the impact of health status, behavioral and psychosocial covariates on SES-inflammation associations.

Methods

Participants

Data were collected in year 20 (2005-2006) of the CARDIA study, a prospective, multisite investigation of the natural history of cardiovascular risk development in young adulthood. In 1985 to 1986, 5,115 White and Black women and men age 18 to 30 years were recruited for participation from four communities: Birmingham, AL, Chicago, IL, Minneapolis, MN, and Oakland, CA. Participants were recruited to achieve a balance of participants at each site by sex, race (White, Black), age (18-24 and 25-30 years), and education (high school degree or less, more than high school degree). Detailed descriptions of the study design and cohort are available elsewhere (Friedman et al., 1988). At the year 20 exam (seventh wave), 69% of the original cohort participated (n = 3,549; White females n = 1008, Black females n = 1005, White males n = 889, Black males n = 646).[1] Subjects participating were more likely to be White, female, slightly older, and more highly educated than those individuals of the original cohort that did not participate.

Measures

Sociodemographic variables—Gender was coded as male or female, age was coded in years, and race was coded as White or Black.

Education and income variables—Educational attainment was measured according to highest self-reported educational degree. A 4-category variable representing less than or equal to a high school degree (≤ HS degree), an associate art degree or 2-year technical/trade degree or certificate (AA degree/equivalent), a bachelor's of arts degree (BA degree), or a master's degree or higher (≥ MA degree: master's degree, PhD, MD, or other professional degree), was used in analyses. Self-reported income was measured in nine brackets (< $5,000, $5,000 -11,999, $12,000-15,999, $16,000 – 24,999, $25,000 – 34,999, $35,000 – 49,999, $50,000 – 74,999, $75,000 – 99,999, and ≥ $100,000) reflecting yearly pre-tax fam ily income (from all sources). Given the low number of participants in the lower income brackets, the bottom 4 categories were recoded into one lowest category (< $25,000) and the next two middle-income categories were combined into a single category ($25,000 - $49,999), yielding a 5-category income variable for use in analyses.

Health status covariates—Given the large number of medical conditions associated with elevations in inflammatory biomarkers (Kushner et al., 2006), a summary index of the total number of twenty-eight major or chronic health conditions (e.g., high blood pressure, diabetes, asthma; see Box 1 for full list) for which the participant was ever told they had the condition by a doctor/healthcare specialist was used to assess health status. Body mass index (BMI), computed as the ratio of weight (kg) to height $(cm)^2$), was used as an index of obesity.

Health behavior variables—Alcohol consumption was assessed with the use of two dummy-variables representing < 1 drink/day on average or 1+ drinks per day on average (no alcohol consumption served as referent group), based on questions about weekly intake of beer, wine and liquor consumption. A physical activity intensity score was computed by multiplying reported frequency of engagement in 13 exercise and recreation activities by the intensity of the activity (Jacobs, Han, Haskell, Pirie, Sidney, 1989). Smoking status was assessed with the use of two dummy variables indicating current smoking status or ex-smoker status (non-smokers served as referent group). Poor sleep quality was measured with a single rating of sleep quality over the past month (1 — very good to 5 — very bad).

[1]One additional subject participated at the year 20 exam whose gender changed from baseline study enrollment to the year 20 exam. This participant was excluded from the current analyses.

Psychosocial variables—Chronic burden level was comput ed as the mean of ratings of chronic strain (1 — no strain in domain to 4 — yes, strain in domain and very stressful) in four domains (health of close others, work, finances, relationships). Social integration was assessed as the average of reported number of close friends and close relatives using a 5-point scale (none, 1 or 2, 3 to 5, 6 to 9, or 10 or more) for each target. Emotional support was computed as the mean of four ratings (1=not at all to 4=a lot) of perceived care and support from friends and family. Social conflict/demands was assessed as the mean of four ratings (1=not at all to 4=a lot) of frequency of demands/criticisms from friends and family. Depressed mood was measured with the Center for Epidemiologic Studies Depression (CESD) scale.

Inflammatory biomarkers—CRP was measured using the BNII nephelometer from Dade Behring utilizing a particle e nhanced immunoepholometric assay. The assay range is 0.175 - 1100 mg/, intrassay CVs range from 2.3-4.4% and inter-assay CVs range from 2.1-5.7%. IL-6 was measured by ultra-sensitive ELISA (R&D Systems, Minneapolis, MN). The lower detection limit is <0.10 pg/mL, with a detection range of 0.156-10.0 pg/mL and a routine inter-assay CV in the lab of 10.0%. CRP and IL-6 values were log-transformed to make the distributions of each more normal.

Statistical Analyses

The current analyses utilize data from 3,434 participants (96.8% of year 20 cohort) for whom complete data were available on SES and inflammation variables. An additional 168 participants with CRP values >= 10 mg/L were excluded from analyses to rule out the possibility of elevated biomarker values due to an acute illness (Pearson et al., 2003), yielding a final analytic sample of 3,266. The rate of missing in formation on covariate variables ranged from 0 to 2.5%. In order to minimize further participant loss, sample mean or mode values were imputed for continuous or categorical covariates, respectively.

All analyses were stratified by the four race/gender subgroups: White females, Black females, White males, and Black males. Descriptive statistics for all study variables were generated for each race/gender subgroup. Scores or the distribution of responses for each covariate across education and income groups were examined to ensure that each health status, behavioral and psychosocial variable was significantly associated with one or both of the SES indicators, and each covariate was also examined for significant association with level of CRP and IL-6. As each covariate was associated with at least one SES indicator and at least one inflammatory biomarker in one or more race/gender subgroups, each was retained in multivariable analyses.

Age-adjusted geometric mean CRP and IL-6 values were graphed by the 4-category education and 5-category income variable in each race/gender subgroup for descriptive purposes. Tests of linear trends using general linear models were conducted to examine the association of SES variables with levels of CRP and IL-6 when adjusting for potential health status, behavioral and psychosocial covariates. Separate models were run for education and income. Age was included as a covariate in the first model (baseline model), health status variables (number of chronic health conditions, BMI) were additionally included as covariates in the second model, health behavior variables (smoking, alcohol use, physical activity frequency, sleep quality) were added as covariates in the third model, and psychosocial variables (chronic burden, social integration, emotional support, social conflict, depressed mood) were additionally included as covariates in the fourth model. Parameter estimates representing differences between each SES group as compared to the highest SES group in log-transformed CRP or IL-6 units were exponentiated so that resulting values represent the percent higher or lower level of the inflammatory biomarker for each group as compared to the referent (highest SES) group. The significance of the linear trend test and change in the magnitude of difference in inflammation biomarker levels between the highest and lower SES groups was examined for each model to

assess the impact of the addition of health status, behavioral and psychosocial factors to the model on SES disparities in inflammation level.

Results

Descriptive statistics for study variables in each race/gender group are presented in Table 1. As noted in the table, White males and females had a more favorable SES profile as compared to Black males and females, with greater representation in higher education and income categories. Females reported a higher number of chronic health conditions as compared to males. Males were more likely to report frequent alcohol consumption, with Black females reporting the lowest rates of alcohol use. Black males had the highest rates of current smoking, followed by Black females, and White males and females had considerably lower rates. Males had higher rates of physical activity than females, and White females had substantially higher levels than Black females. BMI varied considerably across the four groups, with Black females having the highest levels, then Black males and White males, and White females having the lowest levels. Profiles of psychosocial variables were fairly similar across the four groups, although Black females reported higher levels of depressed mood than the other groups and White males reported the lowest levels. Black females had the highest mean levels of CRP and IL-6, Black males had the next highest levels, and White females and males had the lowest levels of each inflammatory marker across the four groups.

In general, lower SES was associated with a greater number of chronic health conditions, higher BMI, greater rates of current smoking, lower levels of physical activity, poorer sleep quality, greater chronic burden, lower levels of social integration and emotional support, greater social conflict, and higher levels of depressed mood (data not shown), although associations between SES indicators and each of these variables were not significant in every group. More frequent alcohol consumption was more concentrated in upper SES categories in Whites and in the lowest SES categories in Black males and the lowest income category in Black females. Unlike in other groups, BMI was higher in higher income groups and did not significantly vary across levels of education in Black males. Associations between potential mediators and inflammation biomarkers are discussed in further detail below.

SES and inflammation burden

Age-adjusted geometric mean levels of CRP and IL-6 by education and income in each race/gender group are depicted in Figure 1. In general, a graded pattern was evident with lower CRP and IL-6 levels with higher education and income, although this pattern was not perfectly linear in each race/gender group and CRP and IL-6 did not significantly vary by education in Black males. The results of general linear models exploring CRP and IL-6 levels by education and income levels in each race/gender group when including covariates into analytic models are noted in Table 2, and described in greater detail below.

White females

Significant linear trends were observed for age-adjusted CRP and IL-6 levels as a function of education and income level in White females (see Table 2). However, these significant linear trends were eliminated with the addition of health covariates into the models, with BMI being a strong and significant predictor of higher inflammation level (data not shown). In final multivariate models, number of major/chronic health conditions and current smoking were also associated with higher IL-6 levels, while frequent alcohol use and poor sleep quality were associated with lower IL-6 levels (data not shown).

Black females

Significant linear trends were observed for age-adjusted CRP and IL-6 levels by education in Black females (see Table 2). Linear trends remained significant in models for CRP that included health status, behavioral and psychosocial covariates, although the magnitude of differences between the lower and the highest education group was moderately reduced (reductions of 34-39% for model coefficients). For IL-6, the linear trend remained significant with the inclusion of health status covariates, but not with the addition of behavioral and psychosocial covariates into analytic models. Although CRP levels did not significantly vary by income level, a significant linear trend was observed for IL-6. This linear trend remained significant even when including covariates into analytic models, although the magnitude of differences between lower and the highest income group was reduced somewhat (reductions of 26-35% for model coefficients). In final multivariate models, higher BMI was associated with higher CRP and IL-6, current smoking with higher CRP, poorer sleep quality with higher CRP, higher levels of physical activity with lower CRP and IL-6, higher levels of chronic burden with lower CRP and IL-6, and greater depressed mood with higher IL-6 in Black females (data not shown).

White males

Significant linear trends were observed for both CRP and IL-6 levels as a function of education and income level in White males (see Table 2). Although linear trends remained significant with the addition of health status, behavioral and psychosocial covariates into analytic models, the magnitude of differences between the lowest and highest SES groups was moderately reduced (reductions of 34-54% for CRP model coefficients; reductions of 10-30% for IL-6 model coefficients). In fully-adjusted models, BMI and current smoking were associated with higher CRP and IL-6, and poor sleep quality with higher IL-6 (data not shown).

Black males

CRP and IL-6 levels did not significantly vary by education level in Black males (see Table 2). Although a significant linear trend was not apparent for CRP by income level, a significant linear trend did emerge in a model (Model 2) including health status covariates. Only BMI was a significant predictor of higher CRP levels in this model, and as noted above, unlike in other race/gender groups, higher income is associated with higher BMI in Black males, which may account for the greater association between income and CRP when including BMI. Significant linear trends were observed for IL-6 levels as a function of income level and the magnitude of differences in IL-6 levels between the lower and the highest income groups were only slightly reduced (reductions of 13-27% for coefficients) when including health status, behavioral and psychosocial covariates into models. In final multivariate models, BMI and current smoking were associated with higher CRP and IL-6, and former smoking and greater physical activity with lower CRP (data not shown).

Supplementary analyses

The summary measure of chronic health conditions was not a significant predictor of inflammation burden in most fully-adjusted models across race/gender subgroups with the exception of models for IL-6 in White females. Our intent in using a summary health condition index was to capture disease burden across a wide range of conditions that might lead to elevations in inflammation levels. However, it is possible that a summary measure might obscure associations between specific health conditions and inflammation levels or that different health conditions might have a larger association with inflammation in different race/gender subgroups. To examine this hypothesis, analyses were repeated with individual dichotomous indicators for frequently occurring (prevalence of 5 % or greater in total sample) conditions. Similar to results using the summary health conditions variable, most individual conditions were also not significant predictors of inflammation markers in fully-adjusted

models. However, significant predictors of CRP levels were asthma and digestive disorders in White females, digestive disorders in Black females and hypertension in White males. Significant predictors of IL-6 were hypertension and pneumonia in White females, hypercholesterolemia and migraines in Black females, and hypertension and diabetes in White males. The pattern of results for SES predictors was similar when including separate disease conditions in models in place of the summary health condition score.

Discussion

Consistent with a growing body of research, this study documented education and income differences in inflammation burden in young to middle-aged adults, although associations between SES and inflammation variables varied somewhat across race and gender subgroups. CRP and IL-6 levels were inversely associated wi Pth education and income levels in both White males and females. Inflammation biomarker levels were also inversely associated with SES variables in Black females, except for CRP by income level. Overall, SES showed little association to inflammation biomarker levels in Black males, with the exception of a significant inverse association between IL-6 and income. Pollitt and colleagues (2007) also found that SES-inflammation associations were less consistent in middle-aged Blacks as compared to Whites, but they did not report whether associations further varied by gender. In regards to gender differences, previous studies have noted no differences in SES-inflammation associations across men and women (e.g., Kivimaki et al., 2005), or stronger associations in women (e.g., Rathmann et al., 2006). Our findings clearly suggest that ties between social status and inflammation vary across race/gender subgroups and indicate that more attention may need to be directed to the intersection of race and gender in regards to understanding SES differences in inflammation burden.

Examination of the health status, behavioral and psychosocial factors that may account for SES-inflammation associations suggest a similar role for some variables (e.g., BMI, smoking) across most groups, but group-specific roles for other factors (e.g., sleep quality, depressed mood). BMI was a strong and consistent predictor of CRP and IL-6 in each group, and its inclusion in analytic models tended to reduce the magnitude of the association between SES and inflammation variables, especially in White females, and to a lesser extent in Black females and White males. Although BMI was as sociated with higher inflammation burden in Black males, higher income was associated with higher BMI in Black males, and the inclusion of BMI into regression models tended to streng inflammatory biomarkers. Anthropometric then the association between income and variables have been found to account for a significant proportion of SES-inflam mation associations in other investigations (Kivimaki et al., 2005; Koster et al., 2006; Rathmann et al., 2006), suggesting that social status variations in body size may partially account for SES disparities in inflammation burden. However, the temporal nature of associations between SES, body size and inflammatory biomarker levels remains to be fully elucidated. Previous research has documented greater weight gain in lower SES CARDIA participants over the first five years of follow-up (Burke, Bild, Hildner, Folsom, Wagenknecht, & Sidney, 1996), and SES has been found to be inversely associated with obesity in a large number of studies, with this relationship being stronger and more consistent in women (see Sobal & Stunkard, 1989, for a review). Adipose tissue can synthesize inflammatory biomarkers, such as IL-6 (which may, in turn, promote synthesis of CRP; Coppack, 2001), suggesting that SES may impact biomarker levels through fat accumulation. However, it is also possible that obesity may impact socioeconomic success (Sobal & Stunkdard, 1989).

Smoking was another covariate factor that emerged as a significant predictor of higher CRP and IL-6 levels in most analyses across the four race/gender groups, a factor that has been found to partially account for associations between SES and inflammation biomarker levels in other investigations (Koster et al., 2006; Pollitt et al., 2007). Other significant covariate

predictors tended to vary across models for race/gender groups. For example, poor sleep quality predicted higher inflammation burden in Black females and White males, frequent alcohol use predicted lower IL-6 in White females, a greater number of chronic health conditions predicted higher IL-6 levels in White females, higher physical activity intensity was associated with lower inflammation burden in Black females and males, and higher depressed mood was associated with higher IL-6 in Black females. The inclusion of these covariates into analytic models was associated with slight to moderate reductions in the magnitude of differences in CRP and IL-6 levels between education and income categories, suggesting that these factors may partially account for SES variations in inflammation burden in the race and gender groups studied. The lack of complete attenuation of SES-inflammation associations with the inclusion of model covariates in some models s uggests that other important factors not measured in this investigation may underlie SES-inflammation associations and/or that our measures failed to completely capture the behavioral and psychosocial constructs of interest, limiting power to find a meditational effect.

There are a number of limitations of the present analysis. One is the low representation of individuals of very low SES (e.g., those with only an elementary education, living in poverty) in the CARDIA cohort, which precludes our ability to capture inflammatory biomarker levels in those at the lowest end of the SES spectrum. Nonetheless, the finding of SES gradients even across higher levels of education and income may point to the general robustness of SES disparities in biological risk factors. The distribution of race and gender subgroup participants was also uneven across education and income categories with the distribution of Black females and males skewed toward the lower end of the SES distribution and the distribution of White females and males toward the higher end of the SES spectrum. While such distributions likely reflect the socioeconomic realities of each of these groups, they may also suggest qualitatively different socioeconomic experiences across groups even within a particular SES category. Nonetheless, patterns of inflammation burden across levels of education and income were fairly similar across the groups, with the exception of inflammation patterns for education in Black males. The distribution was especially skewed to wards lower levels of educational attainment in Black males, which may have limited power to find significant education differences. The cross-sectional nature of the present analyses also precludes the ability to more carefully discern the temporal nature of associations between SES Pvariables, health, behavioral and psychosocial covariates, and inflammatory biomarker levels. However, the change in the association between SES variables and inflammation biomarkers when in cluding covariates into analytic models does suggest potential pathways through which social status may impact biological well-being. The longitudinal dynamics of associations between SES, psychosocial, behavioral, health and inflammatory factors is an important target for future research. Greater attention should also be given to understanding periods of the life course in which SES might have the greatest impact on inflammation burden, the pathways which might link SES to inflammatory processes at different ages, and the potential cumulative impact of lifetime socioeconomic disadvantage (e.g., Tabassum, Kumari, Rumley, Lowe, Power, & Strachan, 2008).

A strength of this study is the examination of SES-inflammation associations, and potential mediating factors, in race and gender subgroups. A number of race/gender subgroup differences emerged in our analyses, which would have been obscured with the simple inclusion of race and gender covariates in models. For example, the finding that income, but not education, was significantly associated with IL-6 levels in Black males, and that regression estimates for SES predictors were differentially affected by inclusion of BMI as a covariate in Black males as compared to the other race/gender groups, are findings that would not have clearly emerged from analysis of the entire sample. Stratified race/gender analyses also allowed for the discernment of health status, behavioral and psychosocial factors that differentially accounted for SES-inflammation associations across the four groups. Another contribution of the present

investigation is the inclusion of a large array of potential mediating factors, including psychosocial variables, in analyses of SES-biomarker associations. Although psychosocial variables were less consistent predictors of inflammation biomarkers in full multivariate models, their inclusion in analyses along with standard health status and behavioral variables allowed for examination of a comprehensive set of factors that may help explain observed SES gradients to in inflammation burden.

In conclusion, the present analyses indicate SES gradients in inflammatory biomarker levels in young to middle-aged Black and Wh ite males and females in the CARDIA Study. Observed SES differences may persist and even widen over time as these individuals age into older adulthood, leading to greater levels of cardiovascular and other disease risk in those of lower SES to the degree that higher levels of CRP and IL-6 act to promote the development and progression of disease. Results of multivariable analyses point to the potentially important role of body mass/weight and smoking in accounting for observed SES differences in inflammation burden in most of the race/gender groups studied in the present analysis, while other behavioral and psychosocial factors varied in prominence in terms of accounting for SES variations in different race/gender groups. Taken together, these findings suggest potential foci (e.g., weight, smoking) of intervention efforts to reduce social disparities in physiological health, which may need to be tailored for different race and gender groups. Whether variations in inflammation burden, in turn, account for social disparities in actual disease outcomes is an important area of future research.

Box 1

The major/chronic health condition summary index assessed the lifetime presence or absence of the following 28 conditions: hypertension, hypercholesterolemia, diabetes, heart problems, stroke or transient ischemic attack, chronic obstructive pulmonary disease, peripheral vascular disease, chronic bronchitis, emphysema, blood clots, tuberculosis, pneumonia, asthma, cancer or malignant tumor, thyroid problem, digestive diseases, gout, kidney problems, liver disease, gallstones or gallbladder disease, migraine headaches, epilepsy/seizures, mental disorder, depression, multiple sclerosis, human immunodeficiency virus, current pregnancy, and any other major or chronic health problem.

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