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Diet Quality Is Inversely Associated with C-Reactive Protein Levels in Urban, Low-Income African-American and White Adults

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ABSTRACT

Background C-reactive protein (CRP), an inflammatory biomarker, is influenced by many factors, including socioeconomic position, genetics, and diet. The inverse association between diet and CRP is biologically feasible because micronutrients with antioxidative properties may enable the body to manage the balance between production and accumulation of reactive species that cause oxidative stress.

Objective To determine the quality of the diet consumed by urban, low-income African-American and white adults aged 30 to 64 years, and association of diet quality with CRP.

Design Data from a cross-sectional study were used to evaluate diet quality assessed by mean adequacy ratio (MAR). Two 24-hour recalls were collected by trained interviewers using the US Department of Agriculture automated multiple pass method.

Participants The sample consisted of Healthy Aging in Neighborhoods of Diversity across the Life Span baseline study participants, 2004-2009, who completed both recalls (n=2,017).

Main outcome measures MAR equaled the average of the ratio of intakes to Recommended Dietary Allowance for 15 vitamins and minerals. CRP levels were assessed by the nephelometric method utilizing latex particles coated with CRP monoclonal antibodies.

Statistical analysis Linear ordinary least square regression and generalized linear models were performed to determine the association of MAR (independent variable) with CRP (dependent variable) while adjusting for potential confounders.

Results MAR scores ranged from 74.3 to 82.2. Intakes of magnesium and vitamins A, C, and E were the most inadequate compared with Estimated Average Requirements. CRP levels were significantly associated with MAR, dual-energy x-ray absorptiometry-measured body fat, and hypertension. A 10% increase in MAR was associated with a 4% decrease in CRP.

Conclusions The MAR was independently and significantly inversely associated with CRP, suggesting diet is associated with the regulation of inflammation. Interventions to assist people make better food choices may not only improve diet quality but also their health, thereby possibly reducing risk for cardiovascular disease.

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IN THE UNITED STATES, IT IS RECOGNIZED THAT HEALTH is consistently worse for people with limited resources and for African Americans compared with whites.[1-3] Since 2000, the Healthy People campaign has included goals to achieve health equity, eliminate disparities, and improve the health of all population groups.[4] Unfortunately, there are still racial disparities in the prevalence of overweight and obesity, with higher rates among non-Hispanic blacks compared to non-Hispanic whites.[5]

Obesity causes a dysregulation of multiple metabolic and endocrine pathways such as low-grade inflammation, which results in chronically elevated serum concentrations of proinflammatory biomarkers.[6,7] C-reactive protein (CRP) is a systemic acute phase protein produced mainly by the liver in response to circulating inflammatory mediators, including interleukin-6 and interleukin-1 with systemic inflammation, injury, infection, and malignancy.[8] The poor are at high risk for elevated CRP.[9,10] Inflammation may be one pathway through which socioeconomic position influences health.[10,11] The affect of socioeconomic position on CRP levels can be influenced by genetics, which accounts for 25% to 40% of the variation in CRP levels between people,[12] and behaviors such as smoking and diet.[11,13-19] Diets high in dietary fiber and rich in fruits and vegetables are associated with lower CRP levels,[20-23] whereas consumption of a Western-style diet—a diet high in fat, sugar, sodium, and refined grains—has been

hypothesized to elevate CRP levels.[20,24,25] Although the mechanisms are still unclear, a healthful diet is known to be inversely associated with inflammatory factors.[25]

Many US adults fail to consume adequate micronutrients in their diets.[26,27] The racial or ethnic differences in micronutrient intakes, especially those nutrients with antioxidant action, might lead to ineffective resolution of inflammation and may contribute to health disparities. Currently there is no definitive study with a low-income urban population that evaluates whether diet contributes to the elevated CRP levels observed in these populations. The objectives of our study were to determine diet quality based on micronutrient intakes of African-American and white participants examined in the baseline Healthy Aging in Neighborhoods of Diversity across the Life Span (HANDLS) study and then to determine whether diet has an independent association with CRP when adjusting for potential confounders.

SUBJECTS AND METHODS

Study Background and Subjects

The HANDLS study, a community-based, prospective longitudinal epidemiologic study, was designed to examine whether race, sex, and socioeconomic status influence age-related health disparities independently or synergistically. Baseline data collection on socioeconomically diverse African Americans and whites residing in the city of Baltimore, MD, began in August 2004 and ended March 2009, with a total of 3,720 participants. There were two phases in the baseline study. The first phase was done in the participant's home. The second phase was completed 4 to 10 days later, on mobile research vehicles located in preselected census tracts where participants resided. The study protocol was approved by the human investigation review boards at both MedStar Health Research Institute and University of Delaware. All HANDLS participants provided written informed consent and were compensated monetarily. Further detailed information on the study design, subject recruitment, and data collected can be found elsewhere.[28]

Our sample consisted of 2,017 (which represents 54% of people enrolled and who completed household interview) individuals who completed 2 days of 24-hour dietary recalls and had all of the anthropometric and clinical variables used in this study (Figure 1). Participants who completed only 1 recall day were not included because their medical examination data were missing. There were no statistical differences in demographic data or energy and nutrient profiles of the participants who completed 1 or 2 days of dietary recall.

Measures

Dietary Collection Method. The US Department of Agriculture's Automated Multiple Pass Method (AMPM)[29] dietary recall survey (versions 2.3 [2004] to 2.6 [2007]) was used to collect both dietary recalls. The survey was supplemented by measurement aids such as measuring cups, spoons, ruler, and an illustrated food model booklet to assist participants in estimating accurate quantities of foods and beverages consumed. Both 24-hour dietary recalls were administered by trained interviewers. The AMPM was validated in a study with 524 healthy, weight-stable volunteers, aged 30 to 69 years, as well as studies with 20 adult women and 12 adult men. The method is effective for collecting accurate group energy intake of adults, based on comparisons of reported energy intake to total energy expenditure using the doubly labeled water technique.[29-31] The dietary recalls were coded using Survey Net, matching foods consumed with codes in the Food and Nutrient Database for Dietary Studies version 3.0 (2008, Agricultural Research Service, Food Surveys Research Group). Observation questions were completed at the end of the recall allowing interviewers to report any unreliable or suspicious behavior during interviews. All interviews undergo rigorous quality control checks and any flags or discrepancies are resolved by a supervisor.

Diet Quality Variables. Nutrient-based diet quality was determined by comparing the proportion of nutrients consumed to the Recommended Dietary Allowance (RDA). Based on models published by Raffensperger and colleagues[32] and Murphy and colleagues,[33] dietary intakes of calcium, magnesium, phosphorus, vitamin A, vitamin C, vitamin E, vitamins B-6 and B-12, folate, iron, thiamin, riboflavin, niacin, copper, and zinc were used as the basis for diet quality. RDAs of these 15 vitamins and minerals were used to determine the nutrient adequacy ratio (NAR), using the following formula:

NAR=Subject's daily intake of nutrient divided by the RDA of nutrient. An adjustment of an additional 35 mg vitamin C was applied to the RDA for participants who were current smokers.[34] The NAR of each nutrient was then converted to a percent, and percentages >100% were truncated to 100%.[33]

The total quality of the diet was then calculated from the NARs to form a mean adequacy ratio (MAR) using the following formula: MAR=Sum of all 15 nutrient NARs divided by 15.

Anthropometric Measure. Body fat was measured by dual-energy x-ray absorptiometry (DXA) using a Lunar DPX-IQ (Lunar Corp). Because there was no consensus on DXA dichotomy for obese vs nonobese,[35] obesity was defined from DXA measures as >25% for men and >35% for women.[36]

Clinical Measures. High-sensitivity CRP levels were assessed by the nephelometric method utilizing latex particles coated with CRP monoclonal antibodies. Insulin resistance, a major pathogenic factor for type 2 diabetes, was estimated using fasting glucose and insulin by the homeostasis model assessment-insulin resistance (HOMA-IR). HOMA-IR was calculated as plasma glucose (milligrams per deciliter) times serum insulin (micro international units/milliliter) divided by 405, where low calculated values specify high insulin sensitivity, and the reverse for high calculated values. Hypertension was defined as a systolic blood pressure ≥140 mm Hg, a diastolic blood pressure ≥90 mm Hg, taking antihypertensive drugs, or self-reported physician diagnosis. Participants' blood pressures were measured in the sitting position after a 5-minute rest period using a stethoscope, a manometer (aneroid), and an inflatable cuff of the appropriate width and length while on the mobile research vehicle.

Statistical Methods and Analysis

Descriptive statistics were computed for demographic, clinical, and dietary data in the entire sample and across race-age-sex categorizations using t test, χ^2 test, and Mann-Whitney U test. Usual nutrient intakes were

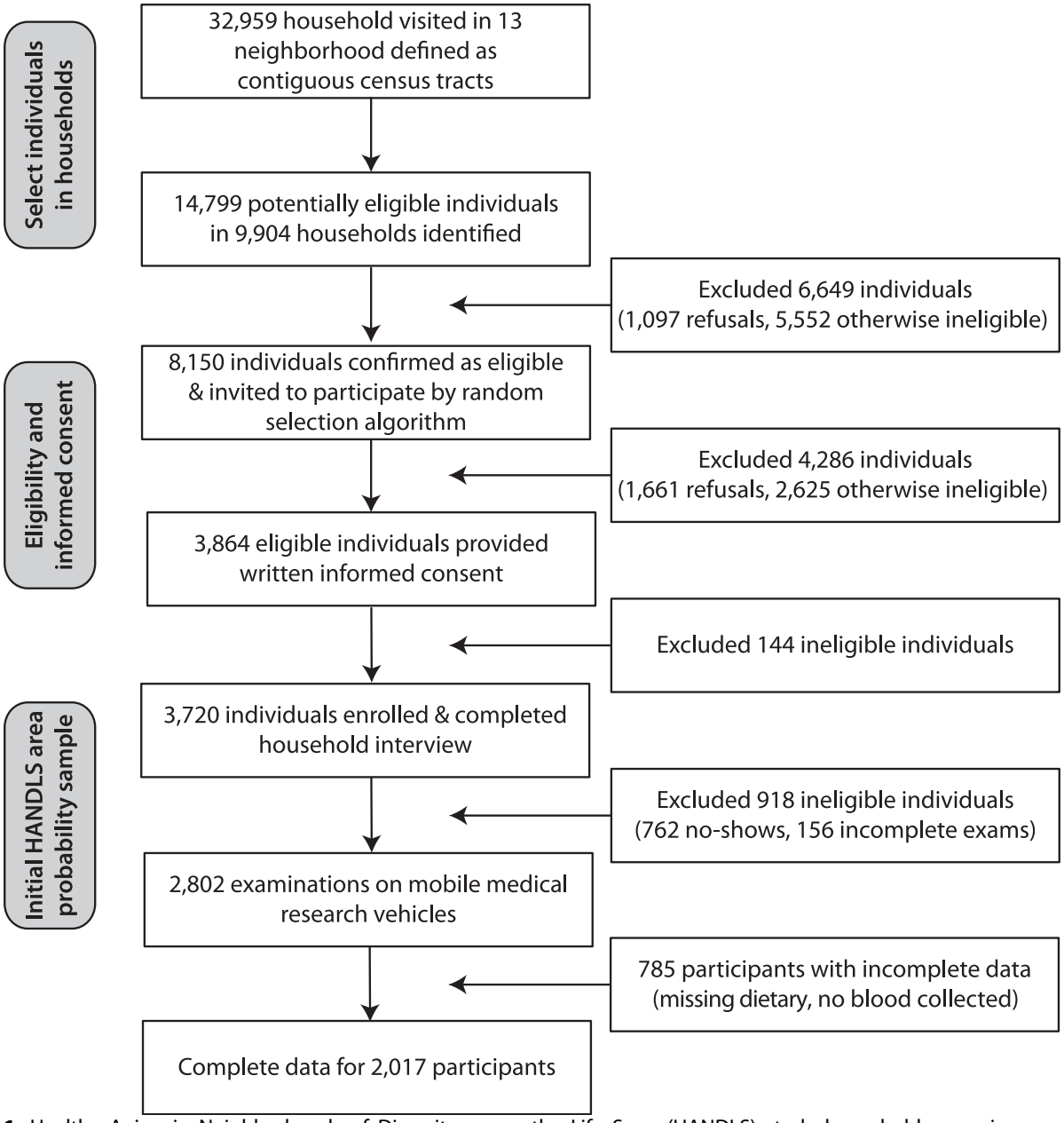

Figure 1. Healthy Aging in Neighborhoods of Diversity across the Life Span (HANDLS) study household screening, participant eligibility, and response rates.

calculated using the amount only model created by the National Cancer Institute[37] that adjusts for the 24-hour recall sequence (Day 1 or Day 2) and day of the week collected, and was dichotomized as weekday (Monday through Thursday) and weekend (Friday through Sunday). Balanced repeated replicates were used to calculate standard errors.[38] In addition, the study population proportions with usual intakes less than the Estimated Average Requirement (EAR) were determined for MAR nutrients to identify the micronutrient intakes that were the most inadequate for this population by race, age, and sex. Because dietary patterns and nutrient intakes of HANDLS study participants significantly differ by age,[39] as well as nutrient requirements and physiological changes differ with age, age was categorized as either 30 to 50 years or 51 to 64 years.

To determine the association of MAR with CRP, the data were analyzed with ordinary least squares (OLS) regression applying log transformations where necessary. The non-transformed CRP regression displayed profound kurtosis and skewness, and deviation in errors from normal ($P<0.0001$ for Shapiro-Wilk W statistic). A Box-Cox transformation of CRP identified $\lambda=0$; that is, the log transformation of CRP was confirmed as the optimal transformation to preserve the linear relationship and facilitate interpretability.[40,41]

The identification and selection of covariates was based on clinical and nutritional insight, correlations among the

regressors and with the outcome CRP, and other selection processes including least absolute shrinkage and selection operator and least angle regression to build an appropriate parsimonious model. Preliminary analysis revealed that smoking, risk for depression, literacy, blood pressure, n-3 fatty acids, protein, total fat, saturated fat, alcohol, and age were not significant contributors to CRP and, thus, were not included in the final OLS regression. In addition to the covariate MAR, total years of education was included in the model, as well as sex, race, education, and DXA obesity. The least absolute shrinkage and selection operator and least angle regression methods selected HOMA-IR and hypertension as additional regressors. Fractional polynomials analyzed (alternative) specifications of the covariates MAR, HOMA-IR, and education and concluded ($P<0.01$ for χ_1^2) a power equal to zero; that is, log-HOMA-IR was a more appropriate functional form of HOMA-IR. Model fit and performance was assessed by residual analyses and model diagnostics.[42]

A second analysis, the generalized linear model (GLM), was performed to confirm the results of the OLS regression. The GLM for CRP utilized an inverse-Gaussian distribution (due to its high peak and lengthy right skewed tail) and a log link function. Using the exact same variables in the GLM as the OLS, MAR affected CRP levels significantly ($P=0.0325$).

Statistical analyses were performed using SAS statistical software (version 9.3, 2010, SAS Institute) with Type I error significance measured at $\alpha=.05$.

RESULTS

Population Characteristics

Descriptive characteristics of the study population categorized by sex, race, and age are found in Table 1. Some noteworthy features about the HANDLS study population is that approximately half the sample currently smoke (compared with 19% of all US adults in 2010[43]) and about one third of both the African Americans and whites did not complete high school (compared with 13% of all US adults in 2009[44]). Significantly more African Americans were poor (defined as self-reported household income <125% of the 2004 Health and Human Services poverty guidelines) compared with whites (Table 1).

Dietary Intake

The NAR scores ranged from 37.3 to 98.2 (Table 2). The highest scores (>90) were seen for riboflavin and phosphorus for all race and sex groups; vitamin B-12, niacin, and copper for men; and iron for all men and older women. The lowest NAR scores (<50) were observed for vitamin E for all race and sex groups and calcium for African-American women. Among the individual NAR scores, significant differences were found for selected nutrients. In general, white men and women had higher scores than African-American men and women (Table 2).

The overall MAR scores, indicators of diet quality, ranged from 74.3 (African-American women, aged 51 to 64 years) to 82.2 (white men, aged 30 to 50 years). For men and women, there were significant racial differences in only the older age groups where whites had higher MAR levels than African Americans (Table 2). MAR scores were significantly associated with sex ($r=0.121$; $P<0.001$), race ($r=-0.099$; $P<0.001$), education ($r=0.210$; $P<0.001$), and poverty status ($r=-0.052$; $P=0.024$).

The percentage of the population with usual micronutrient intakes less than the EAR was generally higher in the ages 51 to 64 years group compared with the ages 30 to 50 years group (Figures 2 and 3). The percentage of African-American participants with usual micronutrient intakes less than the EAR typically exceeded that of white participants.

Anthropometric Measures

Based on DXA measurements, three out of every four African-American and white women aged 30 to 50 years in the HANDLS baseline study were obese (Table 1). The proportion rose to 87% in women aged 51 to 64 years. Unlike the women, the prevalence of obesity was significantly greater among white men compared with African-American men (Table 1).

CRP and Other Clinical Measures

Compared with their racial counterparts, the median values for CRP were greater for white men and African-American women, regardless of age. The median CRP was 1.3±0.1 mg/L (12.4±1.0 nmol/L) and 1.3±0.2 mg/L (12.4±1.9 nmol/L) for African-American and white men, aged 30 to 50 years. For men aged 51 to 64 years, the median CRP was significantly lower ($P=0.04$) for African Americans compared with whites, 1.8±0.2 mg/L (17.1±1.9 nmol/L) vs 2.1±0.2 mg/L (20.0±1.9 nmol/L), respectively. For women aged 30 to 50 years, the median CRP was 2.5±0.3 mg/L (23.8±2.9 nmol/L) for African Americans and 2.1±0.4 mg/L (20.0±3.8 nmol/L) for whites. Among the ages 51 to 64 years group, African-American women had a median CRP of 3.1±0.3 mg/L (29.5±2.9 nmol/L) compared with white women who had a median value of 2.8±0.4 mg/L (26.7±3.8 nmol/L). Significant correlations ($P<0.05$) with CRP were found with MAR, sex, race, HOMA-IR, fat, saturated fat, protein, hypertension, and education groups.

About one third of the sample aged 30 to 50 years had hypertension and this rate roughly doubled for the ages 51 to 64 years group regardless of race. There were no significant differences in the prevalence of hypertension among the men by race for either age group. However, African-American women had higher rates of hypertension compared with white women for both age groups (Table 1).

Medical history reviews revealed low prevalences of most inflammatory conditions, including systemic lupus erythematosis, rheumatoid arthritis, Crohn's disease, sarcoidosis, multiple sclerosis, and hepatitis B and C.

Association of Diet with CRP

The main association of MAR with CRP was assessed with OLS regression while adjusting for specific factors (eg, sex, race, and DXA-determined obesity), covariate (education in total years), explanatory variables (HOMA-IR and hypertension diagnosis), as well as assessing effect modifications (first and second order interactions) (see Table 3 and Figures 4 and 5). The main objective of an appropriate model based on the regressors demonstrated the independent influence of diet quality (ie, MAR) on CRP where a 10% increase in MAR was

Table 1. Comparison of baseline characteristics of 2,017 Healthy Aging in Neighborhoods of Diversity across the Life Span study participants, by race and sex

Characteristic	Men (n=881)		Women (n=1,136)	
	African American	White	African American	White
	←mean±standard error→			
Age 30-50 y	(n=310)	(n=206)	(n=385)	(n=284)
Sociodemographic characteristics				
Age (y)	41.7±0.3	41.3±0.4	41.7±0.3	41.1±0.4
Education (% < high school)	36.5±2.7	31.1±3.2	29.1±2.3	32.0±2.8
Income (% <125% poverty income ratio)	52.6±2.8	27.2±3.1***	56.6±2.5	34.9±2.8***
Employed in last month (% unemployed)	35.8±2.7	25.2±3.0*	44.2±2.5	39.4±2.9
Health and diet behaviors				
Self-reported health status (% fair/poor status)	19.4±2.2	23.3±3.0	20.0±2.0	24.3±2.5
Regular health care professional (% without care)	60.7±2.8	42.2±3.4***	37.4±2.5	33.5±2.8
Usual energy average intake (kcal)	2,625±101	2,580±42	2,040±135	1,814±46
Usual sodium average intake (mg)	3,953±169	4,179±87	3,158±182	2,881±82
Smoking status (% current smokers)	64.3±2.8	50.5±3.5**	51.5±2.6	49.3±3.0
Anthropometric measures				
Total body fat from dual-energy x-ray absorptiometry (%)	21.7±0.5	25.2±0.5***	40.7±0.5	39.9±0.5
Obese[a] (%)	37.1±2.7	52.9±3.5**	75.3±2.2	73.2±2.6
Clinical measures				
Hypertension (%)	32.3±2.7	31.1±3.2	35.6±2.4	23.6±2.5**
Homeostatis model of assessment-insulin resistance	2.3±0.2	2.8±0.3	3.0±0.2	2.7±0.2
Center for Epidemiologic Studies Depression score[b] (% at risk for depression)	39.7±2.8	34.3±3.4	42.1±2.5	46.6±3.0
Age 51-64 y	(n=205)	(n=160)	(n=263)	(n=204)
Sociodemographic characteristics				
Age (y)	57.1±0.3	56.9±0.3	57.1±0.2	57.1±0.3
Education (% < high school)	33.2±3.3	33.8±3.7	32.7±2.9	29.9±3.2
Income (% <125% poverty income ratio)	43.4±3.5	25.0±3.4**	48.3±3.1	34.8±3.3**
Employed in last month (% unemployed)	52.7±3.5	38.1±3.8**	54.4±3.1	49.5±3.5
Health and diet behaviors				
Self-reported health status (% fair/poor status)	34.2±3.3	25.0±3.4	31.9±2.9	28.9±3.2
Regular health care professional (% without care)	32.2±3.3	27.5±3.5	20.2±2.5	22.1±2.9
Usual energy average intake (kcal)	2,083±168	2,449±98	1,472±83	1,741±113
Usual sodium average intake (mg)	3,323±211	3,850±179	2,296±153	2,880±241
Smoking status (% current smoker)	51.8±3.6	41.1±3.9*	34.4±3.0	37.6±3.5

(*continued on next page*)

Table 1. Comparison of baseline characteristics of 2,017 Healthy Aging in Neighborhoods of Diversity across the Life Span study participants, by race and sex (*continued*)

	Men (n=881)		Women (n=1,136)	
Characteristic	African American	White	African American	White
Anthropometric measures				
Total body fat from dual-energy x-ray absorptiometry (%)	25.8±0.6	28.4±0.5**	43.4±0.5	43.0±0.5
Obese[a] (%)	56.1±3.5	73.1±3.5**	87.1±2.1	87.3±2.3
Clinical measures				
Hypertension (%)	61.8±3.4	56.9±3.9	76.1±2.6	52.0±3.5***
Homeostasis model of assessment-insulin resistance	3.6±0.5	3.6±0.3	3.3±0.2	3.2±0.2
Center for Epidemiologic Studies Depression score[b] (% at risk for depression)	41.1±3.5	29.3±3.6*	39.8±3.1	39.5±3.5

[a]For men obesity is defined as >25% total body fat and for women >35% body fat.[36]
[b]Risk for depression is defined as Center for Epidemiologic Studies Depression score of 16 or greater. Based on Radloff.[54]
*Significantly different at $P<0.05$ (t, χ^2, or Wilcoxon test per respective statistic) from African-American counterpart within sex and age group (30-50 y or 51-64 y).
**Significantly different at $P<0.01$ (t, χ^2, or Wilcoxon test per respective statistic) from African-American counterpart within sex and age group (30-50 y or 51-64 y).
***Significantly different at $P<0.0001$ (t, χ^2, or Wilcoxon test per respective statistic) from African-American counterpart within sex and age group (30-50 or 51-64 y).

associated with a 4% decrease in CRP while holding all other terms constant. Model fit was assessed at approximately 20% variance explained. Normality assumptions were upheld and residuals were homogeneous, and so a smearing transformation[45] will provide unbiased and consistent mean estimates on back-transformations to the original scale (ie, CRP) for prediction.

DISCUSSION

The findings of this study demonstrated that the micronutrient quality of the diet as determined by MAR significantly affect CRP levels. To our knowledge, this is the first study to examine the relationship of MAR to CRP in a low-income urban population of both African Americans and whites. The inverse association between MAR and CRP is biologically feasible because many of the micronutrients have antioxidative and anti-inflammatory properties.[16] Exogenous antioxidants provided by the diet may enable the body to manage the balance between the production and accumulation of the reactive species that cause oxidative stress.[46,47]

Fruits, vegetables, and whole grains are sources of nutrients with antioxidant properties, namely zinc, beta carotene, and vitamins C and E. These foods also provide magnesium and zinc that have essential roles in numerous enzymatic functions. The antioxidant enzymes such as superoxide dismutase, catalase, and glutathione peroxidase are considered endogenous antioxidants that also help the body manage oxidative stress.

Because the analysis was performed on cross-sectional data, the statistical model tested for independent associations of diet quality controlling for demographics rather than the potential mediating role of diet. However, Deverts and colleagues[11] examined the influence of socioeconomic status on CRP mediated by behaviors, controlling for demographics of Coronary Artery Risk in Young Adults study participants over a 13-year period. They reported fruit and vegetable consumption accounting for a significant proportion of the effects of education and income on change in CRP concentrations.[11] Specifically, eating more fruits and vegetables accounted for 29% of the apparent protective effect of having more education on CRP. They suggested that scavenging reactive oxygen species by the antioxidant nutrients found in fruits and vegetables suppressing the nuclear factor-κB signaling pathway was the mechanism explaining the anti-inflammatory effects of fruits and vegetables.[11]

Other researchers have suggested that the relationship between socioeconomic position and behaviors may be mediated by psychostressors.[18] Individuals who are more exposed to psychosocial stressors may be more likely to have such behavioral risk factors as nutrient-poor diets, smoking, and obesity. Genetics also appears to directly affect inflammation.[10,18] The variation in genetic coding of antioxidant enzymes may influence their activity, thereby affecting the uptake, use, and metabolism of antioxidant nutrients.[46]

Regardless of the published models, there is much evidence to support the link between socioeconomic position and CRP level.[10,11,18] Increases in CRP levels are observed among people with lower socioeconomic status practicing poor health behaviors.[11,18] In our model, education was moderated by race, where increasing education in whites showed a more profound reduction in CRP level than in their African-American counterparts. In addition, CRP, a marker of inflammation, is associated with chronic conditions. Among

Table 2. Comparison of MAR[a] and NAR[b] scores for Healthy Aging in Neighborhoods of Diversity across the Life Span study participants, by race, sex, and age

	Men		Women	
Diet quality	African American	White	African American	White
	←——mean±standard error——→			
Age 30-50 y	(n=310)	(n=206)	(n=385)	(n=284)
MAR[c]	80.3±0.8	82.2±0.9	74.8±0.8	75.7±1.0
NAR scores[d]				
Thiamin	88.9±1.0	93.4±1.0*	85.6±1.0	87.9±1.2
Riboflavin	94.3±0.8	96.1±0.8	92.1±0.8	95.0±0.8*
Niacin	96.1±0.6	95.6±0.9	93.6±0.7	91.4±1.0
Vitamin B-6	92.8±0.9	92.1±1.2	86.8±1.0	82.8±1.4*
Folate	86.4±1.2	90.1±1.3*	79.4±1.2	82.1±1.4
Vitamin B-12	93.5±1.0	96.1±0.9	90.0±1.0	89.3±1.2
Vitamin C	58.6±2.1	50.9±2.5*	56.7±1.8	48.9±2.1*
Vitamin A	53.2±1.7	60.3±2.1*	57.3±1.5	59.9±1.8
Vitamin E	46.2±1.4	48.3±1.8	38.8±1.1	40.3±1.5
Phosphorus	97.1±0.6	98.1±0.6	93.5±0.7	93.6±0.9
Magnesium	60.8±1.3	64.8±1.7	60.9±1.2	67.5±1.5*
Iron	97.3±0.5	97.7±0.7	64.1±1.2	66.1±1.5
Zinc	85.1±1.2	87.2±1.4	86.1±1.0	86.8±1.2
Copper	93.5±0.8	93.6±1.0	87.3±1.0	87.4±1.1
Calcium	60.4±1.5	69.0±1.8*	49.0±1.2	55.7±1.6*
Age 51-64 y	(n=205)	(n=160)	(n=263)	(n=204)
MAR[c]	76.6±0.9	81.1±1.1*	74.3±1.0	78.6±1.1*
NAR scores[d]				
Thiamin	86.7±1.3	91.6±1.3*	80.7±1.4	88.8±1.3*
Riboflavin	93.5±1.0	96.5±0.9*	90.5±1.0	95.3±0.8*
Niacin	93.4±0.9	95.7±1.0	89.7±1.1	92.2±1.1
Vitamin B-6	81.7±1.5	84.8±1.7	77.4±1.5	81.3±1.6
Folate	82.1±1.4	88.9±1.5*	74.4±1.5	81.4±1.6*
Vitamin B-12	94.2±1.1	94.2±1.3	85.8±1.5	90.1±1.4*
Vitamin C	50.7±2.5	48.6±2.9	59.5±2.2	56.5±2.6
Vitamin A	52.6±2.1	61.6±2.5*	60.4±1.9	64.1±2.1
Vitamin E	39.3±1.5	46.4±2.0*	37.3±1.5	39.6±1.5
Phosphorus	96.9±0.7	98.2±0.6	90.8±1.0	94.8±0.9*
Magnesium	53.2±1.4	64.4±1.9*	60.1±1.4	67.5±1.6*
Iron	97.9±0.5	97.6±0.6	92.6±0.9	94.7±1.0
Zinc	81.4±1.4	86.2±1.6*	81.8±1.4	86.0±1.5*
Copper	92.7±0.9	93.2±1.1	86.7±1.1	88.8±1.3
Calcium	51.9±1.7	68.2±2.0*	46.6±1.4	58.4±1.8*

[a]MAR=mean adequacy ratio.
[b]NAR=nutrient adequacy ratio.
[c]Calculated as the sum of all 15 nutrients.
[d]NARs divided by 15; calculated as the subject's daily intake of nutrient divided by the Recommended Dietary Allowance of nutrient. Nutrients included calcium, magnesium, phosphorus, vitamin A, vitamin C, vitamin E, vitamins B-6 and B-12, folate, iron, thiamin, riboflavin, niacin, copper, and zinc.
*Significantly different from African-American counterpart within sex and age group (30-50 y or 51-64 y) ($P< 0.05$, t test).

HANDLS study participants, obesity significantly contributed to a higher CRP levels, as did hypertension. However, the prevalence of inflammatory and autoimmune diseases was low and did not contribute to CRP levels. HOMA-IR was moderated by sex, where increasing HOMA-IR in women resulted in a higher proportion of CRP than in men. To our knowledge, this is the first study to report the effect of HOMA-IR.

The results documented the inadequacies of micronutrients in the diets consumed by a multiracial representative sample of working-age noninstitutionalized urban dwellers. The HANDLS study participants eat a preponderance of fried and fast foods, red and processed meats, sweets, desserts, and refined grains.[39] So it was not surprising to find a substantial number of participants with micronutrient inadequacies. Intakes of vitamins A, C, and E; magnesium; and calcium were the nutrients most affected. The percentage of HANDLS participants with usual intakes less than the EAR of these nutrients exceeded that of the US adult population aged 19 years and older examined in National Health and Nutrition Examination Survey between 2003 and 2006.[48] Given the complexities associated with diet, it is difficult to isolate the effects of individual micronutrients. The role of these nutrients in inflammation needs further research.

To reduce health disparities, a better understanding of the complex relationships among inflammation; socioeconomic position; demographic factors, including race, sex, and age; individual behaviors such as diet, smoking, alcohol use, and physical activity; and health are needed. Examination of diets using NAR scores revealed significant differences for vitamins A, C, and E, and folate, as well as magnesium and zinc between African-American and white HANDLS study participants. It is evident that changes in food intake of HANDLS participants are warranted, but barriers such as limited availability of healthful foods, low income, cultural preferences, and untreated mental health problems may exist.[49,50] A study involving a sample of low-income urban African Americans from Philadelphia, PA, revealed that they recognized such items as fried foods, fat back, butter, and bacon as unhealthy but they believed

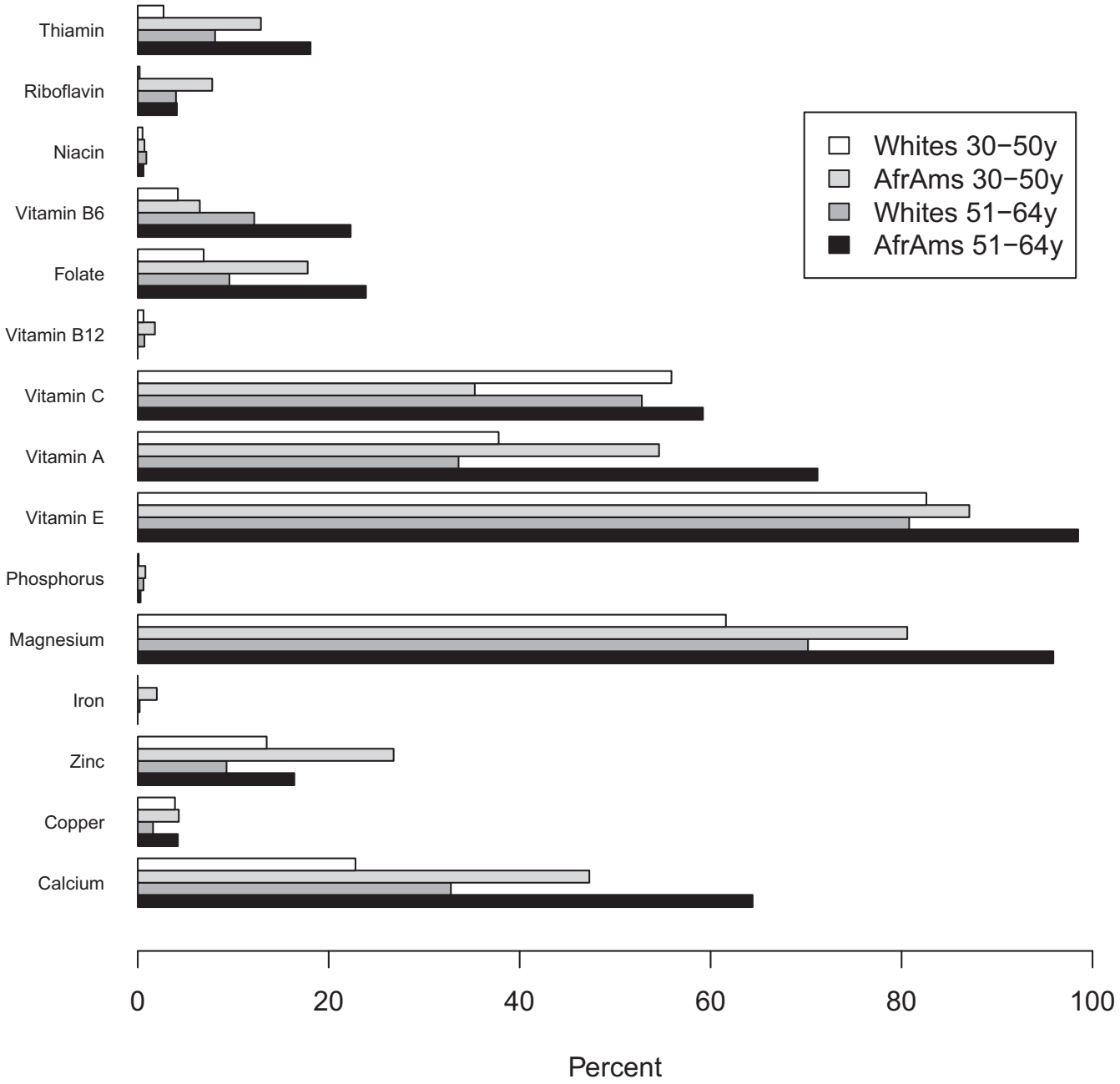

Figure 2. Percentage of urban African American (AfrAms) and white men in the Healthy Aging in Neighborhoods of Diversity across the Life Span (HANDLS) study with usual intakes less than the Estimated Average Requirement.

avoiding them would mean giving up part of their cultural heritage. In addition, there was little knowledge among these participants of cooking methods outside of the African-American cooking culture.[51] Depressive symptoms can also be significant predictors of food and beverage selections, especially by overweight persons.[52] It should be noted that with the exception of white men, approximately 40% of HANDLS study participants are at risk for depression (Table 1). Registered dietitians and other health professionals need to consider these barriers when planning and implementing interventions.

Our study has several strengths. First, this study utilizes a relatively large African-American and white, low-income population that is understudied due to recruitment difficulty.[28] Second, diet quality was based on two 24-hour recalls. Third, obesity was defined by DXA measures of body fat and not body mass index (BMI). Lastly, the complexity of measuring the relationship of diet quality and CRP were achieved and confirmed using different statistical approaches.

Our study has some limitations. First, it was cross-sectional so causality from the results cannot be inferred. Certain directionality can be assumed because the dietary information

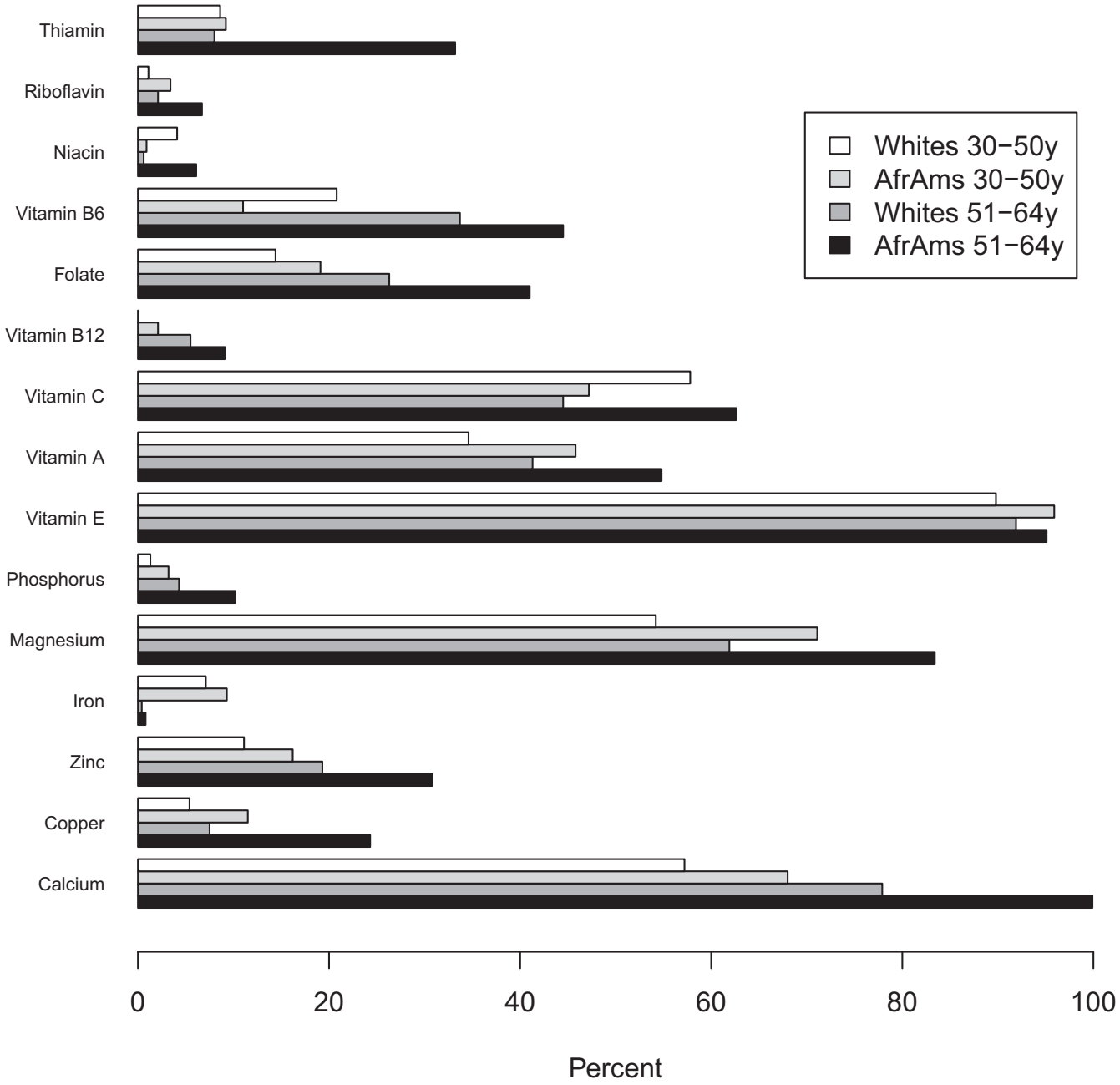

Figure 3. Percentage of urban African American (AfrAms) and white women in the Healthy Aging in Neighborhoods of Diversity across the Life Span (HANDLS) study with usual intakes less than the Estimated Average Requirement.

was collected 4 to 10 days before and on the day of the blood draw. Second, there is always some degree of error associated with the measurement of food consumption despite the validity of US Department of Agriculture's AMPM in both normal and overweight/obese individuals. Energy intake measured by the AMPM compared with total energy expenditure measured by doubly labeled water technique has been reported to underreported energy by 11% overall, by <3% for normal weight subjects with BMI <25, and by 16% for overweight subjects with BMI ≥25.[29] Third, the nutrient intakes do not include nutritional supplements. Supplement data collection began with the next wave of this longitudinal study. Fourth, the study focused on only micronutrients. The effects of other nutrients such as dietary fiber can regulate inflammation but were not examined. Lastly, the results describe a population residing in Baltimore, MD. Even though the findings cannot be generalized to a national population, independent demographic analyses found this population was representative of urban populations from US cities with similar population densities and racial distribution; namely, Atlanta, GA; Bridgeport, CT; Bridgeton, NJ; Buffalo, NY; Camden, NJ; Carson, CA; Chicago, IL; Cleveland, OH; Detroit, MI; Harrisburg, PA; Hartford, CT; Oakland, CA; Springfield, MS; and Trenton, NJ (Lepkowski J. HANDLS Generalizibility,

Table 3. Factors influencing Healthy Aging in Neighborhoods of Diversity across the Life Span study participants' C-reactive protein levels by linear ordinary least squares regression

Parameter	Estimate± standard error	95% CI	*P* value
Mean adequacy ratio	−0.0040±0.0020	(−0.0078,−0.0001)	0.0430
Body fat (obese vs non-obese)	0.5334±0.0743	(0.3876,0.6792)	0.0001
Homeostasis model of assessment-insulin resistance (log)	0.4672±0.0438	(0.3812,0.5532)	0.0001
Sex (male vs female)	−0.0482±0.0732	(−0.1916,0.0953)	0.5104
Sex×homeostasis model of assessment-insulin resistance (male vs female)	−0.3799±0.0596	(−0.4968,−0.2629)	0.0001
Race (African American vs white)	−0.6239±0.2496	(−1.1135,−0.1343)	0.0125
Education	−0.0606±0.0126	(−0.0854,−0.0359)	0.0001
Race×education: (African American vs white)	0.0440±0.0194	(0.0060,0.0820)	0.0233
Hypertension (hypertension vs normal)	0.2089±0.0632	(0.0850,0.3329)	0.0010

2010 and HANDLS Principle Cities Clusters Analysis, 2011, unpublished internal National of Institutes on Aging documents).

CONCLUSIONS

There was an independent inverse influence of diet quality on CRP levels in the urban African-American and white population studied. These findings suggest that diet quality as evaluated by MAR does contribute to CRP levels. Improving diet quality by increasing the MAR scores by 10-point increments may result in 4% or more decrease in CRP levels. Although this decrease in CRP level may seem small, it could result in a different risk categorization of an individual with respect to heart disease. The study findings are supported by other investigators who have reported an inverse relationship between a Western-style dietary pattern and CRP.[20,53] It seems apparent that consumption of an anti-inflammatory diet is associated with a decreased in the odds of elevated CRP.[25] Registered dietitians and public health nutritionists can provide people with advice not only on dietary antioxidants and health, but also foods to select to improve their diet quality, thereby reducing their risk of inflammation. Consuming an anti-inflammatory diet may protect persons from elevated CRP levels and indirectly against the development of cardiovascular disease and other inflammation-related chronic health conditions.

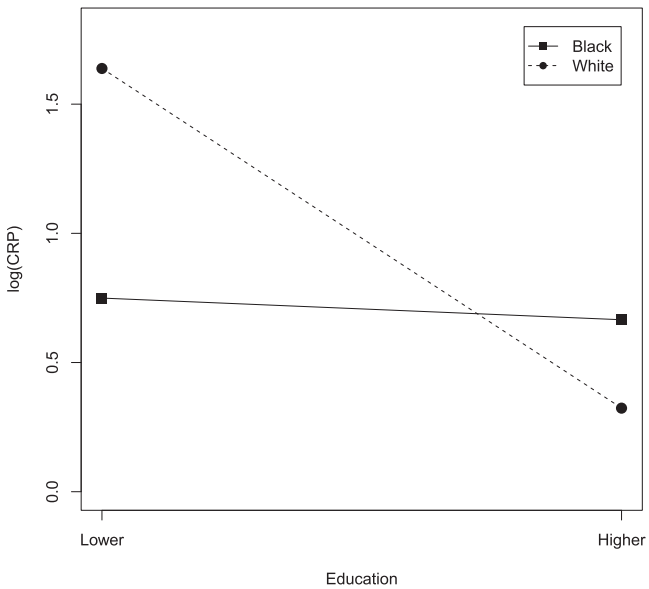

Figure 4. Influence of the interaction of education and race on C-reactive protein (CRP) levels.

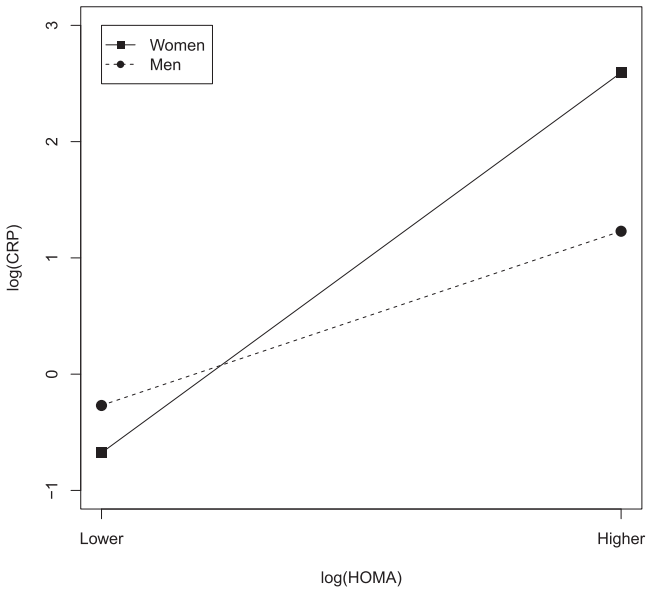

Figure 5. Influence of the interaction of homeostasis model of assessment (HOMA) and sex on C-reactive protein (CRP) levels.

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STATEMENT OF POTENTIAL CONFLICT OF INTEREST

No potential conflict of interest was reported by the authors.

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