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Dietary patterns are associated with biochemical markers of inflammation and endothelial activation in the Multi-Ethnic Study of Atherosclerosis (MESA)[2]

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Abstract

Background—Dietary patterns may influence cardiovascular disease risk through effects on inflammation and endothelial activation.

Objective—We examined relations between dietary patterns and markers of inflammation and endothelial activation.

Design—At baseline, diet (food-frequency questionnaire) and concentrations of C-reactive protein (CRP), interleukin 6 (IL-6), homocysteine, soluble intercellular adhesion molecule-1 (sICAM-1), and soluble E selectin were assessed in 5089 nondiabetic participants in the Multi-Ethnic Study of Atherosclerosis.

Results—Four dietary patterns were derived by using factor analysis. The fats and processed meats pattern (fats, oils, processed meats, fried potatoes, salty snacks, and desserts) was positively associated with CRP (*P* for trend < 0.001), IL-6 (*P* for trend < 0.001), and homocysteine (*P* for trend = 0.002). The beans, tomatoes, and refined grains pattern (beans, tomatoes, refined grains, and high-fat dairy products) was positively related to sICAM-1 (*P* for trend = 0.007). In contrast, the whole grains and fruit pattern (whole grains, fruit, nuts, and green leafy vegetables) was inversely associated with CRP, IL-6, homocysteine (*P* for trend ≤ 0.001), and sICAM-1 (*P* for trend = 0.034), and the vegetables and fish pattern (fish and dark-yellow, cruciferous, and other vegetables) was inversely related to IL-6 (*P* for trend = 0.009). CRP, IL-6, and homocysteine relations across the fats and processed meats and whole grains and fruit patterns were independent of demographics and lifestyle factors and were not modified by race-ethnicity. CRP and homocysteine relations were independent of waist circumference.

Conclusions—These results corroborate previous findings that empirically derived dietary patterns are associated with inflammation and show that these relations in an ethnically diverse population with unique dietary habits are similar to findings in more homogeneous populations.

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Keywords

Multi-Ethnic Study of Atherosclerosis; inflammation; endothelial activation; dietary patterns; factor analysis

Introduction

Vascular inflammation is an important component of atherosclerotic cardiovascular disease (CVD) (1), and studies have found elevated concentrations of inflammation (2–4) and vascular cell activation markers (5–8) in persons with CVD. Various dietary components are hypothesized to influence CVD risk, due, in part, to their potential effect on vascular inflammation (9). For example, foods rich in n–3 polyunsaturated fatty acids, such as walnuts, have been shown to improve endothelial function (10), and total nut and seed consumption has been inversely associated with inflammatory biomarkers (11). Wine, total alcohol, and tea consumption have each been shown in various studies to be favorably related to inflammation, vascular health, or both (12–15), possibly because of their flavonoid and other antioxidant constituents. Research also suggests that diets high in antioxidant-rich fruit and vegetables and whole grains may decrease inflammation and improve endothelial function (9,16,17).

Evaluating the relation between CVD risk factors and dietary patterns may be particularly useful because the effects of single foods are often small, and a high correlation among foods makes reductive approaches problematic (18). Furthermore, foods are not consumed in isolation, and there is likely to be important synergy among and within foods, where the joint effect of the diet's constituent parts is greater than the individual effects of single foods and nutrients (19). Methods most often used to characterize diet and generate dietary scores have been either based on a priori knowledge or empirically derived. Data-driven methods, such as factor analysis, have derived remarkably similar patterns that reflect the dichotomy between essentially nutrient-rich and nutrient-poor eating patterns that currently exist (20).

Numerous studies have reported relations between dietary patterns and risk of CVD (21–26). However, few studies have evaluated the relation between dietary patterns and early indicators of risk, such as inflammation and endothelial activation (27–29), and to our knowledge, no studies have evaluated such associations within ethnically diverse populations who offer the potential to study a broader range in dietary intake. To confirm the findings of previous studies, further investigation is needed in populations with greater ethnic diversity and therefore, greater variation in dietary intake.

The purpose of this analysis was to investigate the relation between empirically derived dietary patterns and biochemical markers of inflammation and endothelial activation in a large multiethnic cohort. We hypothesized that a dietary pattern high in nutrient-rich foods, such as fruit and vegetables, whole grains, nuts, and fish would be inversely associated with concentrations of C-reactive protein (CRP), interleukin-6 (IL-6), homocysteine, intracellular adhesion molecule-1 (sICAM-1), and soluble E selectin (sE selectin). Similarly, we hypothesized that a dietary pattern high in nutrient-poor foods, such as refined grains, fried foods, and sweets, would be positively associated with these markers.

Subjects and Methods

Subjects

The Multi-Ethnic Study of Atherosclerosis (MESA) is a population-based study of 6814 white, black, Hispanic, and Asian men and women aged 45–84 y recruited from 6 field centers in the United States: Baltimore City and County, MD; Chicago, IL; Forsyth County, NC; New York,

NY; Los Angeles County, CA; and St Paul, MN (30). The primary objective of this study was to identify predictors of the prevalence and progression of subclinical cardiovascular disease. Institutional review board approval was obtained at all participating centers, and all participants gave informed consent. The current cross-sectional investigation included data from 5089 participants enrolled in MESA, including 2407 men and 2682 women aged 45–84 y. This sample was chosen after the exclusion of individuals currently taking oral steroid or antiinflammatory asthma medications ($n = 134$), with diabetes mellitus ($n = 919$) (31), and who provided insufficient or implausible dietary information ($n = 630$; described in the following sections).

Assessment of inflammation and endothelial activation and other relevant variables

CRP, IL-6, homocysteine, sICAM-1, and sE selectin concentrations were measured in blood samples collected at baseline and were processed with the use of a standardized protocol based on that used in the Cardiovascular Health Study (32) and stored at −80 °C until analyzed. Participants were asked to fast for 12 h, avoid smoking on the morning of the exam, and avoid heavy exercise 12 h before the exam. CRP was measured in plasma with a particle enhanced immunonephelometric assay with a BNII nephelometer (N High Sensitivity CRP; Dade Behring Inc, Deerfield, IL). Concentrations of plasma IL-6 were measured by ultrasensitive enzyme-linked immunosorbent assay (Qantikine HS Human IL-6 Immunoassay; R&D Systems, Minneapolis, MN). Total plasma homocysteine was measured by polarization immunoassay with an IMx Analyzer (IMx Homocysteine Assay; Axis Biochemicals ASA, Oslo, Norway). sICAM-1 concentrations were measured by enzyme-liked immunosorbent assay (Parameter Human sICAM-1 Immunoassay; R&D Systems), and soluble E selectin was measured in serum samples with a sandwich enzyme immunoassay (Parameter Human sE-Selectin Immunoassay; R&D systems). Interassay CVs were 3.6%, 6.3%, 4.5%, 5.0%, and7.3% for CRP, IL-6, homocysteine, sICAM, and soluble E selectin, respectively. Total and HDL-cholesterol, insulin, and glucose concentrations were also measured directly with reagents from Roche Diagnostics (Indianapolis, IN) and analyzed at the Collaborative Studies Clinical Laboratory (Fairview-University Medical Center; Minneapolis, MN). LDL cholesterol was calculated with the Friedewald equation (33). Resting blood pressure was measured with participants in the seated position with the use of a Dinamap model Pro 100 automated oscillometric sphygmomanometer (Critikon, Tampa, FL). Three measurements were taken, and the average of the last 2 measurements was used in analyses.

CRP, IL-6, and homocysteine were measured in all MESA participants in whom a blood sample was available. In this study, 5053 participants had CRP, 4953 had IL-6, and 5073 had homocysteine measurements available. sICAM-1 was measured in the first one-third of those enrolled in MESA and in others who were randomly selected from among the first 5030 participants enrolled. In this study, 2068 sICAM-1 measurements were used in the analyses. Soluble E selectin was measured in a subgroup of 1000 participants (some overlapping with the first one-third) who were randomly selected from the 5030 MESA participants enrolled before February 2002. In this study, soluble E selectin measurements from 777 of these 1000 participants were used in the analyses. However, the number of observations for each became fewer as variables were added to the models, as indicated in table legends. Because of nonnormal distributions, concentrations of all 4 of these analytes were analyzed on the natural log scale and were reported on the original scale as geometric means.

Diet assessment

At baseline, usual dietary intake over the past year was assessed from a 120-item food-frequency questionnaire (FFQ). Participants recorded the serving size (small, medium, or large) and frequency of consumption (average times per day, week, or month) of specific beverages and foods. Nine frequency options were given that ranged from “rare or never” to a maximum

of "≥2 times/d" for foods and a maximum of "≥6 times/d" for beverages. The FFQ was developed according to the validated Block format (34) and patterned after the FFQ used in the Insulin Resistance Atherosclerosis Study (IRAS), which has been validated in non-Hispanic white, black, and Hispanic persons (35). To accommodate the MESA subject population, the IRAS FFQ was modified to include unique Chinese foods and culinary practices.

Forms that were not completed by participants and forms that were considered unreliable or incomplete for processing were not analyzed (n = 192). In addition, those questionnaires with responses deemed implausible after scanning were excluded from final analysis (n = 271), including those with too few (<5 for men or <4 for women) or too many (>30) foods reported per day, questionable high frequency of foods skipped (≥ 18 foods), too many foods coded with the same frequency (≥90 foods), or coded as the same serving size (≥119 foods). Participants reporting extreme energy intakes, >6000 or <600 kcal/d, were also excluded from the analyses (n = 167). Thus, in total, 630 participants were excluded because of unreliable dietary data.

Food groups

Food and beverage questions from the FFQ were categorized into 47 food groups on the basis of similar nutrient characteristics or hypothesized biological effects (Appendix A). Consideration was also given to groups used in other studies to maintain consistency among studies to the extent possible given differences in assessment instruments (18, 20). Certain questions contributed to multiple food groups (eg, most mixed dishes were disaggregated into their component parts), whereas other items from the questionnaire constituted a single group because of the high reported intake (eg, coffee), unique attributes with suspected biological effect (eg, avocado and guacamole), or inability to adequately disaggregate all foods included in one line item of the questionnaire (eg, egg salad, chicken salad, and tuna salad). Whole-grain cereal intake was determined on the basis of an open-ended question, "If you eat cold cereal, what is the name of cold cereal do [sic] you eat most often?" The cereal reported was considered whole grain if it was known to contain ≥25% whole-grain flour or, in the absence of specific information, if whole grain was prominently listed in the ingredient list and it contained >4 g fiber/100 g dry product weight. Items were then grouped accordingly, and the consumption frequency of each was weighted by the reported serving size. Items reported with serving size "small" were weighted by 0.5, and items reported with serving size "large" were weighted by 1.5. The weighted frequencies were uniformly converted to servings per day.

Assessment of other relevant variables

At the baseline examination, a combination of self-administered and interviewer-administered questionnaires was used to collect information on demographics, education, medication use, smoking history, and physical activity. Body mass index (BMI; in kg/m^2) was calculated from weight measured to the nearest 0.45 kg, and height was measured to the nearest 0.1 cm. Waist circumference was measured at the umbilicus to the nearest 1 cm.

Statistical analyses

All analyses were performed with SAS version 9.1 (SAS Institute Inc, Cary, NC). A principal components analysis was used to derive dietary patterns and determine factor loadings for each of the 47 investigator-defined food groups. Analysis was performed by using SAS PROC FACTOR, and the factors were rotated with varimax rotation to maintain uncorrelated factors and enhance interpretability (36). Solutions ranging from 2 to 10 factors were considered. After evaluation of eigenvalues and the interpretability of the factor solution, a 4-factor solution was chosen. A factor score for each study participant was calculated from the sum of the servings per day from all food groups, multiplied by their respective factor loadings with the use of the NFACT and OUT options in the FACTOR procedure. To calculate mean values of dependent

variables, factor scores were divided into quintiles by using the SAS rank procedure. Dietary patterns were named according to the food groups loading highest on each of the 4 factor patterns (Table 1). The labeling of patterns in this way aided in discussing the patterns and distinguishing them from those reported in other studies.

Linear regression (SAS PROC GLM) was used to calculate unadjusted means of participant characteristics, dietary nutrients, select CVD risk factors, and biochemical markers related to inflammation and endothelial activation in each quintile of dietary pattern score. In addition to the unadjusted analysis, 4 multivariable models were used to assess the relation between dietary pattern score and CRP, IL-6, homocysteine, sICAM, and soluble E selectin. Separate regression analyses were performed for each of the 4 dietary patterns. In model 1, adjustments were made for age (y), sex (male, female), race-ethnicity (white, black, Hispanic, Chinese), examination site (Baltimore County, MD; Forsyth County, NC; Los Angeles County, CA; New York, NY; St Paul, MN), education (less than high school, high school, more than high school), and energy intake (kcal/d). Model 2 included the variables in model 1 plus lifestyle covariates: physical activity (active leisure: walking, sports, and conditioning activities in metabolic equivalent–min/wk; inactive leisure: television watching, reading, and light sitting activities in metabolic equivalent–min/wk), smoking (current or not current and number of pack years), and nutritional supplement use (weekly users of vitamin, mineral,orother nutritional supplements andnonusers). Adjustment for use of alcohol, hormone replacement therapy, aspirin, and blood pressure and lipid-lowering medications did not appreciably affect the estimates; therefore, these variables were not included in any of the models.Cross-product terms were used to test for interactions between the 4 factors (dietary patterns) and race-ethnicity, sex, and statin use. Last, to investigate potential mediators in a causal pathway between diet and inflammation or endothelial activation, models were fit adding to the variables in model 2: waist circumference (model 3), and waist circumference plus fasting insulin, glucose, LDL cholesterol, HDL cholesterol, and systolic blood pressure (model 4). Adjustments made for BMI and waist circumference, together and separately, and including or not including the square of waist circumference were not materially different. Therefore, when body size was included as a covariate, waist circumference was used because visceral adiposity may be most etiologically relevant to inflammation. Tests for trend across dietary patterns were conducted within multivariable regression models by using dietary pattern score as a continuous variable.

Results

Factor analysis showed 4 main dietary patterns from the multiethnic population under study (Table 1). Dietary patterns were named according to the food groups loading highest on each of the 4 factor patterns. Factor 1—fats and processed meats—was characterized by greater loadings for the food groups “fats and oils,” “high-fat and processed meats,” “fried potatoes,” “salty snacks,” and “desserts.” Factor 2—vegetables and fish—was characterized by high loading values for various vegetable groups (“dark-yellow,” “cruciferous,” and “other vegetables”), “fish,” and “soups.” Factor 3—beans, tomatoes, and refined grains—had high factor loads for the food groups “legumes,” “tomatoes,” “refined bread, rice and pasta,” “high-fat cheeses and cheese and cream sauces,” and “avocados and guacamole.” Last, factor 4—whole grains and fruit—was characterized by highest loads for “whole-grain bread, rice, and pasta,” “fruit,” “seeds, nuts, and peanut butter,” “green leafy vegetables,” and “low-fat milk.”

Overall, the population was composed of 2188 whites (43%), 1231 blacks (24%), 1033 Hispanics (20%), and 637 Chinese (13%), and dietary patterns were significantly associated with race-ethnicity [P for trend < 0.05 for all, except for the percentage of blacks across the whole grains and fruit pattern ($P = 0.67$); Table 2]. Nevertheless, persons from each race-ethnicity group were found throughout the range of each of the factors. Other demographic,

lifestyle, and anthropometric characteristics also differed across dietary patterns. Persons with high scores for the fats and processed meats pattern were more likely to be male, currently smoke, have greater BMIs and waist circumferences, and spend more time engaging in inactive pursuits during their leisure, and were less likely to regularly use supplements than were those with the lowest scores (P for trend < 0.001 for all; Table 2). The vegetables and fish and whole grains and fruit patterns generally showed trends opposite that of the fats and processed meats pattern. Persons in the upper quintiles of these dietary patterns were more likely to be female and to have relatively healthier lifestyle profiles, such as a lower smoking prevalence and greater use of supplements (P for trend < 0.01 for all). Lifestyle characteristics associated with high scores on the beans, tomatoes and refined grains pattern were more similar to the fats and processed meats pattern, with the exception that inactive leisure decreased across pattern scores (P for trend < 0.001), whereas inactive leisure increased across the fats and processed meats pattern (P for trend < 0.001).

The nutrient composition of each dietary pattern is depicted for quintiles 1, 2, and 3 in Table 3. Persons with higher scores on the fats and processed meats pattern consumed more total fat, monounsaturated fat, saturated fat, and *trans* fat (energy-adjusted, in g/d, and as a percentage of energy) and less fiber than persons with lower scores (P for trend < 0.001 for all). Fat and fiber intakes also differed significantly across the other dietary patterns: lower total fat and *trans* fat intakes were characteristic of those with high scores on the vegetables and fish and whole grains and fruit patterns, and dietary fiber intake was greater for those with high scores on the vegetables and fish; beans, tomatoes, and refined grains; and whole grains and fruit dietary patterns (P for trend < 0.001 for all). Saturated fat intake was also less in the upper than in the lower quintiles of the vegetables and fish and whole grains and fruit patterns (P for trend < 0.001 for all). Although neither the energy-adjusted intake of total fat nor of saturated fat differed (P for trend = 0.53 and 0.11) across the beans, tomatoes, and refined grains pattern, the percentage of energy from both total and saturated fat significantly increased across this dietary pattern (P < 0.001 for both).

In general, demographic-adjusted systolic blood pressure and concentrations of LDL cholesterol, HDL cholesterol, insulin, and glucose were significantly related to the 4 dietary patterns in the expected directions (model 1; data not shown). However, after additional adjustment for select lifestyle variables (model 2), differences in these CVD risk factors across dietary patterns were attenuated (Table 4). Serum insulin increased across the fats and processed meats pattern and both serum insulin and glucose decreased across the whole grains and fruit pattern (P for trend < 0.05 for all). Concentrations of LDL cholesterol significantly increased across quintiles of the fats and processed meats pattern but decreased across the quintiles of the beans, tomatoes, and refined grains and whole grains and fruit patterns (P for trend < 0.05 for all). HDL-cholesterol concentrations significantly decreased across the beans, tomatoes, and refined grains pattern (P = 0.043), but trends in HDL cholesterol across the other dietary patterns were not statistically significant. Blood pressure was not significantly associated with any of the dietary patterns. Waist circumference significantly increased across the fats and processed meats pattern (P for trend < 0.001) and significantly decreased across the vegetables and fish and whole grains and fruit patterns after multivariable adjustment (P for trend = 0.01 and < 0.001, respectively). Waist circumference was not significantly related to the beans, tomatoes, and refined grains pattern (P for trend = 0.67).

Mean concentrations of CRP, IL-6, homocysteine, sICAM-1, and sE selectin across quintiles of each dietary pattern are shown in Table 5, and the regression coefficients for the relations between log-transformed biomarkers and each dietary pattern are presented in Table 6. The regression coefficients translate approximately into percentage change, eg, a coefficient of −0.05 is equivalent to a change of ≈5% in the dependent variable on its natural scale per unit change of the factor score. The most consistent relations were found with the fats and processed

meats and whole grains and fruit patterns (Table 5). Only select markers were related to the vegetables and fish and beans, tomatoes, and refined grains patterns. After adjustment for demographic and lifestyle covariates and before adjustment for any potential mechanistic variables (model 2), concentrations of CRP, IL-6, and homocysteine were positively associated with the fats and processed meats pattern and inversely associated with the whole grains and fruit pattern ($P < 0.05$ for all). sICAM-1 was also inversely associated with the whole grains and fruit pattern, but positively associated with the beans, tomatoes, and refined grains pattern ($P = 0.044$ and 0.008, respectively). Last, the vegetables and fish pattern was inversely related to IL-6 concentrations ($P = 0.031$). None of the dietary patterns was significantly related to sE selectin. After adjustment for differences in waist circumference (Table 6), relations between IL-6 and the fats and processed meats, vegetables and fish, and whole grains and fruit patterns were no longer significant (P for trend = 0.063, 0.14, 0.062, respectively). sICAM-1 was also no longer significantly associated with scores for the whole grains and fruit pattern (P for trend = 0.088). In contrast, adjustment for waist circumference minimally affected associations between CRP and homocysteine and the fats and processed meats and whole grains and fruit patterns, and sICAM-1 remained positively associated with the beans, tomatoes, and refined grains pattern ($P < 0.05$ for all; Table 6). Model 4 included factors in addition to waist circumference that could theoretically explain the relations observed between dietary patterns and markers related to inflammation and endothelial activation (insulin, glucose, LDL, HDL, and systolic blood pressure). Again, associations were minimally altered, and associations that were significant in model 3 remained significant, including a return of significance for the association between IL-6 and the fats and processed meats pattern ($P = 0.028$) and for other associations, for which the data are not shown: between CRP and homocysteine and the fats and processed meats pattern ($P = 0.046$ and 0.014, respectively), between CRP and homocysteine and the whole grains and fruit pattern ($P = 0.001$ and 0.004, respectively), and between sICAM-1 and the beans, tomatoes, and refined grains pattern ($P = 0.008$).

Interactions between race-ethnicity and each of the 4 dietary patterns were not significant for any biomarker ($P > 0.11$ for all). Interactions between dietary pattern score and sex were not significant for any biomarker when tested across factors 2–4 ($P > 0.05$ for all). However, interactions between sex and factor 1 for CRP and IL-6 were statistically significant ($P = 0.008$ and 0.028, respectively). Although the directions of the estimates were the same for women and men (positive), the relation was stronger for women ($\beta \pm$ SEE: 0.13 ± 0.030) than for men (0.04 ± 0.03). Regarding the interaction between statin use and dietary patterns, only for sICAM-1 was there a significant interaction between statin use and factor 1 ($P = 0.02$). In statin users, there was a positive association between scores for the fats and processed meats pattern and sICAM-1 ($\beta \pm$ SEE: 0.03 ± 0.02). In contrast, in nonusers the association was inverse ($\beta \pm$ SEE: -0.02 ± 0.01).

Discussion

This cross-sectional analysis in an ethnically diverse population of middle-aged men and women from the MESA cohort showed significant associations between empirically derived dietary patterns and CRP, IL-6, homocysteine, and sICAM-1. CRP and IL-6 reflect systemic inflammation, sICAM-1 is considered an indicator of endothelial cell activation, and homocysteine may be involved in both inflammatory and endothelial function pathways. Research has shown that high concentrations of these analytes are related to the development of atherosclerosis (1) and CVD risk (3,4,37,38), which underscores the importance of our results.

With adjustment for multiple variables, CRP, IL-6, and homocysteine showed positive associations with the fats and processed meats pattern and negative associations with the whole grains and fruit pattern. sICAM-1 was also inversely related to the whole grains and fruit pattern

but was positively related to the beans, tomatoes, and refined grains pattern. The vegetables and fish pattern was inversely associated with IL-6 but not with any other markers. None of the dietary patterns was significantly related to the cell adhesion molecule, sE selectin.

The significant relations between the fats and processed meats and whole grains and fruit patterns and CRP and homocysteine and between the beans, tomatoes, and refined grains pattern were independent of waist circumference and other CVD risk factors with dietary origins. Obesity has been associated with elevated concentrations of inflammation markers (39,40) and is arguably on the causal pathway between diet and inflammation. Our findings suggest that the sum of food components represented by these patterns, such as whole grains, fruit, vegetables, and low-fat dairy products, have other biological pro- and antiinflammatory qualities that remain important, independent of body size. Furthermore, our results suggest that relations between these dietary patterns and inflammation are not due to traditionally identified CVD risk factors.

Fruit and vegetables (41), nuts (42), and whole grains (43,44) have each been associated with reduced CVD risk, and effects on inflammation and endothelial function may be partly responsible. Analogously, diets high in saturated and *trans* fatty acids, both of which are common in processed foods, have been implicated in the development of various cardiovascular diseases (45), and related to inflammation and endothelial dysfunction (46–48). For the most part, our results are consistent with these hypotheses. The fats and processed meats pattern, high in processed foods and relatively devoid of nutrient-rich fruit and vegetables, was positively associated with inflammatory markers and homocysteine. in contrast, the whole grains and fruit pattern, which is high in whole grains, fruit, and nuts and low in refined grains and other processed foods, was inversely associated with inflammatory markers, homocysteine, and sICAM-1.

However, contrary to expectations, the vegetables and fish pattern was related only to IL-6 but not other measured markers. Although this dietary pattern had high factor loadings for several nutrient-rich vegetable groups and fish, an important source of n–3 fatty acids, it did not load high on whole grains, fruit, or nuts and loaded relatively high on red meat. The absence of these foods and the inclusion of red meat may partly explain the weaker associations observed with this pattern. Likewise, the beans, tomatoes, and refined grains pattern loaded high on refined grains, high-fat cheeses and sauces, and red meat, possibly negating the potentially beneficial effects of its 2 major food groups, tomatoes and beans, as evidenced by the significant positive relation between this pattern and sICAM-1 and the consistent, although nonsignificant, directions of associations with other biomarkers. These findings suggest that the balance of total diet may be most important in determining its physiologic effects.

The significant associations between dietary patterns and CRP, homocysteine, and sICAM-1 are consistent with findings from previous studies that evaluated empirically derived dietary patterns. In a cohort of predominantly white men, Fung et al (28) reported a positive association between homocysteine and CRP and a dietary pattern high in red meats, high-fat dairy products, and refined grains (“western” pattern). In contrast, the “prudent” pattern, which consists of fruit, vegetables, whole grains, and poultry, was inversely related to homocysteine but not to CRP (28). Similar results were also reported in women, ie, the “prudent” pattern was inversely associated with CRP and soluble E selectin, and the “western” pattern was positively associated with CRP, soluble E selectin, sICAM-1, and soluble vascular cell adhesion molecule-1 (29). In contrast with the findings by Lopez-Garcia et al (29), we observed a significant association between IL-6 and the fats and processed meats and whole grains and fruit patterns, but we did not find soluble E selectin to be associated with any dietary pattern, possibly because there were fewer observations for this analyte. In light of methodologic differences between this and the Lopez-Garcia study, such as differences in diet assessment (multiple compared with single

measures), populations studied, and subtle differences in the dietary patterns derived, the findings of our studies are quite similar, which suggests that the relation between dietary patterns and inflammation is robust.

In secondary analyses, we found that sex and statin use modified the associations between the fats and processed meats dietary pattern and select biomarkers. Because we tested multiple hypotheses without statistical correction, it is possible that these interactions were significant by chance. Moreover, the interaction between statin use and the fats and processed meats pattern is difficult to explain given that relations between other dietary patterns and sICAM-1 were not modified by statin use nor were the relations between the fats and processed meats pattern and other biomarkers. The sex interactions are equivocal in CVD prevention, given that the directions of the associations were similar for both men and women. It is possible that the stronger association observed in women was partly due to a more accurate diet assessment in women (49).

Our study had several limitations that must be considered when interpreting the results. First, no cause-effect relations can be inferred from these cross-sectional data, and a single measure of diet notably reduces the precision of our estimates. Second, it is possible that multiple testing may have resulted in chance associations being declared significant. Third, several assumptions were made when constructing food groups, eg, when mixed dishes were aggregated into component food groups and when questions containing nutritionally diverse foods were categorized. However, our dietary patterns and loading scores were similar to those reported in other studies, and associations between dietary patterns and inflammatory biomarkers were in the expected directions, which suggests that our assumptions were valid (18). Fourth, the limitations and subjective nature of factor analysis techniques are widely acknowledged (18, 20,50,51); however, we tried to minimize subjectivity by using food groups similar to those reported by others and selecting the factor solution after evaluating scree plots and eigenvalues. Fifth, regardless of our findings, which are based on empirically derived dietary patterns, it is possible that other food combinations may be more strongly related to inflammation and endothelial activation, and, therefore, most relevant to CVD risk. However, we found no independent relations between food groups that did not load highly on any dietary pattern and inflammatory or endothelial activation biomarkers. Other empirical methods of characterizing diet that maximize the predictive ability of dietary patterns may help to clarify this issue in the future (52). Last, we cannot exclude the possibility that soluble E selectin may have been significantly related to dietary patterns had it been measured in as many participants as were other analytes.

Results of this study show that factor analysis conducted in an ethnically diverse population identifies dietary patterns similar to those reported in more homogeneous populations. The dietary patterns most comparable with the “western” and “prudent” patterns reported in other populations (23,26,53,54) were related to biomarkers of inflammation, even after adjustment for differences in waist circumference and other CVD risk factors with nutritional origin, and thus emphasize the important potential for diet in preventing inflammation and endothelial activation. In the future it will be important to establish whether changes in diet over time will favorably alter these biomarkers in ways that will translate into a reduction in CVD.

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Appendix A

Component foods of the 47 food groups used in the factor analysis[1]

Food group	Component foods
Fruit	Peaches, apricots, nectarines, plums, cantaloupe, mango, papaya, strawberries, blueberries, other berries, apples, applesauce, pears, bananas, plantains, oranges, grapefruit, tangerines, kiwi, dried fruits (including raisins, prunes, figs, apricots)
Fruit juices	Orange juice, grapefruit juice, other fruit juice
Avocados and guacamole	Avocado, guacamole
Tomatoes	Tomatoes (cooked or raw), tomato juice, salsa, *pico de gallo*, tomatoes in chile stews,[2] pasta with tomato sauce[2], tomatoes (whole or sauce) in burritos, enchiladas, tamales, or tacos[2]
Vegetables, green leafy	Tossed salad with spinach, romaine or dark greens; cooked spinach; turnip greens; collards
Vegetables, cruciferous	Broccoli, cabbage, cauliflower, Brussels sprouts, sauerkraut, *kimchi*, broccoli and other cruciferous vegetables in stir-fried dishes[2]
Vegetables, dark-yellow	Carrots, winter squash, acorn squash, sweet potatoes, yams, chile peppers in mixed dishes and dark-yellow vegetables in vegetable stir-fried dishes[2]
Vegetables, other	Corn, green beans, peas, snow peas, squash, zucchini, asparagus, mixed vegetables, tossed salad with iceberg or light-green lettuce
Vegetables, potatoes	Boiled, baked, mashed, or other potatoes; turnips; potatoes in meat, chicken, or turkey stew, pot pie, or empanada[2]; pea, lentil, black bean, and potajes soups; pinto, black, baked, butter, or red beans; black-eyed peas; refried beans; beans in enchiladas, tamales, tacos, or burritos[2]
Beans Soy foods and beverages	Soy milk, miso soup or sauce with soybean paste, tofu or tempeh in stir-fried dishes
Seeds, nuts, and peanut butter	Almonds, walnuts, pecans, other nuts; sunflower, pinyon, other seeds; peanuts, peanut butter
Whole-grain bread, rice, and pasta	Dark, whole-grain breads or rolls; bran muffins; brown or wild rice; oatmeal; high-fiber cold cereal (by brand name)
Refined-grain bread, rice, and pasta	White bread and rolls, white rice, flour or corn tortillas, other hot cereal, noodles or pasta, refined-grain cold cereal (by brand name)
Eggs and omelets	Eggs, omelets, *huevos rancheros*
Red meat	Hamburger; cheeseburger; meatloaf; hash; beef, pork, or lamb steaks; roasts; barbeque or ribs; red meat in stir-fried and other mixed dishes[2]
Poultry	Roasted, broiled, baked, or ground chicken or turkey; fried chicken; poultry in stir-fried and other mixed dishes[2]
Fish	Shrimp; lobster; crab; oysters, mussels; tuna; salmon; sardines, other broiled, steamed, baked, or raw fish; fish in stir-fried and other mixed dishes[2]
High-fat and processed meats	Ham, hot dogs, bologna, salami, lunchmeats, liver, sausage, chorizo, scrapple, bacon
Fats and oils	Margarine, butter, or oil on vegetables, bread, rice, or pasta; gravies; fried meats (fried chicken, fish, or shrimp)[2]; refried beans (lard used in preparation)[2]
Fried potatoes	French fries, fried potatoes, hash browns
Salty snacks	Potato, corn, or tortilla chips; crackers; pretzels; popcorn
Pizza	Pizza
Pasta and potato salads	Pasta salad, macaroni salad, potato salad, cole slaw
Chicken, tuna, and egg salads	Chicken salad, tuna salad, egg salad
High-fat Chinese dishes	Fried rice, chow mein, Chinese dumplings, spring roll, dim sum, Chinese bun with meat, sausage, and vegetables
Cream soups and chowders	Cream soups, including chowders, potato, and cheese soups
Other soups	Other soups, including vegetable beef, tomato, egg drop, chicken noodle; meat or fish stews, pot pie[2]
Sweet extras	Sugar or honey in coffee or tea, sugar, jelly, jam, molasses, hard candy, licorice, other candy

Food group	Component foods
Sweet breads	Biscuits, other muffins, croissants, corn bread, hush puppies, pancakes, waffles, French toast
Desserts	Pies; pudding; custard; flan; white doughnuts, cookies, cakes, pastries; chocolate doughnuts, cookies, cakes, brownies, candy
Ice cream	Regular ice cream
Low-fat dairy desserts	Frozen yogurt, low-fat ice cream, ice milk, sherbet
Yogurt	Plain yogurt (unflavored), flavored yogurt
Cottage and ricotta cheese	Cottage or ricotta cheese
High-fat cheeses and cheese and cream sauces	Cheddar, American, Chihuahua, Swiss, cream cheese, cheese spreads, pasta with cream sauce or cheese[2]
Coffee and tea creamer	Cream, half-and-half or nondairy creamer in coffee or tea, whole-milk beverages (including milk in caffe latte, café au lait), whole-milk on cereal, milk added to coffee or tea
Whole milk Low-fat milk	2%-fat milk and beverages made with 2%-fat milk, skim or 1%-fat milk and beverages made with skim or 1%-fat milk, 2%-fat, 1%-fat, or skim milk on cereal
Meal-replacement drinks	Instant breakfast[3], Ensure[4], Slim Fast[5]
Nondiet soft drinks	Regular soft drinks, soda, sweetened mineral water, nonalcoholic beer
Diet soft drinks and mineral water	Diet soft drinks, unsweetened mineral water
Tea	Black or green tea
Coffee	Coffee (regular or decaffeinated)
Hot chocolate	Hot chocolate
Beer	Beer
Other alcoholic beverages	Wine, liquor, or mixed drinks

[1] Each row represents a single food-frequency questionnaire item.

[2] Stir-fried and other mixed dishes were disaggregated, and component foods were allocated to food groups accordingly.

[3] Nestle/Carnation, Vevey, Switzerland.

[4] Abbott, Abbott Park, IL.

[5] Unilever, Englewood, NJ.

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TABLE 1

Food group factor loadings for 4 dietary patterns in the Multi-Ethnic Study of Atherosclerosis (MESA)[1]

	High-fat and processed meats	Vegetables and fish	Beans, tomatoes, and refined grains	Whole grains and fruit
Fats and oils	0.65	—	—	0.18
High-fat and processed meats	0.64	—	—	−0.13
Fried potatoes	0.60	—	—	—
Salty snacks	0.50	—	—	—
Desserts	0.48	—	—	—
High-fat cheeses and cheese and cream sauces	0.42	—	0.57	—
Red meat	0.42	0.41	0.46	−0.13
Pizza	0.41	—	—	—
Pasta and potato salads	0.41	—	—	0.29
Sweet breads	0.41	—	—	—
Ice cream	0.40	—	—	—
Vegetables, potatoes	0.38	—	—	—
Poultry	0.36	0.38	0.33	—
Nondiet soft drinks	0.36	—	—	−0.16
Sweet extras	0.36	—	—	—
Eggs and omelets	0.34	—	—	—
Chicken, tuna, and egg salads	0.30	0.16	—	0.29
Coffee	0.29	−0.22	—	0.17
Cream soups and chowders	0.29	—	—	—
Refined-grain bread, rice, and pasta	0.28	0.30	0.60	−0.20
Coffee and tea creamer	0.23	—	—	—
Beer	0.19	—	—	—
Fish	—	0.60	—	—
Seeds, nuts, and peanut butter	—	—	—	0.46
Whole milk	—	—	0.21	—
Cottage and ricotta cheese	—	—	—	0.31
Wine and spirits	—	—	—	0.17
Tomatoes	—	—	0.73	0.25
Other soups	—	0.58	—	—
Diet soft drinks and mineral water	—	—	—	—
Hot chocolate	—	—	—	—
Fruit juices	—	—	0.16	0.23
High-fat Chinese dishes	—	0.41	0.23	−0.21
Vegetables, other	—	0.62	0.18	0.27
Meal-replacement drinks	—	—	—	—
Low-fat dairy desserts	—	—	—	0.28
Vegetables, green leafy	—	—	—	0.38
Yogurt	—	—	0.16	0.21

	High-fat and processed meats	Vegetables and fish	Beans, tomatoes, and refined grains	Whole grains and fruit
Low-fat milk	—	—	—	0.33
Whole-grain bread, rice, and pasta	—	—	—	0.59
Tea	—	0.25	−0.12	—
Beans	—	—	0.76	
Vegetables, dark-yellow	−0.14	0.77	—	0.21
Soy foods and beverages	−0.15	0.37	−0.11	—
Avocados and guacamole	−0.15	—	0.52	—
Fruit	−0.16	0.21	—	0.55
Vegetables, cruciferous	−0.18	0.75	—	—

[1] Positive loadings <0.15 and negative loadings > −0.10 were omitted for simplicity. The food groups are presented in descending order of loading values on the high-fat and processed meats dietary pattern.

TABLE 2

Characteristics of 5089 men and women from the Multi-Ethnic Study of Atherosclerosis (MESA) according to the 1st, 3rd, and 5th quintiles (Q) of dietary pattern score for 4 empirically derived dietary patterns[1]

	Factor 1: fats and processed meats[2]			Factor 2: vegetables and fish[3]			Factor 3: beans, tomatoes, and refined grains[4]			Factor 4: whole grains and fruit[5]		
	Q1 (*n* = 1017)	Q3 (*n* = 1018)	Q5 (*n* = 1018)	Q1 (*n* = 1017)	Q3 (*n* = 1018)	Q5 (*n* = 1018)	Q1 (*n* = 1017)	Q3 (*n* = 1018)	Q5 (*n* = 1018)	Q1 (*n* = 1017)	Q3 (*n* = 1018)	Q5 (*n* = 1018)
Dietary pattern score	− 1.08 ± 0.27[6]	−0.20 ± 0.13	1.55 ± 0.88	− 0.99 ± 0.22	− 0.23 ± 0.11	1.54 ± 1.05	− 0.88 ± 0.21	− 0.26 ± 0.09	1.53 ± 1.20	− 1.23 ± 0.34	− 0.11 ± 0.13	1.49 ± 0.76
White (%)	24.7	46.8	51.1	53.0	48.5	22.0	39.2	51.0	30.1	15.5	42.9	64.5
Chinese (%)	31.1	7.5	1.4	0.3	4.0	43.5	18.6	13.0	2.3	33.7	7.3	3.1
Black (%)	13.6	25.5	35.5	16.6	27.9	23.1	39.0	23.2	12.1	21.3	26.5	21.4
Hispanic (%)	30.7	20.2	12.1	30.3	19.5	11.4	3.1	12.9	55.6	29.4	23.3	10.9
Age (y)	63.6 ± 0.3	61.6 ± 0.3	59.5 ± 0.3	61.8 ± 0.3	61.7 ± 0.3	61.0 ± 0.3	63.9 ±0.3	61.7 ± 0.3	59.1 ± 0.3	59.0 ± 0.3	61.5 ± 0.3	63.8 ± 0.3
Female (%)	63.1	54.1	41.2	47.8	53.3	55.9	57.1	54.9	48.9	40.0	55.1	57.8
High school degree (%)	72.6	85.0	90.7	84.0	86.1	83.4	88.1	87.9	69.8	72.0	84.6	91.4
Supplement users (%)	66.6	60.8	48.6	53.1	60.5	62.4	61.2	60.6	51.0	44.8	57.8	70.1
Current smokers (%)	5.9	15.2	25.8	22.0	13.1	10.5	15.6	13.7	18.4	19.2	13.5	11.1
Smoking pack-years	5.6 ± 0.7	9.9 ± 0.7	18.1 ± 0.7	15.3 ± 0.7	11.7 ± 0.7	7.7 ± 0.7	12.9 ± 0.7	11.1 ± 0.7	10.4 ± 0.7	10.7 ± 0.7	11.7 ± 0.7	10.9 ± 0.7
Active leisure (MET-h/wk)	41.2 ±1.6	40.8 ± 1.6	42.0 ±1.6	38.4 ±1.6	41.8 ± 1.6	42.8 ± 1.6	43.7 ± 1.6	40.6 ±1.6	38.1 ± 1.6	32.7 ± 1.6	39.6 ± 1.6	50.3 ±1.6
Inactive leisure (MET-h/wk)	24.4 ± 0.6	28.3 ± 0.6	31.5 ± 0.6	27.7 ± 0.6	28.2 ± 0.6	27.6 ±0.6	29.3 ±0.6	27.7 ± 0.6	25.3 ± 0.6	25.7 ± 0.6	26.2 ± 0.6	29.4 ± 0.6
BMI (kg/m^2)	26.3 ± 0.2	28.1 ± 0.2	29.5 ± 0.2	28.0 ± 0.2	28.2 ± 0.2	26.6 ± 0.2	27.3 ±0.2	27.5 ± 0.2	28.8 ± 0.2	27.4 ± 0.2	28.1 ± 0.2	27.6 ± 0.2
Waist circumference (cm)	92.3 ± 04	97.1 ± 04	101.8 ± 04	98.1 ± 04	97.3 ± 04	93.1 ± 04	95.2 ± 0.4	95.9 ± 0.4	99.5 ± 0.4	95.4 ± 0.4	97.1 ± 0.4	96.5 ± 0.4

[1] Tests for trend were based on general linear regression with dietary pattern score (continuous) as the independent variable. MET-h/wk, metabolic equivalents in hours per week (energy needed per kilogram of body weight per hour of activity divided by the energy needed per kilogram of body weight per hour at rest). By design, the $\bar{x}$ ± SD values for each dietary pattern and factor are 0.0 and 1.0, respectively.

[2] *P* for trend significant ($P < 0.05$) for all variables listed across this dietary pattern, except for active leisure (MET-h/wk).

[3] *P* for trend significant ($P < 0.05$) for all variables listed across this dietary pattern, except for high school degree.

[4] *P* for trend significant ($P < 0.05$) for all variables listed across this dietary pattern.

[5] *P* for trend significant ($P < 0.05$) for all variables listed across this dietary pattern, except for black, smoking pack-years, BMI, and waist circumference.

[6] $\bar{x}$ ± SD (all such values).

TABLE 3

Energy and nutrient intakes of 5089 men and women from the Multi-Ethnic Study of Atherosclerosis (MESA) according to the 1st, 3rd, and 5th quintiles (Q) of dietary pattern score for 4 empirically derived dietary patterns[1]

	Factor 1: fats and processed meats[2]			Factor 2: vegetables and fish[3]			Factor 3: beans, tomatoes, and refined grains[4]			Factor 4: whole grains and fruit[5]		
	Q1	Q3	Q5	Q1	Q3	Q5	Q1	Q3	Q5	Q1	Q3	Q5
Energy (kcal/d)	1258 ±19[6]	1507 ±19	2601 ±19	1514 ± 24	1635 ± 24	2008 ± 24	1426 ± 22	1507 ± 22	2317 ± 22	1644 ± 23	1553 ± 23	2099 ± 23
Carbohydrate (g/d)	226 ±1.1	212 ± 1.1	187 ± 1.3	208 ±1.1	210 ±1.1	209 ±1.1	207 ±1.1	209 ±1.1	211 ± 1.2	198 ± 1.1	208 ±1.1	226 ±1.1
Carbohydrate (% of energy)	54.8	49.9	46.3	50.4	50.6	49.3	50.0	50.8	49.3	47.2	50.7	52.9
Protein (g/d)	68.9 ± 0.5	68.4 ±0.5	61.5 ± 0.6	58.3 ± 0.4	66.6 ± 0.4	77.7 ± 0.5	66.0 ± 0.5	66.6 ±0.5	67.7 ± 0.5	66.1 ± 0.5	65.0 ± 0.5	69.9 ± 0.5
Protein (% of energy)	16.5	16.2	15.0	14.0	16.1	18.1	16.1	16.0	15.7	16.0	15.7	16.3
Total fat (g/d)	59.4 ± 0.4	62.9 ± 0.4	74.5 ± 0.5	65.6 ± 0.4	64.6 ± 0.4	63.9 ± 0.4	66.7 ± 0.4	64.2 ± 0.4	64.9 ± 0.4	70.1 ± 0.4	65.0 ± 0.4	57.8 ± 0.4
Total (% of energy)	30.8	33.8	37.8	34.1	33.7	34.4	34.8	33.2	35.3	37.1	33.5	31.5
Saturated fat (g/d)	17.0 ± 0.2	20.2 ± 0.2	25.5 ± 0.2	22.9 ± 0.2	21.0 ± 0.2	17.5 ± 0.2	20.8 ± 0.2	20.6 ± 0.2	20.6 ± 0.2	21.6 ± 0.2	20.9 ± 0.2	18.2 ± 0.2
Saturated fat (% of energy)	8.2	10.8	12.8	11.6	10.6	9.5	10.3	10.4	11.4	11.1	10.5	10.0
Polyunsaturated fat (g/d)	15.2 ± 0.2	13.9 ± 0.2	14.7 ± 0.2	13.8 ± 0.2	14.0 ± 0.2	16.3 ± 0.2	15.1 ± 0.2	14.2 ± 0.2	15.1 ± 0.2	16.6 ± 0.1	14.2 ± 0.1	13.0 ± 0.2
Monounsaturated fat (g/d)	22.0 ± 0.2	22.9 ± 0.2	27.1 ±0.2	23.5 ± 0.2	23.6 ± 0.2	23.7 ± 0.2	24.4 ± 0.2	23.4 ± 0.2	23.8 ± 0.2	25.5 ± 0.2	23.9 ± 0.2	21.1 ± 0.2
trans Fat (g/d)	2.0 ± 0.04	3.1 ± 0.04	5.2 ± 0.04	3.7 ± 0.04	3.5 ± 0.04	2.6 ± 0.04	3.8 ± 0.04	3.5 ± 0.04	2.6 ± 0.04	3.5 ± 0.04	3.5 ± 0.04	2.8 ±0.05
Fiber (g/d)	23.7 ± 0.2	18.3 ± 0.2	10.9 ± 0.2	14.5 ± 0.2	17.8 ± 0.2	21.8 ± 0.2	16.7 ± 0.2	17.2 ± 0.2	20.9 ± 0.2	14.4 ± 0.2	17.3 ± 0.2	23.1 ± 0.2

[1] Dietary nutrients in grams were energy-adjusted; nutrients presented as percentages were not adjusted for energy. Tests for trend were based on general linear regression with dietary pattern score (continuous) as the independent variable.

[2] P for trend significant (< 0.05) for all variables listed across this dietary pattern, except for polyunsaturated fat (g/d).

[3] P for trend significant (< 0.05) for all variables listed across this dietary pattern, except for carbohydrate (g/d), monounsaturated fat (g/d), and total fat (% of energy).

[4] P for trend significant (< 0.05) for all variables listed across this dietary pattern, except for carbohydrate (g/d), total fat (g/d), saturated fat (g/d), and monounsaturated fat (g/d).

[5] P for trend significant (< 0.05) for all variables listed across this dietary pattern.

[6] $\bar{x}$ ± SEM (all such values).

TABLE 4

Select cardiovascular disease risk factors in men and women from the Multi-Ethnic Study of Atherosclerosis (MESA) according to the 1st, 2nd, and 3rd quintiles (Q) of dietary pattern score for 4 empirically derived dietary patterns[1]

	Factor 1: fats and processed meats			Factor 2: vegetables and fish			Factor 3: beans, tomatoes, and refined grains			Factor 4 : whole grains and fruit		
	Q1	Q3	Q5	Q1	Q3	Q5	Q1	Q3	Q5	Q1	Q3	Q5
LDL cholesterol (mg/dL)	116.5 ± 1.12	118.3 ± 0.99	120.8 ± 1.27[2]	117.4 ± 1.05	117.10 ± 0.99	119.0 ± 1.16	118.0 ± 1.05	118.4 ± 0.99	115.9 ± 1.20[2]	119.0 ± 1.09	118.0 ± 0.99	115.6 ± 1.07[2]
HDL cholesterol (mg/dL)	51.5 ± 0.49	51.7 ± 0.43	51.2 ± 0.56	52.5 ± 0.46	51.7 ± 0.43	50.7 ± 0.51	52.2 ± 0.46	52.2 ± 0.43	50.9 ± 0.52[2]	51.7 ± 0.48	51.5 ± 0.43	52.2 ± 0.47
Systolic blood pressure (mm Hg)	125.2 ± 0.69	125.3 ± 0.61	125.7 ± 0.78	125.0 ± 0.65	126.1 ± 0.61	124.6 ± 0.72	123.5 ± 0.64	125.7 ± 0.61	126.8 ± 0.74	125.7 ± 0.67	125.2 ± 0.61	124.0 ± 0.66
Serum insulin (pmol/L)	40.0 ± 1.04	44.2 ± 0.91	48.5 ± 1.18[2]	43.7 ± 0.97	43.6 ± 0.91	41.8 ± 1.07	43.7 ± 0.97	43.4 ± 0.92	43.6 ± 1.11[2]	46.2 ± 1.00	43.3 ± 0.91	40.4 ± 0.99[2]
Serum glucose (mg/dL)	95.2 ± 0.33	96.1 ± 0.29	96.0 ± 0.38	95.2 ± 0.31	96.4 ± 0.29	95.6 ± 0.34	95.4 ± 0.31	95.9 ± 0.29	95.7 ± 0.35	96.6 ± 0.32	95.5 ± 0.29	95.2 ± 0.32[2]
Waist circumference (cm)	94.6 ± 0.47	97.0 ± 0.41	99.6 ± 0.53[2]	96.9 ± 0.44	96.6 ± 0.41	95.7 ± 0.48[2]	96.2 ± 0.43	96.6 ± 0.41	97.0 ± 0.50	97.5 ± 0.45	96.8 ± 0.41	95.0 ± 0.44[2]

[1] All values are $\bar{x}$ ± SEM and were adjusted for study center (Baltimore County, MD; Forsyth County, NC; Los Angeles County, CA; New York, NY; and St Paul, MN), age (y), sex (male or female), race (white, black, Chinese, or Hispanic), education (less than high school, high school, or more than high school), energy (kcal/d), active leisure activity (metabolic equivalent-min/wk), inactive leisure activity (metabolic equivalent-min/wk), smoking (never versus current and pack-years), and supplement use (at least weekly users versus nonusers). Data are based on available measurements, including LDL cholesterol (n = 4970), HDL cholesterol (n = 5013), systolic blood pressure (n = 5034), insulin (n = 5015), and glucose (n = 5013).

[2] P for trend significant (<0.05) based on multiple linear regression, with dietary pattern score (continuous) as the independent variable.

TABLE 5

Concentrations of biochemical markers of inflammation and endothelial activation in men and women from the Multi-Ethnic Study of Atherosclerosis (MESA) across quintiles (Q) of dietary pattern score for 4 empirically derived dietary patterns[1]

	Q1	Q2	Q3	Q4	Q5	*P* for trend[2]
Factor 1: fats and processed meats						
CRP (mg/L)	1.52 ± 1.04	1.71 ± 1.04	1.81 ± 1.04	1.99 ± 1.04	2.02 ± 1.05	< 0.001
IL-6 (pg/mL)	1.09 ± 1.02	1.15 ± 1.02	1.16 ± 1.02	1.21 ± 1.02	1.26 ± 1.03	< 0.001
Homocysteine (μmol/L)	8.60 ± 1.01	8.69 ± 1.01	8.80 ± 1.01	8.84 ± 1.01	8.95 ± 1.01	0.004
sICAM-1 (ng/mL)	265 ± 1.01	257 ± 1.01	261 ± 1.01	253 ± 1.01	254 ± 1.02	0.21
sE selectin (ng/mL)	49.7 ± 1.05	44.3 ± 1.04	49.0 ± 1.04	48.5 ± 1.04	46.6 ± 1.05	0.80
Factor 2: vegetables and fish						
CRP (mg/L)	1.75 ± 1.04	1.90 ± 1.04	1.82 ± 1.04	1.81 ± 1.04	1.73 ± 1.04	0.31
IL-6 (pg/mL)	1.21 ± 1.02	1.18 ± 1.02	1.17 ± 1.02	1.15 ± 1.02	1.14 ± 1.02	0.031
Homocysteine (μmol/L)	8.85 ± 1.01	8.82 ± 1.01	8.80 ± 1.01	8.73 ± 1.01	8.67 ± 1.01	0.98
sICAM-1 (ng/mL)	259 ± 1.01	256 ± 1.01	256 ± 1.01	260 ± 1.01	258 ± 1.02	0.99
sE selectin (ng/mL)	49.2 ± 1.04	45.2 ± 1.04	50.0 ± 1.04	45.3 ± 1.04	48.2 ± 1.05	0.12
Factor 3: beans, tomatoes, and refined grains						
CRP (mg/L)	1.70 ± 1.04	1.74 ± 1.04	1.80 ± 1.04	1.93 ± 1.04	1.84 ± 1.04	0.09
IL-6 (pg/mL)	1.18 ± 1.02	1.14 ± 1.02	1.16 ± 1.02	1.20 ± 1.02	1.17 ± 1.02	0.42
Homocysteine (μmol/L)	8.66 ± 1.01	8.80 ± 1.01	8.79 ± 1.01	8.79 ± 1.01	8.82 ± 1.01	0.78
sICAM-1 (ng/mL)	252 ± 1.01	263 ± 1.01	249 ± 1.01	259 ± 1.01	264 ± 1.02	0.008
sE selectin (ng/mL)	48.9 ± 1.05	48.1 ± 1.04	47.2 ± 1.04	48.0 ± 1.03	46.1 ± 1.04	0.75
Factor 4: whole grains and fruit						
CRP (mg/L)	1.96 ± 1.04	1.99 ± 1.04	1.80 ± 1.04	1.74 ± 1.04	1.55 ± 1.04	< 0.001
IL-6 (pg/mL)	1.26 ± 1.02	1.21 ± 1.02	1.16 ± 1.02	1.11 ± 1.02	1.12 ± 1.02	< 0.001
Homocysteine (μmol/L)	8.97 ± 1.01	8.89 ± 1.01	8.73 ± 1.01	8.68 ± 1.01	8.58 ± 1.01	< 0.001
sICAM-1 (ng/mL)	262 ± 1.01	256 ± 1.01	258 ± 1.01	259 ± 1.01	253 ± 1.01	0.044
sE selectin (ng/mL)	49.6 ± 1.04	47.2 ± 1.04	49.5 ± 1.04	46.3 ± 1.04	46.3 ± 1.04	0.26

[1] All values were log transformed and therefore are presented as geometric $\bar{x}$ ± estimated SEM in each quintile of factor score for the respective factor pattern, adjusted for study center (Baltimore County, MD; Forsyth County, NC; Los Angeles County, CA; New York, NY; St Paul, MN), age (y), sex (male or female), race (white, black, Chinese, or Hispanic), education (less than high school, high school, or more than high school), energy (kcal/d), active leisure activity (metabolic equivalent-min/wk), inactive leisure activity (metabolic equivalent-min/wk), smoking (never vs current and pack-years), and supplement use (at least weekly users vs nonusers). CRP, C-reactive protein; IL-6, interleukin 6; sICAM-1, soluble intercellular adhesion molecule-1; sE selectin, soluble E selectin. CRP, IL-6, homocysteine, sICAM, and sE selectin values were based on 5001, 4903, 5020, 2043, and 771 observations, respectively.

[2]Based on multiple linear regression, with dietary pattern score (continuous) treated as the independent variable.

TABLE 6

Regression coefficients for the relation between log-transformed biomarkers of inflammation and endothelial activation and dietary pattern scores for 4 empirically derived dietary patterns in the Multi-Ethnic Study of Atherosclerosis (MESA)[1]

	Fats and processed meats	Vegetables and fish	Beans, tomatoes, and refined grains	Whole grains and fruit
log CRP (mg/L)				
Model 2[2]	0.087 ± 0.024[3]	−0.019 ± 0.020	0.041 ± 0.021	−0.089 ± 0.018[3]
Model 3[4]	0.048 ± 0.023[3]	−0.003 ± 0.019	0.038 ± 0.020	−0.060 ± 0.018[3]
log IL-6 (pg/mL)				
Model 2[2]	0.050 ± 0.014[3]	−0.025 ± 0.012[3]	0.011 ± 0.012	−0.036 ± 0.011[3]
Model 3[4]	0.025 ± 0.014	−0.016 ± 0.011	0.009 ± 0.012	−0.019 ± 0.010
log Homocysteine (μmol/L)				
Model 2[2]	0.018 ± 0.006[3]	<0.001 ± 0.005	0.001 ± 0.005	−0.016 ± 0.005[3]
Model 3[4]	0.016 ± 0.006[3]	0.001 ± 0.005	0.001 ± 0.005	−0.015 ± 0.005[3]
log sICAM-1 (ng/mL)				
Model 2[2]	−0.013 ± 0.009	<0.001 ± 0.008	0.022 ± 0.008[3]	−0.013 ± 0.007[3]
Model 3[4]	−0.016 ± 0.009	0.001 ± 0.007	0.021 ± 0.008[3]	−0.011 ± 0.007
log sE selectin (ng/mL)				
Model 2[2]	−0.006 ± 0.026	−0.035 ± 0.022	−0.007 ± 0.022	−0.021 ± 0.019
Model 3[4]	−0.024 ± 0.025	−0.034 ± 0.022	−0.002 ± 0.022	−0.009 ± 0.019

[1] All values are regression coefficients ± SEE based on available observations: 5001 for C-reactive protein (CRP), 4903 for interleukin 6 (IL-6), 5020 for homocysteine, 2043 for soluble intercellular adhesion molecule-1 (sICAM-1), and 771 for soluble E selectin (sE selectin).

[2] Adjusted for study center (Baltimore County, MD; Forsyth County, NC; Los Angeles County, CA; New York, NY; and St Paul, MN), age (y), sex (male or female), race (white, black, Chinese, or Hispanic), education (less than high school, high school, or more than high school), energy (kcal/d), physical activity (active leisure: total of walking + sports + conditioning activities in metabolic equivalent-min/wk; inactive leisure: television watching, reading and other sedentary leisure activities in metabolic equivalent-min/wk), smoking (never vs current and pack-years), and supplement use (at least weekly users vs nonusers).

[3] $P < 0.05$.

[4] Estimates adjusted for the same variables as in model 2 + waist circumference (cm).