The American Journal of Clinical Nutrition

Associations between microalbuminuria and animal foods, plant foods, and dietary patterns in the Multiethnic Study of Atherosclerosis[1–3]

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ABSTRACT

Background: The balance between the intake of animal and the intake of plant foods may influence renal vascular integrity as reflected by urinary albumin excretion.

Objective: We assessed cross-sectional associations between urinary albumin excretion and dietary patterns and intake of plant and animal foods.

Design: At baseline, diet (food-frequency questionnaire) and the urinary albumin-to-creatinine ratio (ACR; spot urine collection) were measured in 5042 participants in the Multi-Ethnic Study of Atherosclerosis who were aged 45–84 y and were without clinical cardiovascular disease, diabetes, or macroalbuminuria (sex-adjusted ACR ≥ 250). We derived dietary patterns by principal components analysis. We also summed food groups to characterize plant food intake (fruit, fruit juice, vegetables, nuts, legumes, whole grains, and refined grains), animal food intake (red meat, processed meat, poultry, fish, high-fat dairy, and low-fat dairy), and nondairy animal food intake.

Results: After adjustment for multiple demographic and lifestyle confounders, a dietary pattern characterized by high consumption of whole grains, fruit, vegetables, and low-fat dairy foods was associated with 20% lower ACR across quintiles (P for trend = 0.004). Neither total animal nor total plant food intake was associated with ACR. However, greater low-fat dairy consumption was associated with 13% lower ACR across quartiles (P for trend = 0.03). Total nondairy animal food consumption was associated with 11% higher ACR across quintiles (P for trend = 0.03).

Conclusions: A high intake of low-fat dairy foods and a dietary pattern rich in whole grains, fruit, and low-fat dairy foods were both associated with lower ACR. In contrast, collectively, nondairy animal food intake was positively associated with ACR. *Am J Clin Nutr* 2008;87:1825–36.

INTRODUCTION

Urinary excretion of albumin is the result of changes in renal glomerular membrane permeability along with alterations in glomerular hydrostatic pressures and may also result from renal vascular injury (1). Microalbuminuria [defined clinically as an albumin-to-creatinine ratio (ACR) of 25–355 mg/g in men or 17–250 mg/g in women] may also reflect widespread endothelial dysfunction (2–6) and atherosclerosis in extrarenal vascular beds (7–13). Although microalbuminuria is particularly common in persons with diabetes and hypertension (14, 15), population-based studies also show that, even in nondiabetic persons, albumin excretion starting in submicroalbuminuric ranges (16–18) is positively associated with cardiovascular disease (CVD) risk, independent of sex, age, hypertension, and other CVD risk factors (19). Thus, renal vascular dysfunction (represented by microalbuminuria) may itself lead to overt macrovascular CVD, or the 2 forms of vascular disease may result from a shared upstream pathway of dysfunction. Lifestyle factors, like diet, may influence CVD by slowing or accelerating processes along this pathway.

Although high total dietary protein intake is hypothesized to contribute to kidney dysfunction and damage in diabetic and healthy adults (20–25), some studies suggest that dietary protein from animal sources may be more detrimental than protein from plant sources in terms of renal health (26). However, dairy food intake has been inversely associated with hypertension, diabetes, and other metabolic disturbances associated with kidney damage (27–31), which suggests that the biological effects of dairy foods may be unique from those of other animal protein sources. Consistent with this hypothesis, a previous study showed that greater nondairy animal protein intake was associated with declining kidney function in women with mild renal insufficiency (32).

Both clinical and observational studies in this area have largely focused on dietary macronutrient intake (particularly total dietary protein) (23–25, 33–36). However, other constituents of animal and plant foods may be equally important, perhaps acting synergistically within the food matrix. The current literature also notably lacks data relating patterns of food consumption to microalbuminuria, even though dietary pattern interventions

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[2] Supported by training grant T32 HL07779 and contracts N01-HC-95159 through N01-HC-95166 from the National Heart, Lung, and Blood Institute and General Clinical Research Center Grant M01-RR00645 from the National Center for Research Resources.

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Received August 12, 2007.
Accepted for publication January 8, 2008.

favorably influence factors associated with microalbuminuria (28, 37).

We investigated associations between dietary intake and ACR in a population-based sample of white, black, Hispanic, and Chinese persons without clinical CVD or diabetes. We hypothesized that nondairy animal foods, and dietary patterns characterized by high nondairy animal food intake, would be positively associated with ACR, whereas plant foods, and dietary patterns characterized by high plant food intake, would be inversely associated with ACR. We further hypothesized that, as the result of differences in saturated fat content (35), intake of low-fat, but not high-fat, dairy foods would be inversely associated with ACR. Finally we hypothesized that dietary associations with ACR would be stronger in those with evidence of kidney dysfunction [estimated glomerular filtration rate (eGFR) <60 mL · min^{-1} · 1.73 m^{-2}] than in those with normal kidney function (eGFR $\geq$ 60 mL · min^{-1} · 1.73 m^{-2}).

SUBJECTS AND METHODS

Subjects

The Multi-Ethnic Study of Atherosclerosis (MESA) is a longitudinal, population-based study of 6814 white, African American, Hispanic, and Asian men and women free of clinical cardiovascular disease at baseline and aged 45–84 y. The field centers (and affiliate university) were in Baltimore City and County, MD (Johns Hopkins); Chicago, IL (Northwestern); Forsyth County, NC (Wake Forest); New York, NY (Columbia); Los Angeles County, CA (UCLA); and St Paul, MN (University of Minnesota) (38). Institutional review boards at each participating university approved the protocol, and all participants gave written informed consent. The current baseline cross-sectional investigation includes 5042 men and women, excluding those with diabetes mellitus (39) ($n = 922$), macroalbuminuria ($n = 121$), and insufficient or implausible dietary information (40) ($n = 618$) (numbers not mutually exclusive).

Urinary albumin and creatinine

Urinary albumin and creatinine were assayed from one untimed urine sample at the Fletcher Allen Health Care Clinical Chemistry Laboratory (Burlington, VT). Albumin was assayed by use of the Array 360 CE Protein Analyzer (Beckman Instruments Inc, Drea, CA) and the Vitros 950IRC instrument (Johnson & Johnson Clinical Diagnostics Inc, Rochester, NY). Urinary creatinine was measured by rate reflectance spectrophotometry by using thin film adaptation of the creatine amidinohydrolase method on the Vitros analyzer (Johnson & Johnson Clinical Diagnostics Inc). The urinary albumin (μg/mL)-to-creatinine (mg/mL) ratio (ACR) was calculated, with correction for the characteristically higher creatinine excretion level of men than of women (creatinine × 0.68 in men and creatinine × 1.00 in women) (41, 42). Microalbuminuria was defined as an ACR of 25–249 mg/g.

Diet assessment

At the baseline examination, a food-frequency questionnaire was used to quantify usual dietary intake over the past year (40, 43, 44). Participants recorded the serving size and frequency consumed for 120 foods and beverages. Responses were quantified in serving/d: frequency (average times per day) × serving size (40).

Dietary patterns

Dietary factors (food groups with high factor loadings) were derived from 47 food groups by principal components analysis (SAS proc factor, with varimax rotation; SAS Institute Inc, Cary, NC) (40): fats and processed meats (added fats, processed meat, fried potatoes, and desserts); vegetables and fish (vegetables, fish, soups, and Chinese dishes); beans, tomatoes, and refined grains (beans, tomatoes, refined grains, high-fat dairy foods, red meat, and poultry); and whole grains and fruit (whole grains, fruit, nuts and seeds, green leafy vegetables, and low-fat dairy foods). A dietary pattern score was calculated for each participant for each dietary pattern as servings/d of food group$_i$ × factor loading for food group$_i$, summed across all food groups. A higher score indicated greater conformity with the pattern being calculated. Each pattern score was categorized into quintiles.

Food groups

To characterize animal and plant food intakes, we focused on 6 animal food groups (red meat, processed meat, poultry, fish, high-fat dairy foods, and low-fat dairy foods) and 7 plant food groups (fruit, fruit juice, vegetables, legumes, nuts and seeds, whole grains, and refined grains). In some cases, food groups used in the PCA were collapsed to create broader food groups (**Appendix A**). Servings per day of animal food groups and servings per day of plant food groups were summed to characterize total animal food intake and total plant food intake, respectively. A nondairy animal food group comprised the sum of servings/d of red meat, processed meat, poultry, and fish. Individual food groups were categorized in quartiles; summary food groups (plant, animal, and nondairy animal foods) were categorized into quintiles.

Assessment of other relevant variables

Baseline demographics, education, medication use, smoking history, and physical activity were ascertained by a combination of interviewer-administered and self-administered questionnaires. Body mass index (in kg/m^2) was calculated from measured weight and height, and waist circumference was measured at the umbilicus (in cm). Resting seated blood pressure was measured 3 times by using a Dinamap model Pro 100 automated oscillometer (Critikon; General Electric Health Care, United Kingdom). The average of the last 2 measures was used in the analyses. Medication use was assessed by self-report and subsequent verification by inspection of medication bottles. Glomerular filtration rate was estimated by using the abbreviated Modification of Diet in Renal Disease Study equation: eGFR (mL · min^{-1} · 1.73 m^{-2}) = 186.3 × (serum creatinine (mg/dL)$^{-1.154}$) × (age$^{-0.203}$) × (0.742 if female) × (1.21 if African American) (45).

Statistical analyses

We used linear regression (PROC GLM, SAS version 9.1, SAS Institute Inc) to calculate unadjusted means and frequencies of demographics, lifestyle characteristics, and CVD risk factors stratified by microalbuminuria status (ACR $<$ 25 mg/g versus

ACR of 25–249 mg/g). We also calculated food group intake for each stratum, with adjustment for total energy intake (kcal/d).

We used logistic regression to estimate the odds of microalbuminuria from dietary exposures (dietary patterns or food groups) by using the lowest exposure category as the referent. We calculated the *P* for trend across dietary patterns (scores) or food groups (servings/d) by modeling them as continuous variables. We derived odds ratios of microalbuminuria per 1-SD difference in dietary pattern score or per 1-serving/d difference in food group intake from regression with continuous diet variables.

We also evaluated the association between continuously modeled ACR and dietary patterns and food groups. To correct for skewness, ACR was transformed to the natural log scale. Geometric mean ACR (and 95% CI) was calculated for each dietary pattern or food group category. Regression coefficients per 1-SD difference in dietary pattern score or 1-serving/d difference in food group intake as well as the *P* for trend were calculated from regression with continuous variables. Regression coefficients for ln(ACR) can be interpreted as the approximate expected percentage difference in ACR per dietary unit.

We used 2 main multivariate models. In model 1, we adjusted for energy intake (kcal/d), demographic characteristics [study center, age (y), sex, and race/ethnicity (white, black, Hispanic, or Chinese)], and lifestyle variables [education (< high school, = high school, > high school), physical activity (active leisure activity and inactive leisure activity in metabolic equivalent-h/wk), smoking (current or not current and pack years), and supplement use (weekly use of vitamin, mineral, or other nutritional supplements versus nonuse)]. In model 2, we further included potential pathway intermediates (ie, mediators on the causal pathway of the association between dietary intake and microalbuminuria or ACR): including waist circumference (cm), systolic blood pressure (mm Hg), and current use of hypertensive medications. We tested interactions between dietary exposures and eGFR (<60 versus ≥ 60 mL $\cdot$ min^{-1} $\cdot$ 1.73 m^{-2}) by including a cross-product term in our main multivariate model (model 1).

RESULTS

Characteristics according to microalbuminuria status

Participants with microalbuminuria at baseline were older, were more likely to be male, were less educated, were less active, and had greater waist circumferences (**Table 1**). Clinical characteristics also differed; participants with microalbuminuria had higher systolic blood pressure, insulin, and glucose and lower eGFR. With adjustment for energy intake, participants with microalbuminuria ate fewer servings of low-fat dairy foods and more servings of fruit juice and scored lower on the whole grains and fruit dietary pattern. The prevalence of microalbuminuria was 8.6% (7.2%, 11.3%, 9.0%, and 9.4% in whites, Chinese, blacks, and Hispanics, respectively), which is comparable with recent data from the National Health and Nutrition Examination Surveys (46, 47).

Dietary patterns and the odds of microalbuminuria

Only the whole grains and fruit dietary pattern was significantly associated with the odds of microalbuminuria after multivariate adjustment (**Table 2**, model 1). Compared with participants in the lowest quintile, participants in the 5th quintile had a 39% lower odds of microalbuminuria [odd ratio (OR) and 95%

TABLE 1

Demographic, lifestyle, and clinical characteristics of 5042 participants with and without microalbuminuria from the Multi-Ethnic Study of Atherosclerosis (MESA)

	Microalbuminuria (ACR 25–249 mg/g)[1]		
	No (*n* = 4609)	Yes (*n* = 433)	*P*
Demographic, lifestyle, and clinical characteristics			
Age (y)	61.2 ± 0.2[2]	67.0 ± 0.5	<0.001
Sex (% male)	46.1	58.2	<0.001
Race/ethnicity			0.007[3]
White (%)	43.9	36.4	0.003
Black (%)	23.9	25.1	0.59
Hispanic (%)	20.1	22.3	0.29
Chinese (%)	12.1	16.2	0.01
Education ≥ high school (%)	84.8	77.3	<0.001
Active leisure (MET-h/wk)	42.2 ± 0.7	36.9 ± 2.4	0.04
Inactive leisure (MET-h/wk)	27.6 ± 0.3	30.5 ± 0.9	0.003
Supplement use ≥weekly (%)	59.1	57.1	0.42
Current smoking (%)	14.7	13.5	0.49
BMI (kg/m^2)	27.7 ± 0.1	28.1 ± 0.2	0.13
Pack years smoking (y)	10.8 ± 0.3	13.7 ± 1.1	0.009
Waist circumference (cm)	96.4 ± 0.2	99.0 ± 0.7	<0.001
Hypertension (%)	37.6	68.2	<0.001
Systolic blood pressure (mm Hg)	123.7 ± 0.3	138.3 ± 1.0	<0.001
Fasting insulin (mg/dL)	42.9 ± 0.4	48.1 ± 1.4	<0.001
Fasting glucose (mg/dL)	95.4 ± 0.1	98.8 ± 0.5	<0.001
eGFR (mL $\cdot$ min^{-1} $\cdot$ 1.73 m^{-2})	80.7 ± 0.3	77.6 ± 0.8	<0.001
eGFR <60 mL $\cdot$ min^{-1} $\cdot$ 1.73 m^{-2} (%)	7.7	17.6	<0.001
Food group intake (servings/wk)[4]			
Red meat	2.6 ± 0.03	2.6 ± 0.1	0.89
Processed meat	1.2 ± 0.02	1.3 ± 0.08	0.05
Poultry	2.7 ± 0.03	2.5 ± 0.1	0.11
Fish	2.1 ± 0.3	2.2 ± 0.1	0.77
High-fat dairy	5.6 ± 0.1	5.8 ± 0.3	0.38
Low-fat dairy	6.2 ± 0.1	5.4 ± 0.4	0.03
Fruit	13.1 ± 0.2	12.4 ± 0.5	0.20
Fruit juice	2.5 ± 0.05	2.8 ± 0.2	0.04
Vegetables	13.0 ± 0.1	12.7 ± 0.4	0.39
Beans	1.8 ± 0.04	2.0 ± 0.1	0.28
Nuts and seeds	2.0 ± 0.04	2.1 ± 0.1	0.46
Whole grains	4.0 ± 0.06	3.7 ± 0.2	0.12
Refined grains	12.1 ± 0.1	12.6 ± 0.3	0.08
Dietary patterns (score)[4,5]			
Fats and processed meats	−0.001 ± 0.01	0.011 ± 0.03	0.73
Vegetables and fish	−0.003 ± 0.01	0.035 ± 0.05	0.43
Beans, tomatoes, and refined grains	−0.002 ± 0.01	0.019 ± 0.04	0.64
Whole grains and fruit	0.011 ± 0.01	−0.117 ± 0.05	0.01

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[1] ACR, urinary albumin-to-creatinine ratio, with creatinine correction (k) for sex (0.68 in men and 1 in women); MET, metabolic equivalent; eGFR, estimated glomerular filtration rate. Data and *P* values are from linear regression.

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

[3] Chi-square test for difference among race/ethnic groups.

[4] Data are adjusted for total energy intake (kcal/d).

[5] By design, principal components analysis-derived dietary patterns have mean = 0.00, SD = 1.00, and *r* = 0.00.

TABLE 2

Odds ratios (ORs) for microalbuminuria (ACR 25–249 mg/g) according to 4 dietary patterns derived by principal components analysis in 5042 men and women from the Multi-Ethnic Study of Atherosclerosis (MESA)[1]

	OR (95% CI)					*P* for trend[2]	OR (95% CI) per SD difference in dietary pattern score[3]
	Q1	Q2	Q3	Q4	Q5		
Fats and processed meats							
ACR 25–249/ACR <25 (*n*)	93/915	79/930	94/914	88/921	79/929		
Model 1[4]	1.00	0.92 (0.66, 1.28)	1.31 (0.94, 1.83)	1.31 (0.90, 1.88)	1.36 (0.86, 2.13)	0.15	1.13 (0.96, 1.33)
Model 2[5]	1.00	0.88 (0.63, 1.23)	1.25 (0.88, 1.76)	1.27 (0.87, 1.85)	1.29 (0.81, 2.04)	0.19	1.12 (0.94, 1.33)
Vegetables and fish							
ACR 25–249/ACR <25 (*n*)	73/935	102/907	81/927	92/917	85/923		
Model 1[4]	1.00	1.51 (1.09, 2.09)	1.21 (0.86, 1.71)	1.32 (0.93, 1.86)	1.13 (0.74, 1.70)	0.98	1.00 (0.87, 1.14)
Model 2[5]	1.00	1.45 (1.04, 2.02)	1.16 (0.82, 1.65)	1.30 (0.91, 1.86)	1.12 (0.74, 1.72)	0.94	1.00 (0.87, 1.14)
Beans, tomatoes, and refined grains							
ACR 25–249/ACR <25 (*n*)	71/937	115/894	78/930	92/917	77/931		
Model 1[4]	1.00	1.77 (1.29, 2.43)	1.29 (0.91, 1.82)	1.60 (1.13, 2.27)	1.40 (0.92, 2.13)	0.25	1.09 (0.94, 1.25)
Model 2[5]	1.00	1.70 (1.23, 2.36)	1.18 (0.83, 1.67)	1.53 (1.07, 2.19)	1.24 (0.81, 1.91)	0.46	1.06 (0.92, 1.22)
Whole grains and fruit							
ACR 25–249/ACR <25 (*n*)	117/891	99/910	69/939	71/938	77/931		
Model 1[4]	1.00	0.80 (0.59, 1.08)	0.56 (0.40, 0.78)	0.56 (0.39, 0.80)	0.61 (0.42, 0.89)	0.02	0.86 (0.76, 0.98)
Model 2[5]	1.00	0.81 (0.59, 1.11)	0.56 (0.40, 0.80)	0.54 (0.37, 0.77)	0.65 (0.45, 0.95)	0.04	0.87 (0.76, 0.99)

[1] ACR, urinary albumin-to-creatinine ratio; MET, metabolic equivalent.

[2] *P* for trend across quintiles calculated with the original dietary pattern score modeled as a continuous variable.

[3] OR (95% CI) for microalbuminuria per 1-SD difference (1.00) in dietary pattern score, adjusted as described above.

[4] Adjusted for energy intake (kcal/d), study center (Baltimore County, MD; Forsyth County, NC; Los Angeles County, CA; New York, NY; St Paul, MN), age (y), sex (male, female), race/ethnicity (white, black, Chinese, Hispanic), education (<, =, > high school degree), active leisure-time physical activity (MET-h/wk), inactive leisure-time physical activity (MET-h/wk), current smoking status (yes, no), smoking duration (pack years), and current supplement use (≥weekly: yes, no).

[5] Adjusted for the above plus waist circumference (cm), systolic blood pressure (mm Hg), and hypertension medication use.

CI for Q5 versus Q1: 0.61 (0.42, 0.89), *P* for trend = 0.02]. This association remained with additional adjustment for the potential mediating variables waist circumference, systolic blood pressure, and hypertension medication use (Table 2, model 2).

Dietary patterns and the urinary albumin-to-creatinine ratio

The sequences of geometric mean ACR across quintiles of the 4 dietary patterns generally supported those for microalbuminuria, with an inverse association between ACR and whole grains and fruit dietary pattern scores and a positive association between ACR and beans, tomatoes, and refined grains dietary pattern scores (**Table 3**, model 1). Specifically, ACR was 20.3% lower in participants scoring in the highest versus lowest quintile of the whole grains and fruit dietary pattern (*P* for trend = 0.004). In contrast, ACR was 11.5% greater in participants in the highest versus lowest quintile of the beans, tomatoes, and refined grains dietary pattern (*P* for trend = 0.04). Further adjustment for potential pathway intermediates did not materially alter the association with the whole grains and fruit dietary pattern but did attenuate the association with the beans, tomatoes, and refined grains pattern to nonsignificance (Table 3, model 2).

Food groups and the odds of microalbuminuria

Of the 13 individual food groups evaluated (**Table 4**), the strongest association was noted between intake of low-fat dairy foods and odds of microalbuminuria. After adjustment for demographic and lifestyle confounders (model 1), persons in the highest versus lowest quartile of low-fat dairy intake had a 37% lower odds of microalbuminuria [OR (95% CI): 0.63 (0.46, 0.87); *P* for trend = 0.02]. The association remained statistically significant after adjustment for whole grains and fruit dietary pattern scores [OR (95% CI) for Q5 versus Q1: 0.68 (0.49, 0.95)] or adjustment for the other 12 food groups [OR (95% CI) for Q5 versus Q1: 0.70 (0.50, 0.97)]. Adjustment for pathway intermediates also had little effect on these estimates (Table 4, model 2).

Other food groups were not significantly associated with the odds of microalbuminuria after multivariate adjustment. Distinguishing fried from nonfried fish and white potatoes from other vegetables foods did not change these conclusions (data not shown). Although not statistically significant, there were suggestive inverse associations between microalbuminuria and intake of fruit [OR (95% CI) per serving/d in model 1: 0.94 (0.87, 1.01)] and whole grains [OR (95% CI) per serving/d in model 1: 0.84 (0.69, 1.03)] (Table 3).

Food groups and the urinary albumin-to-creatinine ratio

Associations between food group intake and continuously modeled ACR generally mirrored those for microalbuminuria (**Table 5**). For each serving/d greater low-fat dairy consumption, the estimated ACR was 2.3% lower ($\beta \pm$ SE per serving/d change: -0.023 ± 0.01, *P* for trend across quartiles = 0.03,

TABLE 3
Geometric mean ACR according to 4 dietary patterns derived by principal components analysis in 5042 men and women from the Multi-Ethnic Study of Atherosclerosis (MESA)[1]

	Geometric mean ACR (95% CI)					*P* for trend[2]	β ± SE per 1-SD difference in dietary pattern score[3]
	Q1	Q2	Q3	Q4	Q5		
			mg/g				
Fats and processed meats							
Model 1[4]	6.66 (6.27, 7.07)	6.71 (6.35, 7.10)	6.93 (6.57, 7.31)	7.05 (6.68, 7.44)	7.05 (6.59, 7.55)	0.19	0.025 ± 0.02
Model 2[5]	6.69 (6.31, 7.10)	6.79 (6.43, 7.17)	6.91 (6.57, 7.28)	7.03 (6.68, 7.41)	6.97 (6.53, 7.45)	0.31	0.019 ± 0.02
Vegetables and fish							
Model 1[4]	6.75 (6.38, 7.14)	7.00 (6.63, 7.39)	6.86 (6.50, 7.23)	6.87 (6.52, 7.25)	6.92 (6.50, 7.36)	0.68	0.006 ± 0.02
Model 2[5]	6.79 (6.43, 7.17)	6.95 (6.60, 7.33)	6.80 (6.46, 7.16)	6.86 (6.52, 7.22)	6.99 (6.58, 7.42)	0.58	0.008 ± 0.02
Beans, tomatoes, and refined grains							
Model 1[4]	6.27 (5.93, 6.63)	6.94 (6.57, 7.33)	6.83 (6.48, 7.20)	7.30 (6.93, 7.70)	7.09 (6.65, 7.55)	0.04	0.034 ± 0.02
Model 2[5]	6.41 (6.07, 6.76)	7.00 (6.64, 7.38)	6.78 (6.45, 7.14)	7.27 (6.91, 7.65)	6.96 (6.55, 7.41)	0.12	0.025 ± 0.02
Whole grains and fruit							
Model 1[4]	7.75 (7.31, 8.21)	7.02 (6.66, 7.41)	6.63 (6.29, 6.99)	6.63 (6.29, 6.99)	6.44 (6.08, 6.82)	0.004	−0.042 ± 0.01
Model 2[5]	7.72 (7.30, 8.17)	6.98 (6.63, 7.35)	6.63 (6.30, 6.98)	6.57 (6.24, 6.92)	6.56 (6.21, 6.94)	0.01	−0.036 ± 0.01

[1] ACR, albumin-to-creatinine ratio; MET, metabolic equivalent.

[2] *P* for trend across quintiles calculated with the original dietary pattern score modeled as a continuous variable.

[3] β regression coefficient ± SE per 1-SD difference in dietary pattern score. The regression coefficients translate approximately into expected percentage difference, eg, a coefficient of −0.05 translates approximately into a difference of 5% in urinary ACR on its natural scale per 1-SD difference of the dietary pattern score. By design, dietary patterns derived by principal components analysis have a mean = 0 and SD = 1.00.

[4] Adjusted for energy intake (kcal/d), study center (Baltimore County, MD; Forsyth County, NC; Los Angeles County, CA; New York, NY; St Paul, MN), age (y), sex (male, female), race/ethnicity (white, black, Chinese, Hispanic), education (<, =, > high school degree), active leisure-time physical activity (MET-h/wk), inactive leisure-time physical activity (MET-h/wk), current smoking status (yes, no), smoking duration (pack years), and current supplement use (≥weekly: yes, no).

[5] Adjusted for the above, plus waist circumference (cm), systolic blood pressure (mm Hg), and current hypertension medication use.

model 1). Similarly, for each serving/d greater fruit consumption, estimated ACR was 1.7% lower (β ± SE per serving/d change: −0.017 ± 0.01, *P* for trend across quartiles = 0.04, model 1). Although not formally significant, intake of whole grains also showed a moderate inverse association with ACR (*P* for trend = 0.06). Results were similar when further adjusted for waist circumference, systolic blood pressure, and hypertension medication use (model 2).

Plant, animal, and nondairy animal food groups

Neither the sum intake of all animal foods nor the sum intake of all plant foods was significantly associated with the odds of microalbuminuria (*P* for trend = 0.49 and 0.20 for total animal food and total plant food, respectively) or ACR modeled continuously (*P* for trend = 0.90 and 0.20 for total animal food and total plant food, respectively; data not shown).

Although individual nondairy animal foods (red meat, processed meat, poultry, and fish) were not significantly associated with ACR, each serving/d greater intake of the sum of these foods was associated with an estimated 3.9% greater ACR (β ± SE per serving/d difference: 0.039 ± 0.02, *P* for trend = 0.03, model 1; data not shown). Some of this association appeared to be mediated collectively by waist circumference, systolic blood pressure, and need for hypertension medication (current use) (β ± SE per serving/d difference: 0.028 ± 0.02, *P* for trend = 0.12, model 2; data not shown).

Interactions between estimated glomerular filtration rate and dietary patterns or food groups

We noted significant interactions between eGFR (< 60 versus ≥ 60 mL · min^{-1} · 1.73 m^{-2}) and whole grains and fruit dietary pattern scores (*P* for interaction < 0.001), nuts and seeds intake (*P* for interaction = 0.04), and low-fat dairy intake (*P* for interaction = 0.01). In each case, associations tended to be inverse in both strata, but substantially stronger inverse associations were observed in the smaller group of participants with eGFR < 60 mL · min^{-1} · 1.73 m^{-2} (**Table 6**; median eGFR = 56.1 mL · min^{-1} · 1.73 m^{-2}; 12% with eGFR < 45 mL · min^{-1} · 1.73 m^{-2}). There were no statistically significant interactions between eGFR (< 60 or ≥ 60 mL · min^{-1} · 1.73 m^{-2}) and other studied dietary patterns or food groups.

DISCUSSION

In this cross-sectional analysis in a large multiethnic cohort free of clinical CVD and diabetes, a dietary pattern characterized by high consumption of whole grains, fruit, vegetables, and low-fat dairy foods was inversely associated with ACR and the odds of microalbuminuria. Consistent with this, greater intakes of low-fat dairy foods and fruit were each associated with lower ACR, and greater whole-grain intake was marginally associated with lower ACR. By contrast, a dietary pattern characterized by high consumption of beans, tomatoes, refined grains, high-fat dairy foods, and meat food groups and nondairy animal food consumption were each positively associated with ACR.

Greater ACR is associated with greater risk of CVD, even in low-risk individuals (19) and may portend development of chronic kidney disease. Both disease conditions place a heavy burden on public health resources (48, 49). Few studies have evaluated relations between albumin excretion and foods and dietary patterns. Our findings are consistent with the hypothesis that particular aspects of diet may be important intervention

TABLE 4

Odds ratios (ORs) for microalbuminuria (ACR 25–249 mg/g) according to food group intake of 5042 men and women from the Multi-Ethnic Study of Atherosclerosis (MESA)[1]

	OR (95% CI)					
	Q1	Q2	Q3	Q4	*P* for trend[2]	OR (95% CI) per serving/d difference in intake[3]
Red meat						
ACR 25–249/ACR <25 (*n*)	118/1142	115/1157	100/1152	100/1158		
Intake range (servings/d)	0–0.14	0.14–0.28	0.28–0.50	0.50–3.8		
Model 1[4]	1.00	1.03 (0.78, 1.37)	0.97 (0.71, 1.31)	1.03 (0.73, 1.44)	0.48	1.14 (0.80, 1.62)
Model 2[5]	1.00	1.05 (0.79, 1.40)	0.97 (0.71, 1.33)	0.96 (0.68, 1.36)	0.66	1.09 (0.75, 1.57)
Processed meat						
ACR 25–249/ACR <25 (*n*)	104/1115	107/1223	110/1125	112/1146		
Intake range (servings/d)	0.0–0.0	0.0–0.07	0.08–0.20	0.21–2.8		
Model 1[4]	1.00	0.99 (0.74, 1.32)	1.20 (0.89, 1.63)	1.21 (0.87, 1.68)	0.16	1.34 (0.89, 2.00)
Model 2[5]	1.00	0.99 (0.74, 1.33)	1.18 (0.87, 1.62)	1.19 (0.85, 1.66)	0.23	1.28 (0.85, 1.94)
Poultry						
ACR 25–249/ACR <25 (*n*)	131/1124	107/1159	106/1155	89/1171		
Intake range (servings/d)	0.0–0.16	0.16–0.30	0.30–0.52	0.52–4.2		
Model 1[4]	1.00	0.84 (0.64, 1.11)	0.94 (0.71, 1.25)	0.87 (0.63, 1.19)	0.88	0.97 (0.67, 1.41)
Model 2[5]	1.00	0.81 (0.61, 1.07)	0.89 (0.66, 1.18)	0.80 (0.58, 1.11)	0.56	0.89 (0.61, 1.31)
Fish						
ACR 25–249/ACR <25 (*n*)	115/1143	103/1159	100/1162	115/1145		
Intake range (servings/d)	0.0–0.10	0.10–0.21	0.21–0.41	0.41–5.1		
Model 1[4]	1.00	0.94 (0.70, 1.25)	0.89 (0.66, 1.20)	1.17 (0.86, 1.60)	0.45	1.14 (0.81, 1.60)
Model 2[5]	1.00	0.92 (0.68, 1.23)	0.87 (0.65, 1.18)	1.14 (0.83, 1.57)	0.45	1.14 (0.81, 1.60)
High-fat dairy						
ACR 25–249/ACR <25 (*n*)	116/1139	99/116	107/1159	111/1150		
Intake range (servings/d)	0.0–0.20	0.20–0.51	0.51–1.1	1.1–11		
Model 1[4]	1.00	0.97 (0.72, 1.31)	1.21 (0.89, 1.64)	1.29 (0.92, 1.81)	0.20	1.08 (0.96, 1.23)
Model 2[5]	1.00	1.04 (0.76, 1.40)	1.32 (0.97, 1.81)	1.41 (1.00, 2.00)	0.05	1.13 (1.00, 1.28)
Low-fat dairy						
ACR 25–249/ACR <25 (*n*)	129/1117	105/1137	117/1180	82/1175		
Intake range (servings/d)	0.0–0.14	0.14–0.50	0.50–1.1	1.1–12		
Model 1[4]	1.00	0.87 (0.66, 1.16)	0.82 (0.62, 1.08)	0.63 (0.46, 0.87)	0.02	0.88 (0.79, 0.98)
Model 2[5]	1.00	0.88 (0.66, 1.17)	0.82 (0.62, 1.09)	0.64 (0.46, 0.88)	0.02	0.88 (0.80, 0.98)
Whole fruit						
ACR 25–249/ACR <25 (*n*)	121/1139	108/1151	98/1163	106/1156		
Intake range (servings/d)	0.0–0.79	0.80–1.5	1.5–2.5	2.5–14		
Model 1[4]	1.00	0.83 (0.63, 1.10)	0.71 (0.53, 0.95)	0.81 (0.60, 1.09)	0.10	0.94 (0.87, 1.01)
Model 2[5]	1.00	0.83 (0.62, 1.10)	0.68 (0.50, 0.92)	0.79 (0.58, 1.08)	0.11	0.94 (0.87, 1.02)
Fruit juice						
ACR 25–249/ACR <25 (*n*)	116/1254	87/1064	121/1187	109/1104		
Intake range (servings/d)	0.0–0.0	0.0–0.15	0.15–0.50	0.51–6.0		
Model 1[4]	1.00	0.94 (0.70, 1.27)	1.15 (0.87, 1.51)	1.01 (0.76, 1.36)	0.46	1.08 (0.88, 1.31)
Model 2[5]	1.00	0.87 (0.64, 1.18)	1.09 (0.82, 1.44)	0.95 (0.71, 1.28)	0.65	1.05 (0.86, 1.28)
Vegetables						
ACR 25–249/ACR <25 (*n*)	127/1133	106/1155	93/1168	107/1153		
Intake range (servings/d)	0.0–1.4	1.4–2.1	2.1–3.1	3.1–18		
Model 1[4]	1.00	0.87 (0.65, 1.15)	0.74 (0.55, 1.00)	0.89 (0.65, 1.23)	0.20	0.96 (0.88, 1.05)
Model 2[5]	1.00	0.87 (0.65, 1.15)	0.75 (0.56, 1.03)	0.88 (0.63, 1.22)	0.34	0.96 (0.88, 1.05)
Beans						
ACR 25–249/ACR <25 (*n*)	110/1163	109/1129	115/1155	99/1162		
Intake range (servings/d)	0.0–0.03	0.04–0.12	0.13–0.31	0.31–5.3		
Model 1[4]	1.00	1.16 (0.87, 1.54)	1.21 (0.90, 1.62)	1.02 (0.72, 1.43)	0.33	1.16 (0.86, 1.57)
Model 2[5]	1.00	1.11 (0.82, 1.49)	1.18 (0.87, 1.59)	0.96 (0.68, 1.36)	0.47	1.12 (0.82, 1.52)
Nuts and seeds						
ACR 25–249/ACR <25 (*n*)	123/1141	97/1120	99/1197	114/1151		
Intake range (servings/d)	(0.0–0.03)	(0.04–0.14)	(0.14–0.39)	(0.39–6.8)		
Model 1[4]	1.00	0.93 (0.70, 1.26)	0.84 (0.63, 1.13)	1.00 (0.74, 1.35)	0.48	1.09 (0.86, 1.38)
Model 2[5]	1.00	0.93 (0.69, 1.26)	0.86 (0.63, 1.15)	1.04 (0.77, 1.42)	0.27	1.14 (0.90, 1.45)

(*Continued*)

TABLE 4 (*Continued*)

	OR (95% CI)				*P* for trend[2]	OR (95% CI) per serving/d difference in intake[3]
	Q1	Q2	Q3	Q4		
Whole grains						
ACR 25–249/ACR <25 (*n*)	135/1129	112/1146	82/1176	104/1158		
Intake range (servings/d)	0.0–0.12	0.13–0.44	0.44–0.89	0.89–6.1		
Model 1[4]	1.00	0.89 (0.68, 1.17)	0.63 (0.47, 0.86)	0.75 (0.56, 1.01)	0.09	0.84 (0.69, 1.03)
Model 2[5]	1.00	0.88 (0.67, 1.17)	0.63 (0.46, 0.86)	0.76 (0.56, 1.02)	0.14	0.86 (0.70, 1.05)
Refined grains						
ACR 25–249/ACR <25 (*n*)	104/1153	109/1154	120/1143	100/1159		
Intake range (servings/d)	0.0–0.91	0.91–1.5	1.5–2.3	2.3–9.2		
Model 1[4]	1.00	1.06 (0.79, 1.42)	1.15 (0.84, 1.56)	0.98 (0.67, 1.43)	0.41	1.06 (0.93, 1.20)
Model 2[5]	1.00	1.04 (0.77, 1.40)	1.15 (0.84, 1.57)	0.97 (0.66, 1.43)	0.41	1.06 (0.93, 1.20)

[1] ACR, urinary albumin-to-creatinine ratio; MET, metabolic equivalent.

[2] *P* for trend across quartiles calculated with the original food group variable modeled as a continuous variable as servings/d.

[3] OR (95% CI) for microalbuminuria per 1-serving/d difference in food group intake.

[4] Adjusted for energy intake (kcal/d), study center (Baltimore County, MD; Forsyth County, NC; Los Angeles County, CA; New York, NY; St. Paul, MN), age (y), sex (male, female), race/ethnicity (white, black, Chinese, Hispanic), education (<, =, > high school degree), active leisure-time physical activity (MET-h/wk), inactive leisure-time physical activity (MET-h/wk), current smoking status (yes, no), smoking duration (pack years), and current at least weekly supplement use (yes, no).

[5] Adjusted for the above plus waist circumference (cm), systolic blood pressure (mm Hg), and current hypertension medication use.

targets to prevent elevations in albumin excretion and subsequent development of CVD and kidney disease.

Previous epidemiologic studies of diet and albuminuria in persons with (23–25, 33, 35, 36) and without (28, 34) diabetes largely focused on nutrient intake alone and not on dietary patterns or food intake. To our knowledge, only 2 observational studies have reported associations between albumin excretion and food intake: one in this population (50) and one in a Swedish cohort of persons with type 1 diabetes (51). The latter study reported that young men and women (mean age: 18 y) with type 1 diabetes who had an albumin excretion rate ≥ 15 μg/min consumed less fish than did those with an albumin excretion rate < 15 μg/min (51). In contrast with the results of that study, we found no relation between fish consumption and ACR. Differences in frequency and type of fish consumption, disease states (type 1 diabetes versus nondiabetic), and age (young versus middle-aged) of our samples may partly explain the discrepancy between findings.

A previous analysis of data from MESA showed a weak inverse association between whole grains and ACR (50), which we duplicated here with a slightly different study sample and analytic approach. As previously described, the association was strongest in Hispanic and Chinese participants (50). Although associations noted in the current study were weak, <1% of our sample met current recommendations for whole grain intake (3 servings/d) (52). Greater intake is likely needed to fully evaluate the potential of whole grain intake in terms of albumin excretion. We also noted a moderate inverse association between fruit intake and ACR. Ours is the first study to report such an association. Given the relation between inflammation and albuminuria (53–56), fiber or antioxidant components of fruit may partly contribute to the association we observed (57–59).

Although we noted only weak associations between ACR and whole-grain and fruit intake, the dietary pattern characterized by high consumption of these foods (and also low-fat dairy foods) was inversely associated with ACR and microalbuminuria. This observation underscores the importance of the many dimensions of diet. Although the effects of individual dietary constituents may be small, the overall impact of a diet high in several weakly protective foods may result in greater health benefit than each food alone (18).

The results of studies evaluating associations between different food sources of protein and albumin excretion have been inconsistent, with some suggesting adverse effects of animal protein (especially from red meat) and others showing no difference between animal and plant proteins (26). Partially consistent with the hypothesis that animal protein has an unfavorable impact, we found that nondairy animal food intake was positively associated with ACR, whereas low-fat dairy food intake was inversely associated with ACR. Our findings are similar to those from the Nurse's Health Study, where women with mild renal insufficiency at baseline who consumed more nondairy animal protein experienced a greater decline in kidney function over 11 y of follow-up (32).

Differences in the amino acid and fatty acid composition of nondairy and dairy food groups may partially explain the differing directions of associations. Studies have shown that amino acids metabolized in the splanchnic region have greater renal impact than do those metabolized peripherally, and branched-chain amino acids, common to dairy foods, have lesser renal impact (60, 61). Saturated fat, predominantly supplied by animal foods (but amounts negligible in low-fat dairy foods), has previously been associated with greater ACR in persons with diabetes (35) and also with poor endothelial function (62, 63), inflammation (62, 63), and atherosclerosis (64, 65). Furthermore, there is mounting evidence that dairy foods lower the risk of diabetes and other disorders of glucose metabolism that are related to microalbuminuria (29–31). Milk proteins, vitamin D, magnesium, and calcium may partly contribute to these associations (28–31).

Hypertension contributes to renal vascular damage (17, 66), and excess adiposity is a key antecedent of hypertension. However, adjustment for these potential mediators did not alter associations between ACR and the whole grains and fruit dietary pattern or low-fat dairy. This may be due to incomplete adjustment or, alternatively, may be an indication that these dietary factors intervene

TABLE 5

Geometric mean ACR according to food group intake in 5042 men and women from the Multi-Ethnic Study of Atherosclerosis (MESA)[1]

	Geometric mean ACR (95% CI)				*P* for trend[2]	β ± SE per 1-serving/d difference in intake[3]
	Q1	Q2	Q3	Q4		
Red meat						
Model 1[4]	6.77 (6.43, 7.12)	6.88 (6.56, 7.21)	6.81 (6.49, 7.14)	7.07 (6.70, 7.45)	0.28	0.045 ± 0.04
Model 2[5]	6.82 (6.49, 7.16)	6.95 (6.64, 7.27)	6.85 (6.55, 7.17)	6.90 (6.56, 7.26)	0.59	0.020 ± 0.04
Processed meat						
Model 1[4]	6.68 (6.36, 7.03)	6.75 (6.44, 7.07)	7.00 (6.67, 7.34)	7.10 (6.74, 7.47)	0.28	0.056 ± 0.05
Model 2[5]	6.72 (6.40, 7.05)	6.76 (6.47, 7.07)	6.97 (6.66, 7.30)	7.08 (6.73, 7.44)	0.37	0.045 ± 0.05
Poultry						
Model 1[4]	6.93 (6.60, 7.27)	6.83 (6.51, 7.16)	6.74 (6.43, 7.07)	7.02 (6.68, 7.38)	0.29	0.044 ± 0.04
Model 2[5]	7.02 (6.69, 7.35)	6.83 (6.52, 7.15)	6.73 (6.43, 7.04)	6.95 (6.62, 7.30)	0.61	0.020 ± 0.04
Fish						
Model 1[4]	6.95 (6.62, 7.30)	6.80 (6.49, 7.13)	6.63 (6.33, 6.95)	7.14 (6.79, 7.50)	0.10	0.065 ± 0.04
Model 2[5]	6.96 (6.63, 7.30)	6.84 (6.53, 7.16)	6.62 (6.33, 6.93)	7.11 (6.78, 7.46)	0.10	0.062 ± 0.04
High-fat dairy						
Model 1[4]	6.62 (6.28, 6.97)	6.80 (6.48, 7.13)	6.95 (6.63, 7.29)	7.15 (6.79, 7.54)	0.13	0.023 ± 0.02
Model 2[5]	6.54 (6.22, 6.87)	6.78 (6.47, 7.09)	7.00 (6.69, 7.33)	7.22 (6.86, 7.59)	0.23	0.019 ± 0.02
Low-fat dairy						
Model 1[4]	7.25 (6.91, 7.61)	6.98 (6.65, 7.32)	6.89 (6.58, 7.21)	6.42 (6.12, 6.75)	0.03	−0.023 ± 0.01
Model 2[5]	7.23 (6.90, 7.58)	6.94 (6.62, 7.27)	6.89 (6.59, 7.21)	6.48 (6.18, 6.79)	0.04	−0.022 ± 0.01
Whole fruit						
Model 1[4]	7.20 (6.86, 7.56)	6.85 (6.53, 7.18)	6.74 (6.43, 7.06)	6.75 (6.43, 7.08)	0.04	−0.017 ± 0.01
Model 2[5]	7.17 (6.85, 7.52)	6.87 (6.57, 7.19)	6.74 (6.44, 7.05)	6.75 (6.44, 7.07)	0.04	−0.017 ± 0.01
Fruit juice						
Model 1[4]	6.88 (6.58, 7.20)	6.74 (6.41, 7.08)	6.92 (6.61, 7.25)	6.97 (6.63, 7.32)	0.29	0.027 ± 0.03
Model 2[5]	6.99 (6.69, 7.30)	6.71 (6.39, 7.04)	6.90 (6.60, 7.21)	6.91 (6.59, 7.24)	0.58	0.013 ± 0.02
Vegetables						
Model 1[4]	6.97 (6.63, 7.33)	7.08 (6.75, 7.42)	6.54 (6.24, 6.85)	6.94 (6.60, 7.30)	0.40	−0.009 ± 0.01
Model 2[5]	7.00 (6.67, 7.35)	6.88 (6.57, 7.20)	6.67 (6.38, 6.98)	6.97 (6.64, 7.33)	0.95	−0.001 ± 0.01
Beans						
Model 1[4]	6.56 (6.24, 6.89)	7.02 (6.69, 7.37)	6.99 (6.66, 7.32)	6.97 (6.61, 7.34)	0.17	0.051 ± 0.04
Model 2[5]	6.63 (6.32, 6.95)	6.99 (6.67, 7.32)	6.97 (6.67, 7.30)	6.94 (6.59, 7.30)	0.25	0.042 ± 0.04
Nuts and seeds						
Model 1[4]	7.11 (6.77, 7.47)	6.95 (6.63, 7.29)	6.86 (6.55, 7.18)	6.61 (6.30, 6.94)	0.28	−0.031 ± 0.03
Model 2[5]	7.05 (6.73, 7.40)	6.92 (6.60, 7.24)	6.88 (6.58, 7.19)	6.68 (6.37, 7.00)	0.62	−0.014 ± 0.03
Whole grains						
Model 1[4]	7.34 (6.99, 7.70)	7.02 (6.69, 7.35)	6.52 (6.22, 6.84)	6.67 (6.35, 7.00)	0.06	−0.043 ± 0.02
Model 2[5]	7.34 (6.99, 7.70)	7.02 (6.69, 7.35)	6.52 (6.22, 6.84)	6.67 (6.35, 7.00)	0.06	−0.043 ± 0.02
Refined grains						
Model 1[4]	6.92 (6.57, 7.30)	6.78 (6.46, 7.11)	7.07 (6.75, 7.41)	6.74 (6.37, 7.14)	0.08	0.027 ± 0.02
Model 2[5]	6.97 (6.62, 7.34)	6.74 (6.43, 7.06)	7.05 (6.74, 7.38)	6.76 (6.40, 7.14)	0.08	0.026 ± 0.01

[1] ACR, urinary albumin-to-creatinine ratio; MET, metabolic equivalent.

[2] *P* for trend across quintiles calculated with food group intake (servings/d) modeled continuously.

[3] β regression coefficient ± SE per 1-serving/d difference in food group intake. The regression coefficients translate approximately into expected percentage difference, eg, a coefficient of −0.05 is approximately a difference of 5% in urinary ACR on its natural scale per 1-serving/d difference in food group intake.

[4] Adjusted for energy intake (kcal/d), study center (Baltimore County, MD; Forsyth County, NC; Los Angeles County, CA; New York, NY; St. Paul, MN), age (y), sex (male, female), race/ethnicity (white, black, Chinese, Hispanic), education (<, =, > high school degree), active leisure-time physical activity (MET-h/wk), inactive leisure-time physical activity (MET-h/wk), current smoking status (yes, no), smoking duration (pack years), and current at least weekly supplement use (yes, no).

[5] Adjusted for the above plus waist circumference (cm), systolic blood pressure (mm Hg), and current hypertension medication use.

along multiple pathways and not exclusively through their known influence on body weight and blood pressure.

We noted interactions between eGFR and the whole grains and fruit dietary pattern and the low-fat dairy and nuts and seeds food groups, where the stronger association with ACR existed in those with (eGFR < 60 mL $\cdot$ min^{-1} $\cdot$ 1.73 m^{-2}). However, it is possible that these interactions were the result of chance. Duplication of our findings in other studies is essential before we can conclude that particular dietary aspects are more important in those with early pathology versus normal kidney function.

Several limitations deserve discussion. A single spot urine sample was used to determine microalbuminuria, which may have overestimated the prevalence of microalbuminuria (41, 67), compromising specificity and attenuating odds ratios. We

TABLE 6

Interactions between eGFR, and the whole grains and fruit dietary pattern scores, nuts and seeds intake, and low-fat dairy intake with respect to geometric mean ACR in the Multi-Ethnic Study of Atherosclerosis (MESA)[1]

	Geometric mean ACR (95% CI)					*P* for trend[2]	$\beta \pm$ SE per SD difference in score or intake[3]
	Q1	Q2	Q3	Q4	Q5		
Whole grains and fruit dietary pattern[4]							
eGFR <60 mL · min^{-1} · 1.73m^{-2}							
n	65	84	76	101	105		
Score range	−2.6 to −0.83	−0.82 to −0.34	−0.34 to 0.12	0.12 to 0.72	0.74 to 5.2		
Model 1	15.6 (11.3, 21.4)	8.82 (6.97, 11.2)	7.88 (6.20, 10.0)	8.20 (6.60, 10.2)	6.99 (5.60, 8.74)	0.01	−0.177 ± 0.07
eGFR ≥60 mL · min^{-1} · 1.73m^{-2}							
n	938	920	927	903	900		
Score range	−3.1 to −0.83	−0.82 to −0.34	−0.34 to 0.12	0.12 to 0.74	0.74 to 7.8		
Model 1	7.36 (6.94, 7.79)	6.85 (6.49, 7.23)	6.52 (6.18, 6.88)	6.50 (6.15, 6.86)	6.42 (6.05, 6.80)	0.04	−0.029 ± 0.01
Nuts and seeds[5]							
eGFR <60 mL · min^{-1} · 1.73m^{-2}							
n	100	96	113	122			
Intake range (servings/d)	0.00 to 0.03	0.04 to 0.14	0.14 to 0.39	0.39 to 6.1			
Model 1	10.3 (8.20, 12.8)	8.34 (6.72, 10.3)	8.54 (7.00, 10.4)	8.19 (6.73, 9.96)		0.058	−0.212 ± 0.11
eGFR ≥60 mL · min^{-1} · 1.73m^{-2}							
n	1157	1116	1176	1139			
Intake range (servings/d)	0.00 to 0.03	0.04 to 0.14	0.14 to 0.39	0.39 to 6.8			
Model 1	6.86 (6.53, 7.21)	6.82 (6.50, 7.16)	6.74 (6.43, 7.06)	6.47 (6.16, 6.80)		0.62	−0.014 ± 0.03
Low-fat dairy[6]							
eGFR <60 mL · min^{-1} · 1.73m^{-2}							
n	101	87	131	112			
Intake range (servings/d)	0.00 to 0.14	0.14 to 0.50	0.50 to 1.1	1.1 to 9.2			
Model 1	9.20 (7.41, 11.4)	9.34 (7.43, 11.7)	9.18 (7.63, 11.1)	7.49 (6.05, 9.27)		0.08	−0.087 ± 0.05
eGFR ≥60 mL · min^{-1}1.73m^{-2}							
n	1139	1146	1165	1138			
Intake range (servings/d)	0.00 to 0.14	0.14 to 0.50	0.50 to 1.1	1.1 to 12			
Model 1	7.06 (6.72, 7.42)	6.78 (6.46, 7.12)	6.72 (6.41, 7.04)	6.35 (6.04, 6.67)		0.15	−0.016 ± 0.01

[1] eGFR, estimated glomerular filtration rate; ACR, urinary albumin-to-creatinine ratio. Model 1 was adjusted for energy intake (kcal/d), study center (Baltimore County, MD; Forsyth County, NC; Los Angeles County, CA; New York, NY; St. Paul, MN), age (y), sex (male, female), race/ethnicity (white, black, Chinese, Hispanic), education (<, =, > high school degree), active leisure-time physical activity (MET-h/wk), inactive leisure-time physical activity (MET-h/wk), current smoking status (yes, no), smoking duration (pack years), and current at least weekly supplement use (yes, no).

[2] *P* for trend across categories calculated with the dietary variable (dietary pattern score, or food group servings/d) modeled continuously.

[3] $\beta \pm$ SE for ACR per 1-serving/d difference in food group intake or per 1-SD difference in dietary pattern score, multivariable adjusted (as above).

[4] *P* for interaction < 0.001.

[5] *P* for interaction = 0.04.

[6] *P* for interaction with eGFR <60 versus ≥60 mL · min^{-1} · 1.73m^{-2} = 0.01.

attempted to overcome this limitation by modeling ACR continuously to avoid a presumed cutoff to characterize increased risk (16–18). Our cross-sectional analysis cannot define a temporal sequence between dietary exposures and subsequent development of kidney damage, nor can we rule out residual confounding by inadequately measured or unmeasured variables. For example, regular consumers of low-fat dairy foods likely differ from irregular or nonconsumers in terms of other healthy lifestyle practices that lower microalbuminuria risk. Also important to our low-fat dairy analyses is the fact that low-fat milk intake was queried by the following: "low-fat milk or beverages made with low-fat milk, such as café latte and café au lait." Thus, some degree of measurement error exists. Lastly, nonsignificant associations may have been declared significant by chance alone. For example, applying the conservative Bonferroni correction to our food group analyses ($P < 0.004$) would render most associations nonsignificant.

In conclusion, high intake of low-fat dairy foods and a dietary pattern rich in whole grains, fruit, and low-fat dairy food (among other foods) were both associated with lower odds of microalbuminuria and mean ACR in adults free of clinical CVD and diabetes. In contrast, nondairy animal food intake was positively associated with ACR. To the extent that microvascular disease (reflected here by elevated ACR) occurs upstream of overt CVD, these findings point to modifiable dietary factors that may reduce CVD risk. Research in larger studies with prospective dietary measures are need to elucidate the best dietary approach, although it appears a DASH-like (28) dietary pattern excluding meat would be successful.

The authors thank the other investigators, the staff, and the participants of the MESA study for their valuable contributions. A full list of participating MESA investigators and institutions can be found at http://www.mesa-nhlbi.org.

JAN was responsible for analytic design, data analysis, and manuscript preparation. LMS critically reviewed the manuscript. WP and GLB were involved in data acquisition and manuscript review. DRJ was involved in data acquisition, critically reviewed the manuscript, and contributed to data analysis. None of the authors had conflicts of interest to report.

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APPENDIX A

Food group component foods used to study the association between dietary consumption and albuminuria in the Multi-Ethnic Study of Atherosclerosis (MESA)[1]

Food group[2]	Food group components
Red meat	Hamburger, cheeseburger, meat loaf, hash
	Beef, pork or lamb steaks, roasts, barbeque or ribs
	[Chile with meat and beans]
	[Oriental noodles with meat]
	[Chile con carne]
	[Pasta dishes with meat]
	[Stir fry with meat]
	[Burritos, quesadillas, fajitas with meat]
	[Meat stew]
Processed meat	Ham, hot dogs, bologna, salami, other lunch meats
	Ham hocks, pigs' feet, chicarones
	Sausage, chorizo, scrapple, bacon
	Liver including chicken livers, other organ meats
Poultry	Roasted, broiled, baked, or ground chicken or turkey
	Fried chicken
	[Arroz con pollo]
	[Pasta dishes with poultry]
	[Burritos, quesadillas, fajitas with poultry]
	[Turkey stew]
Fish	Shrimp, lobster, crab, oysters, mussels (not fried)
	Tuna, salmon, sardines (including sashimi or sushi)
	Other broiled, steamed, baked, or raw fish (trout, sole, halibut, poke, grouper)
	Fried fish or fish sandwich, fried shrimp, calamari
	[Fish stew or seafood gumbo]
	[Stir-fry dishes with fish]
	[Pasta dishes with fish]
High-fat dairy	Cheddar, American, Chihuahua, Swiss, cream cheese, cheese spreads, any other cheese
	Whole milk and beverages made with whole milk including café latte, café au lait
	Milk in coffee or tea
	Cream, half-and-half or nondairy creamer in coffee or tea
	Regular ice cream
	Cream soups including chowders, potato, and cheese soups
	[Pasta dishes with cream sauce or cheese]
	[Cheese in burritos and enchiladas or tamales]
Low-fat dairy	Skim milk and beverages made with skim milk including café latte, café au lait
	Low-fat milk and beverages made with low-fat milk including café latte, café au lait
	Cottage or ricotta cheese
	Plain yogurt (unflavored)
	Flavored yogurt
	Sweetened condensed milk
	Frozen yogurt, low-fat ice cream, ice milk, sherbet
	Pudding, custard, or flan
Fruit	Peaches, apricots, nectarines, plums
	Cantaloupe, mango, papaya
	Strawberries, blueberries, other berries
	Apples, applesauce, pears
	Bananas, plantains
	Oranges, grapefruit, tangerines, kiwi
	Dried fruits (eg, raisins, prunes, figs, apricots)
	Any other fruits (eg, pineapples, persimmons, grapes, other melons, canned peaches, fruit cocktail, etc)
Fruit juice	Orange juice, grapefruit juice
	Any other juice (eg, apple, grape, punch, Kool-aid,[3] guava juice, etc)
Vegetables	Cruciferous vegetables:
	broccoli, cabbage, cauliflower, brussels sprouts, sauerkraut, kimchee
	[Vegetables in stir-fry dishes]
Vegetables (*Continued*)	Dark yellow vegetables:
	Carrots
	Winter squash, acorn squash
	Sweet potatoes, yams
	[Vegetables in stir-fry dishes, stews, or pot pie]
	Other vegetables:
	Corn hominy
	Green beans, peas, snow peas
	Any other vegetables (eg, summer squash, zucchini, asparagus, mixed vegetables)
	Tossed salad with iceberg or light-green lettuce
	[Vegetables in stir-fry dishes; stews, pot pies, empanada; burritos; enchiladas or tamales]
	Tomatoes:
	Tomatoes (cooked or raw), tomato juice
	Salsa
	[Tomatoes in chile, picadillo, pasta with tomato sauce, burritos, enchiladas or tamales]
	White potatoes:
	Boiled, baked, mashed, or other potatoes, turnips
	[Potatoes in stews or pot pies, empanada]
	Green leafy vegetables:
	Tossed salad with spinach, romaine, or dark greens; cooked spinach; turnip greens; collards
Beans	Peas, lentils, black beans, potajes soups
	Pinto, black, baked, butter, or red beans; pork and beans; black-eyed peas
	Refried beans as a side dish
	[Beans in chile with meat and beans, enchiladas or tamales, or burritos without meat]
Nuts and seeds	Almonds, walnuts, pecans, other nuts
	Sunflower, pinyon, other seeds
	Peanuts, peanut butter
Whole grains	Dark, whole-grain bread or rolls (eg, hamburger buns, bagels, pitas, English muffins, etc)
	Bran muffins
	Brown or wild rice
	Oatmeal
	High-fiber cold cereal
Refined grains	White bread or rolls (eg, hamburger buns, bagels, pitas, English muffins, etc)
	White, Mexican, or sticky rice
	Flour or corn tortillas on the side
	Other hot cereal (eg, grits, cream of wheat, mush, congee)
	Low-fiber cereal
	Biscuits, other muffins, croissants, corn bread, hush puppies
	Pancakes, waffles, French toast
	Potato, corn, or tortilla chips
	Crackers, pretzels, popcorn
	Chinese dumplings, spring roll, dim sum (not fried), Chinese bun
	Chow mein
	Fried rice
	[Oriental noodles with meat]
	[Fish stew or seafood gumbo, paella]
	[Other pasta dishes]
	[Arroz con pollo]
	[Burritos or enchiladas or tamales]
	[Stews or pot pies or empanada]

[1] Each item represents a single question on the MESA food-frequency questionnaire. Items in brackets were included in multiple food groups after disaggregation to component parts (mixed dishes).

[2] Note that the narrowly defined 47 food groups used in the principal components analysis to derive dietary patterns (presented in detail in reference 40) were collapsed to form these 13 more general food groups.

[3] Kraft Foods, Inc, Northfield, IL.