Macronutrients, Diet Quality, and Frailty in Older Men

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Background. Frailty, a phenotype of multisystem impairment and expanding vulnerability, is associated with higher risk of adverse health outcomes not entirely explained by advancing age. We investigated associations of macronutrients, dietary fiber, and overall diet quality with frailty status in older community-dwelling men.

Methods. Participants were 5,925 men aged ≥65 years enrolled in the Osteoporotic Fractures in Men (MrOS) study at six U.S. centers. Diet was assessed at baseline with a food frequency questionnaire. We assessed frailty status (robust, intermediate, or frail) at baseline and at a second clinic visit (a mean of 4.6 years later) using a slightly modified Cardiovascular Health Study frailty index. We used multinomial logistic regression to assess associations between macronutrient intake, dietary fiber, and the Diet Quality Index Revised with frailty status at baseline and at the second clinic visit.

Results. At baseline, 2,748 (46.4%) participants were robust, 2,681 (45.2%) were intermediate, and 496 (8.4%) were frail. Carbohydrate, fat, protein, and dietary fiber showed no consistent associations with frailty status. Overall diet quality exhibited fairly consistent associations with frailty status. The Diet Quality Index Revised was inversely associated with frail status relative to robust status at the baseline visit (odds ratio for Q5 vs Q1 = 0.44, 95% confidence interval: 0.30, 0.63; p for trend < .0001) and at the second clinic visit (odds ratio for Q5 vs Q1 = 0.18, 95% confidence interval: 0.03, 0.97; p for trend = .0180).

Conclusions. Overall diet quality was inversely associated with prevalent and future frailty status in this cohort of older men.

Key Words: Frailty—Nutrition—Epidemiology.

FRAILTY, a phenotype of multisystem impairment and expanding vulnerability, becomes more prevalent with increasing age (1–3). Older persons characterized as frail have a higher risk of adverse health outcomes not entirely explained by advancing age, poorer functional status, and greater prevalence of comorbid conditions (4,5). Fried and colleagues have proposed a standard definition of frailty based on data from the Cardiovascular Health Study (CHS)—the CHS frailty index (6). In this index, frailty is defined by the presence of three or more of the following criteria: unintentional weight loss, poor endurance or energy, weakness, slow walking speed, and low physical activity. The CHS frailty index was predictive of falling, hospitalization, disability, and mortality (6). The predictive validity of the CHS frailty index has been confirmed in several cohorts of older persons (1,2,7–9).

Although poor diet often is assumed to be a component of frailty, whether it is a predictor or consequence of frailty has not been investigated adequately, especially using standard definitions of frailty. In addition, few studies have examined the association of diet with frailty beyond the level of specific micronutrients. Of the few published factors, poor nutritional score and low protein intake have been associated with a greater risk of frailty (10,11) . There is limited evidence that low intakes of fat and carbohydrate may be associated with increased mortality in frail elderly adults (12). It also has been suggested that dietary fiber may play a role in the progression of frailty, with frail geriatric hospital patients receiving fiber supplements for 12 weeks showing no reduction in body weight compared with those who did not receive the supplements (13). Overall, however, there are few published data on the possible association between

diet, a potentially modifiable risk factor, and frailty, especially with measures of overall dietary intake and quality.

The objectives of this study were to describe the associations between dietary macronutrients, dietary fiber, and overall diet quality with frailty status in Osteoporotic Fractures in Men (MrOS) study participants at baseline and to investigate whether these dietary components were associated with frailty status in MrOS participants at a second clinic visit, a mean of 4.6 years later.

Methods

Participants

Participants were older community-dwelling men enrolled in the MrOS study, the objective of which is to identify risk factors for osteoporosis and fractures in older men. Detailed descriptions of the study design and recruitment for MrOS have been published (14,15). Briefly, MrOS participants were recruited at six U.S. clinical centers: Birmingham, Alabama; Minneapolis, Minnesota; Palo Alto, California; Monongahela Valley near Pittsburgh, Pennsylvania; Portland, Oregon; and San Diego, California. Eligibility criteria included age 65 years or older; the ability to walk without assistance from another person or aid; and no history of bilateral hip replacements. Baseline examinations were completed between March 2000 and April 2002. A second clinic visit was conducted after an average period of 4.6 years, between March 2005 and May 2006. Institutional review boards at each institution approved the study, and all participants provided written informed consent.

Clinic Measurements

At baseline, height was measured with Harpenden stadiometers and weight with balance beam or digital scales. Body mass index was calculated as kg/m^2. Appendicular lean mass (ALM) and total body fat mass were measured using dual energy x-ray absorptiometry on Hologic QDR4500 machines (Hologic, Inc., Bedford, Massachusetts) using standardized protocols. Walking speed was measured on a 6-m walking course with participants asked to walk at their usual pace. The fastest pace of two trials was recorded. Grip strength was measured using a JAMAR hand dynamometer (16).

Dietary Assessment

Dietary data were derived from the Block 98 semiquantitative food frequency questionnaire (FFQ) administered at baseline. The Block 98 FFQ has been used extensively and has been validated with diet records (17,18). The questionnaire included 69 individual food item questions, and an additional 13 questions about food preparation and low-fat foods were asked and used to refine nutrient calculations.

There were nine categories of frequency responses for foods and beverages and four categories of portion size responses. A graphic representation of standard portion sizes was included with the questionnaire. The Block group determined the nutrient composition of each reported FFQ using the United States Department of Agriculture Database for Standard Reference for Version 12 and the 1994–1996 Continuing Survey of Food Intakes by Individuals database.

We assessed diet quality with the Diet Quality Index Revised (DQI-R), a 10-component estimate of diet quality relative to national guidelines (19,20). The DQI-R incorporates the following dietary variables as estimated from the Block 98 FFQ: percent of energy intake from fat; percent of energy intake from saturated fat; dietary cholesterol; fruit servings; vegetable servings; grain servings; calcium intake; iron intake; dietary diversity; and dietary moderation. Each component can contribute up to 10 points to an overall diet quality score ranging from 0 (lowest quality) to 100 (highest quality).

Covariate Assessment

MrOS ascertained baseline demographic information and current smoking status through self-administered questionnaires. Current physical activity was assessed with the Physical Activity Scale for the Elderly (PASE) questionnaire (21). Men were considered to have one or more of the following medical conditions if they reported a physician diagnosis of diabetes, hyperthyroidism, hypothyroidism, hypertension, stroke, myocardial infarction, congestive heart failure, chronic obstructive pulmonary disease, Parkinson's disease, or cancer (except nonmelanoma skin cancer). Perceived health status was self reported as "excellent," "good," "fair," "poor," or "very poor" in response to the question "Compared to other people your own age, how would you rate your overall health?"

Frailty Assessment

Frailty was defined using the CHS frailty index (6,22) based on MrOS baseline data. Because MrOS did not have data on body weight prior to enrollment, for the shrinking component of the frailty index, we used ALM (regressed in linear models on height and total body fat mass) in the lowest quintile, as has been used in several previous published analyses of frailty, including several utilizing the MrOS cohort (1,23,24). The regression equation used was as follows: expected ALM = −23.68 + 0.254 height (cm) + 0.169 total body fat (kg). The difference between actual ALM and expected ALM from the linear regression model (ie, the residual) was used to quantify shrinking in each participant. Poor energy was identified by the responses "a little" or "none of the time" to the question "How much of the time during the past 4 weeks have you had a lot of energy?" on the Medical Outcomes Study 12-item Short Form (SF-12)

questionnaire. Weakness was identified by maximal grip strength in the lowest quintile stratified by body mass index (quartiles). Slowness was identified by a walk speed in the lowest quintile stratified by standing height (median). Low physical activity level was identified by a PASE score in the lowest quintile. We characterized men with none of the components as robust, those with one or two components as intermediate, and those with three or more components as frail.

Mortality Ascertainment

Vital status was ascertained through mailed questionnaire (with phone follow-up for nonresponse) every 4 months. Reported deaths were confirmed with death certificates. Follow-up for vital status was 99% complete.

Statistical Analysis

Of the full cohort of 5,994 MrOS participants, we excluded 67 participants (1.1%) from this analysis based on the FFQ, including 19 (0.3%) who refused to complete the FFQ, 21 (0.4%) with >10% missing data on the FFQ, and 27 (0.5%) with implausibly low reported energy intake (<400 kcal/d; no maximum energy intake was set). Two additional participants at baseline (0.03%) could not have frailty defined because of at least two missing frailty components. This resulted in 5,925 participants available for the baseline cross-sectional analyses (98.8% of the original cohort). The 2,748 participants who were robust at baseline were considered for the prospective analysis. A total of 262 of these participants (9.5%) at the second clinic visit could not have their frailty status defined because of at least two missing frailty index components. In addition, 62 participants (2.3%) were alive but did not attend the second clinic visit and were excluded from the prospective analyses. This resulted in 2,424 participants available for the prospective analyses (88.2% of men who were robust at baseline). Three participants were missing baseline covariates and one participant was missing second clinic visit covariates included in the regression models described subsequently, which reduced the final analytic sample sizes to 5,922 and 2,423 for the baseline and prospective analyses, respectively.

We calculated descriptive statistics of demographic, health history, anthropometric, and dietary intake variables at the baseline visit according to categories of frailty status. To test the association of frailty status with demographic and dietary variables, the Pearson chi-square test and analysis of variance were used.

We categorized dietary intake variables into quintiles and conducted regression analyses, investigating associations between the dietary variables and frailty status. Given the ordinal nature of the outcome (robust [0 components], intermediate [1 or 2 components], or frail [3, 4, or 5 components]), ordinal logistic regression with a proportional odds

assumption was considered. However, due to the violation of the proportionality assumption for several models, multinomial logistic regression was employed. Multinomial logistic regression simultaneously modeled the odds of being classified as intermediate relative to robust and the odds of being classified as frail relative to robust (and the odds of being classified as deceased relative to robust in the follow-up analysis) as a function of the explanatory variables. Models examined the association between quintiles of the dietary variables and baseline frailty status adjusting for covariates, including age, race, center, education, marital status, smoking, health status, medical conditions, body mass index, and energy intake. A prospective analysis, including only men who were robust at baseline and adjusting for the same covariates, was conducted to examine whether dietary variables were associated with incident frailty states (intermediate, frail, or deceased) at the second clinic visit. In order to perform a test of linear trend across quintiles of dietary variables, level of quintiles was treated as a continuous explanatory variable. Analyses were performed using SAS statistical software, version 9.2 (SAS institute Inc., Cary, NC).

RESULTS

At baseline, 2,748 men (46.4%) were robust, 2,681 (45.2%) were intermediate, and 496 (8.4%) were frail. On average, frail participants were almost 7 years older than those who were robust at baseline and 4 years older than men who were intermediate (Table 1). Frail participants were on average less educated, less likely to be married, more likely to smoke, more likely to rate their health as fair/poor/very poor, and more likely to have multiple medical conditions. Frail men were more likely to have a body mass index $< 25 \, kg/m^2$. Energy intake was inversely associated with frailty status, with frail men consuming an average of 63 kcal/d less than their robust counterparts. Protein and dietary fiber intakes were slightly lower in frail men. Although overall diet quality was somewhat low in all three groups relative to the maximum possible score, it was slightly lower in frail men compared with the other two groups.

In multivariable analyses examining the associations between baseline dietary variables and baseline frailty status, higher intake of fiber was significantly associated with reduced odds of intermediate relative to robust status, with an odds ratio (OR) comparing the highest quintile (Q5) to lowest quintile (Q1) of 0.83 (95% confidence interval [CI]: 0.69, 1.00; *p* for trend = .0224; Table 2). Intakes of carbohydrate, fat, and protein and the DQI-R were not associated with the risk of intermediate relative to robust status. Higher intakes of carbohydrate (OR for Q5 vs Q1 = 0.65; 95% CI: 0.45, 0.94; *p* for trend = .0074) and fiber (OR for Q5 vs Q1 = 0.51; 95% CI: 0.36, 0.73; *p* for trend < .0001) were significantly associated with reduced odds of frail relative to robust status,

Table 1. Characteristics of Participants at Baseline According to Frailty Status (*n* = 5,925)

	Frailty Status			
	Robust	Intermediate	Frail	*p* Value*
N	2,748	2,681	496	
Age (y)	71.9±5.0	74.5±5.8	78.6±6.3	<.0001
Caucasian	90.1	89.7	87.3	.18
Site				<.0001
Birmingham	13.8	18.3	19.0	
Minneapolis	18.0	16.3	12.9	
Palo Alto	17.1	16.3	15.3	
Pittsburgh	17.3	16.2	17.9	
Portland	15.8	16.9	17.9	
San Diego	18.1	16.0	16.9	
College or graduate education	56.1	51.4	47.4	<.0001
Married	85.5	80.8	74.2	<.0001
Smoking, current	2.8	3.7	5.4	.0092
Health status fair/poor/very poor	6.4	17.2	41.6	<.0001
Selected medical conditions[†]				<.0001
0–1	75.2	62.1	42.1	
2–3	23.2	33.8	47.4	
≥4	1.6	4.1	10.5	
BMI (kg/m^2)				<.0001
<25	24.7	28.5	35.3	
25–29.9	55.0	48.8	44.4	
≥30	20.3	22.7	20.4	
Energy (kcal/d)	1,652±635	1,597±642	1,589±641	.0035
Macronutrients (% energy)				
Carbohydrate	50.1±8.8	50.4±8.6	49.7±8.4	.21
Fat	36.6±8.1	36.4±8.0	37.0±8.4	.24
Protein	16.2±2.8	16.0±2.9	15.9±3.1	.0283
Dietary fiber (g/1000 kcal)	11.4±3.9	11.2±3.9	10.6±3.8	<.0001
DQI-R	62.9±13.1	62.8±12.9	60.7±12.9	.0025

Notes: BMI = body mass index; DQI-R = Diet Quality Index Revised. Data are shown as mean ± *SD* or as percentage.

*Derived from Pearson chi-square test (for proportions) and analysis of variance (for continuous variables).

[†]History of selected medical conditions, including diabetes, hyperthyroidism, hypothyroidism, hypertension, stroke, myocardial infarction, congestive heart failure, chronic obstructive pulmonary disease, Parkinson's disease, or cancer (except nonmelanoma skin cancer).

whereas higher intake of fat (OR for Q5 vs Q1 = 1.61; 95% CI: 1.12, 2.31; *p* for trend = .0018) was significantly associated with greater odds of frail relative to robust status. Notably, protein was not associated with the risk of frail relative to robust status. DQI-R was inversely associated with frail relative to robust status, with an OR comparing Q5 to Q1 = 0.44 (95% CI: 0.30, 0.63; *p* for trend < .0001).

In the prospective analysis including only the 2,423 men who were robust at baseline, 1,618 (66.8%) were robust, 647 (26.7%) were intermediate, 25 (1.0%) were frail, and 133 (5.5%) were deceased at the second clinic visit. In multivariable analyses examining the association between baseline dietary variables with frailty status at the second clinic visit, neither carbohydrate nor fat, or fiber, was associated with frailty status (Table 3). Only DQI was significantly associated with the odds of intermediate relative to robust status, with an OR for Q5 versus Q1 of DQI = 0.82 (95% CI: 0.60, 1.11; *p* for trend = .0196). DQI also was the only dietary variable significantly associated with the odds of frail relative to robust status, with an OR for Q5 versus Q1 of DQI = 0.18 (95% CI: 0.03, 0.97; *p* for trend = .0180). Protein was significantly inversely

associated with the odds of deceased relative to robust status, with an OR for Q5 versus Q1 of protein = 0.52 (95% CI: 0.27, 0.99; *p* for trend = .0463), but was not associated with the odds of intermediate or frail status relative to robust status.

DISCUSSION

In this study of diet and frailty in participants in the MrOS study, the most consistent finding was the association of overall diet quality (as assessed with a standard index) with frailty status. An inverse association was observed when DQI-R at baseline was related both to frail status at baseline and to frail status at the second MrOS clinic visit, an average of 4.6 years later.

Few previous studies have evaluated the relationship between diet and frailty using an operational definition of frailty. One of the first such studies using the CHS frailty index and a population-based sample with a large proportion of older persons was a study of aging by Bartali and colleagues in the Chianti area of Italy (11). In this study, after adjusting for potential confounders, participants in the

Table 2. Association of Baseline Dietary Variables With Baseline Frailty Status (*n* = 5,922)

	OR (95% CI)*,† of Intermediate Status Relative to Robust Status	OR (95% CI)*,† of Frailty Status Relative to Robust Status
Carbohydrate (% energy)		
Q1 (9.3–43.3)	1.00 (ref)	1.00 (ref)
Q2 (43.4–47.7)	1.15 (0.97, 1.38)	1.08 (0.77, 1.51)
Q3 (47.8–52.0)	1.03 (0.86, 1.23)	0.79 (0.56, 1.11)
Q4 (52.1–57.1)	1.13 (0.94, 1.35)	0.83 (0.59, 1.18)
Q5 (57.2–91.9)	1.03 (0.86, 1.24)	0.65 (0.45, 0.94)
p Value for linear trend	.83	.0074
Fat (% energy)		
Q1 (4.9–29.8)	1.00 (ref)	1.00 (ref)
Q2 (29.9–34.9)	0.98 (0.82, 1.17)	0.90 (0.63, 1.29)
Q3 (35.0–38.8)	0.94 (0.78, 1.13)	1.32 (0.93, 1.87)
Q4 (38.9–43.2)	0.96 (0.80, 1.15)	1.28 (0.90, 1.83)
Q5 (43.3–72.5)	0.97 (0.81, 1.17)	1.61 (1.12, 2.31)
p Value for linear trend	.74	.0018
Protein (% energy)		
Q1 (6.0–13.7)	1.00 (ref)	1.00 (ref)
Q2 (13.8–15.2)	0.94 (0.79, 1.13)	0.82 (0.59, 1.08)
Q3 (15.3–16.5)	0.92 (0.77, 1.10)	0.77 (0.55, 1.08)
Q4 (16.6–18.3)	0.96 (0.80, 1.15)	0.69 (0.49, 0.97)
Q5 (18.4–29.3)	0.91 (0.76, 1.09)	0.87 (0.62, 1.21)
p Value for linear trend	.42	.23
Dietary fiber (g/1000 kcal)		
Q1 (1.8–8.1)	1.00 (ref)	1.00 (ref)
Q2 (8.2–9.8)	0.89 (0.74, 1.06)	0.65 (0.46, 0.90)
Q3 (9.9–11.6)	0.79 (0.66, 0.95)	0.57 (0.41, 0.79)
Q4 (11.7–14.1)	0.79 (0.66, 0.94)	0.38 (0.27, 0.54)
Q5 (14.2–33.9)	0.83 (0.69, 1.00)	0.51 (0.36, 0.73)
p Value for linear trend	.0224	<.0001
DQI-R		
Q1 (20.4–50.7)	1.00 (ref)	1.00 (ref)
Q2 (50.8–59.7)	1.02 (0.85, 1.22)	0.78 (0.56, 1.09)
Q3 (59.8–66.9)	0.89 (0.74, 1.07)	0.73 (0.52, 1.02)
Q4 (67.0–74.5)	0.94 (0.78, 1.13)	0.57 (0.41, 0.81)
Q5 (74.6–91.4)	0.96 (0.80, 1.16)	0.44 (0.30, 0.63)
p Value for linear trend	.45	<.0001

Notes: CI = confidence interval; DQI-R = Diet Quality Index Revised; OR = odds ratio. Baseline analyses are based on 2,747 men classified as robust, 2,680 men classified as intermediate, and 495 classified as frail.

*Derived from multinomial logistic regression.

†Results adjusted for age, race, center, education, marital status, smoking, health status, medical conditions, body mass index, and energy intake.

lowest quintile of protein intake had a significantly greater risk of frailty. This was a cross-sectional analysis, with no prospective component, and frailty was based on only four of the five CHS frailty index components. In another study employing the CHS frailty index, a prospective analysis in a subset of women 65–79 years of age in the Observational Study of the Women's Health Initiative, following adjustment for potential confounders, a 20% increase in urinary nitrogen–calibrated total protein intake (as % energy) was associated with a statistically significant 24% lower risk of intermediate status and a 32% lower risk of frailty (10). In contrast to these results, we found little evidence of an association of protein intake and frailty status in MrOS participants.

The finding of an inverse association of overall diet quality with frailty in this study is in agreement with the analysis by Bartali and colleagues, in which participants with the lowest nutritional score (as indicated by the greatest number of nutrients in the lowest quintile of intake) were significantly more likely to be frail (11). In a study of community-dwelling adults conducted in Nurnberg, Germany, the risk of being frail was significantly reduced in participants in the highest quartile of the Mediterranean diet score, a diet perceived to be beneficial based on its high content of vegetables, fruits, legumes, unrefined grains, nuts, and fish (25). Another study of community-dwelling adults in Tuscany, Italy showed that higher adherence to a Mediterranean-style diet was associated with lower odds of developing frailty (26). Our results suggest a greater importance of overall diet quality compared with individual dietary components in relation to frailty status. If the present results are corroborated in future studies, they would provide justification for the development of multifaceted interventions aimed at improving overall diet quality, rather than

Table 3. Association of Baseline Dietary Variables With Frailty Status at the Second Clinic Visit in Men Who Were Robust at Baseline ($n = 2,423$)

	OR (95% CI)*,† of Intermediate Status Relative to Robust Status	OR (95% CI)*,† of Frailty Status Relative to Robust Status	OR (95% CI)*,† of Deceased Status Relative to Robust Status
Carbohydrate (% energy)			
Q1 (9.3–43.3)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Q2 (43.4–47.7)	0.75 (0.56, 1.00)	0.81 (0.24, 2.75)	0.92 (0.52, 1.64)
Q3 (47.8–52.0)	0.84 (0.63, 1.12)	0.82 (0.25, 2.65)	1.18 (0.68, 2.06)
Q4 (52.1–57.1)	0.78 (0.58, 1.04)	0.59 (0.16, 2.18)	1.08 (0.61, 1.92)
Q5 (57.2–80.6)	0.85 (0.63, 1.41)	0.60 (0.16, 2.28)	1.06 (0.58, 1.94)
p Value for linear trend	.35	.38	.68
Fat (% energy)			
Q1 (8.1–29.7)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Q2 (29.8–34.9)	1.17 (0.87, 1.57)	1.33 (0.34, 5.11)	0.61 (0.31, 1.21)
Q3 (35.0–38.7)	0.95 (0.70, 1.28)	0.22 (0.02, 2.05)	1.61 (0.92, 2.84)
Q4 (38.8–43.1)	0.88 (0.64, 1.19)	2.67 (0.78, 9.09)	0.87 (0.47, 1.62)
Q5 (43.2–72.5)	1.25 (0.93, 1.67)	1.42 (0.35, 5.67)	1.06 (0.57, 1.96)
p Value for linear trend	.63	.25	.62
Protein (% energy)			
Q1 (8.2– 13.7)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Q2 (13.8–15.2)	1.14 (0.84, 1.55)	1.27 (0.39, 4.17)	1.09 (0.63, 1.88)
Q3 (15.3–16.5)	0.97 (0.71, 1.32)	0.93 (0.27, 3.19)	0.83 (0.47, 1.47)
Q4 (16.6–18.3)	1.13 (0.83, 1.53)	0.53 (0.12, 2.28)	0.94 (0.53, 1.65)
Q5 (18.4–28.6)	1.08 (0.80, 1.46)	0.70 (0.18, 2.76)	0.52 (0.27, 0.99)
p Value for linear trend	.71	.30	.0463
Dietary fiber (g/1000 kcal)			
Q1 (1.8–8.1)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Q2 (8.2–9.7)	0.81 (0.60, 1.09)	0.94 (0.28, 3.17)	1.21 (0.64, 2.26)
Q3 (9.8–11.6)	0.75 (0.56, 1.02)	0.53 (0.14, 2.03)	1.64 (0.91, 2.98)
Q4 (11.7–14.1)	0.85 (0.63, 1.13)	0.68 (0.19, 2.43)	1.24 (0.66, 2.34)
Q5 (14.2–32.5)	0.86 (0.64, 1.16)	0.83 (0.23, 3.01)	1.50 (0.79, 2.83)
p Value for linear trend	.47	.63	.27
DQI-R			
Q1 (21.9–50.7)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Q2 (50.8–59.7)	1.01 (0.75, 1.36)	0.84 (0.25, 2.87)	0.74 (0.42, 1.31)
Q3 (59.8–66.9)	0.83 (0.61, 1.11)	1.04 (0.33, 3.32)	0.70 (0.40, 1.23)
Q4 (67.0–74.5)	0.66 (0.48, 0.89)	0.37 (0.09, 1.46)	0.67 (0.38, 1.18)
Q5 (74.6–90.7)	0.82 (0.60, 1.11)	0.18 (0.03, 0.97)	0.67 (0.37, 1.22)
p Value for linear trend	.0196	.0180	.18

Notes: DQI-R = Diet Quality Index Revised. Second clinic visit analyses are based on 1,618 men classified as robust, 647 men classified as intermediate, 25 men classified as frail, and 133 men who had died.
*Derived from multinomial logistic regression.
†Results adjusted for age, race, center, education, marital status, smoking, health status, medical conditions, body mass index, and energy intake.

interventions focused on individual dietary components, to prevent frailty.

This study had several notable strengths. MrOS participants were recruited from the community and characterized with a comprehensive set of measures at baseline. In addition, this analysis included a prospective component, an established index was utilized to characterize frailty status, and a validated instrument was used to assess diet. Limitations include the enrollment of mostly white community-dwelling men; the results may not be generalizable to institutionalized or less-healthy men, or to women. Because the baseline analyses were cross-sectional, the direction of any association noted (eg, whether men who were frail were more likely to have a lower quality diet or those with a lower quality diet were more likely to be frail) could not

be determined. Dietary assessment was conducted only at baseline; therefore, it is not known how dietary intake might have changed between baseline and the second clinic visit. In addition, underreporting of energy and protein on FFQs (compared with other instruments or to biomarkers) has been documented (27). This underreporting can limit the ability of even the largest cohort studies to detect modest associations when using an FFQ for dietary assessment and may have been one reason for the lack of an association between dietary protein and frailty in this study. It also should be noted that diet quality indices/scores besides the DQI-R, such as the previously mentioned Mediterranean diet score, might have been used in this analysis. The definition of frailty used in this analysis differed from the published CHS definition because MrOS did not include data

on body weight prior to enrollment. Instead of weight loss in the previous year, we used ALM, accounting for body size and fat mass. Although the effect of this substitution on the estimation of frailty is unclear, a direct measure of muscle mass that accounts for body size and fat mass may be a better measure of shrinking than recent weight loss because weight loss might not accurately represent muscle loss, a key component of frailty (1). Finally, several MrOS measures utilized in the current analysis were based on self-report, creating the potential for misclassification bias.

In summary, in this cohort of older men, we observed an inverse association between overall diet quality and frailty status. Although these results require replication in other studies, they provide evidence that a potentially modifiable factor—dietary intake—may play a role in frailty status.

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