Diet quality and risk of frailty among older women in the Nurses' Health Study

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ABSTRACT

Background: The frailty syndrome is associated with higher risk of disability and death after accounting for multimorbidity. Therefore, the determinants of frailty need to be identified to ensure older adults live not only longer but also healthier lives. However, the effect of diet quality on frailty is mostly unknown.

Objectives: We aimed to evaluate the alternate Mediterranean diet (AMED), the Dietary Approaches to Stop Hypertension (DASH) diet, and the alternate Healthy Eating Index-2010 (AHEI-2010) in association with frailty risk among older women.

Methods: We analyzed data from 71,941 women aged ≥60 y participating in the Nurses' Health Study. The AMED, DASH, and AHEI-2010 were computed from validated FFQs in 1990 and repeated every 4 y until 2010. Frailty was defined as having ≥3 of the following 5 criteria from the FRAIL scale: fatigue, reduced resistance, reduced aerobic capacity, having ≥5 illnesses, and weight loss ≥5%. The occurrence of frailty was assessed every 4 y.

Results: During follow-up we identified 11,564 incident cases of frailty. After adjusting for potential confounders, the RRs (95% CIs) of frailty per 1-SD increase in the AMED, DASH, and AHEI-2010 scores were 0.87 (0.85, 0.90), 0.93 (0.91, 0.95), and 0.90 (0.88, 0.92), respectively. All diet quality scores were associated with lower risk of the individual frailty criteria fatigue, reduced resistance, reduced aerobic capacity, and weight loss. Lower consumption of red and processed meat, a lower sodium intake, a higher ratio of monounsaturated to saturated fat, vegetables, and moderate alcohol intake were components of the diet quality scores independently associated with lower risk of frailty.

Conclusions: Adherence to a healthy diet, as defined by the AMED, DASH, and AHEI-2010 scores, was associated with reduced risk of frailty in older women. *Am J Clin Nutr* 2020;111:877–883.

Keywords: diet quality, frailty, older adults, Mediterranean diet, DASH diet, Healthy Eating Index, Nurses' Health Study

Introduction

The world's population is rapidly ageing. Life expectancy at age 65 y increased in almost all countries from 1970 to 2016 (1). This has significant implications for health care and social security systems, because population aging is accompanied by an increased number of people with chronic diseases, frailty, and disability (2).

Frailty is a prevalent geriatric syndrome, which affects >10% of people aged >60 y, and is characterized by a progressive decline in physiological systems and functional reserve that leads to a high risk of falls, disability, hospitalization, and death (3, 4). Identification of the determinants of frailty represents useful information added to the well-established causes of chronic

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Supplemental Methods, Supplemental Tables 1–10, and Supplemental Figure 1 are available from the "Supplementary data" link in the online posting of the article and from the same link in the online table of contents at https://academic.oup.com/ajcn/.

Information including the procedures to obtain and access data from the Nurses' Health Studies is described at www.nurseshealthstudy.org/researchers.

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Abbreviations used: AHEI-2010, alternate Healthy Eating Index-2010; AMED, alternate Mediterranean diet; DASH, Dietary Approaches to Stop Hypertension; MET, metabolic equivalent task; NHS, Nurses' Health Study; SF-36, Medical Outcomes Study Short-Form.

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diseases. This is because frailty may, or may not, coexist with multimorbidity (and in some cases may partly result from the synergistic effect of several diseases) but it always entails functional limitation and energy imbalance (4, 5). In fact, there is evidence that the frailty syndrome is associated with a higher risk of adverse health outcomes even after accounting for multimorbidity (4–6). Accordingly, a better understanding of the determinants of frailty is needed to support evidence-based prevention interventions that will ensure older adults live not only longer but also healthier lives.

Research on dietary determinants of frailty is relatively recent. So far, studies have suggested that low protein and micronutrient intake is linked to frailty (7). However, because nutrients or food groups may correlate or even interact with each other and the impact of some individual dietary factors may be too small to be detected, it is of interest to also consider a broader view of diet, focusing on overall diet quality (8, 9). Adherence to a Mediterranean diet pattern has been associated with lower risk of frailty in 4 different studies with small-to-moderate sample sizes in Europe and China (10). By contrast, other dietary patterns have found inconclusive results (11–14). Because diet quality scores are dependent on the sample data, comparison of the results across populations is very difficult. Thus, it is of interest to understand the relation between the Mediterranean diet and frailty in the US population, as well as the impact of other diet quality scores on frailty incidence to be able to formulate appropriate dietary counselling for frailty prevention in the United States. Therefore, we aimed to evaluate the alternate Mediterranean diet (AMED), the Dietary Approaches to Stop Hypertension (DASH) diet, and the alternate Healthy Eating Index-2010 (AHEI-2010) in association with frailty among a very large population of older women from the Nurses' Health Study (NHS).

Methods

Study design and participants

The NHS was established in 1976 with the enrollment of 121,700 female nurses aged 30–55 y at inception (15). Participants completed biennial mailed questionnaires to update information on their medical history, health-related behaviors, and dietary intake. The follow-up rate in the NHS is ∼90%. The Harvard TH Chan School of Public Health and Brigham and Women's Hospital Human Subjects Committee Review Board approved the protocol of the study.

Dietary assessment

An FFQ was included in the biennial questionnaires in 1990, 1994, 1998, 2000, 2006, and 2010. In each questionnaire, participants were asked how often on average during the previous year they had consumed each food (with specification of standard portion sizes). Nutrient intake was estimated by multiplying the consumption of each food by its nutrient content, using the USDA database. Previous validation studies revealed good correlations between nutrients or foods assessed by the FFQs and multiple weeks of food records completed over the preceding year in the NHS (16).

The adherence to 3 diet quality scores, AMED, DASH, and AHEI-2010, was calculated. Details about the components and scoring of the diet quality scores are provided in the **Supplemental Methods** and **Supplemental Table 1**.

Frailty assessment

We used the FRAIL scale (17), which has previously been used in the NHS (18). The FRAIL scale comprises 5 self-reported frailty criteria: fatigue, reduced resistance, reduced aerobic capacity, having several illnesses, and a significant weight loss during the previous year. In 1992, 1996, 2000, 2004, 2008, and 2012 participants completed the Medical Outcomes Study Short-Form (SF-36), a 36-item-questionnaire with 8 health dimensions, including physical and mental components (19). From the SF-36, we assessed the first 3 frailty criteria with the following questions: *1*) for fatigue: "Did you have a lot of energy?," with replies "some of the time" or "none of the time" (in years 1992, 1996, and 2000), and the statement "I could not get going" in an updated version of the SF-36 (in 2004, 2008, and 2012), with responses "moderate amount" or "all of the time"; *2*) for reduced resistance: "In a normal day, is your health a limitation to walk up 1 flight of stairs?," with responses "yes" or "a lot"; and *3*) for reduced aerobic capacity: "In a normal day, is your health a limitation to walk several blocks or several miles?," with responses "yes" or "a lot." In addition, the illnesses criterion was assessed from the question, "In the last 2 years, have you had any of these physician-diagnosed illnesses?" We considered that this criterion was met when participants reported $\geq$5 of the following diseases: cancer, hypertension, type 2 diabetes, angina, myocardial infarction, stroke, congestive heart failure, asthma, chronic obstructive lung disease, arthritis, Parkinson disease, kidney disease, and depression. Finally, the weight loss criterion was defined as a $\geq$5% decrease in weight reported in 2 consecutive follow-up cycles. At the end of each follow-up cycle, incident frailty was defined as having $\geq$3 criteria on the FRAIL scale.

Ascertainment of mortality

Deaths were reported by next of kin or the postal system or ascertained through the National Death Index. Follow-up for mortality was >98% complete (20). We obtained copies of death certificates and medical records to determine the causes of death (classified according to the categories of the International Classification of Diseases, Ninth Revision). Death records were reviewed and coded by physicians.

Medical history, anthropometric data, and lifestyle factors

In the analytic baseline questionnaire (1992), we collected information on age, weight, smoking status, and medication use. This information has been updated on each of the subsequent biennial questionnaires. BMI was calculated as kg/m^2. Leisure-time physical activity was reported as the average time spent per week during the preceding year in specific activities (e.g., walking outdoors, jogging, and bicycling). The time spent in each activity was multiplied by its typical energy expenditure, expressed in metabolic equivalent tasks (METs), and then summed over all activities. Detailed information on the validity and reproducibility of self-reported weight and physical activity has been published elsewhere (21, 22).

Statistical analysis

In this study we included women aged ≥60 y with complete information on the exposure and outcome variables. Women younger than 60 y at baseline in 1992 entered the study when they turned 60 during follow-up. Women with an unreasonably high (>3500 kcal/d) or low (<500 kcal/d) caloric intake were excluded from follow-up, as well as women identified as frail at analytic baseline in 1992, leaving a total population of 71,941 women for analysis (**Supplemental Figure 1**). The relation between habitual diet and frailty occurrence was examined up to 2014.

Participants were classified into 4 groups according to quartiles of each diet quality score (AMED, DASH, and AHEI-2010). We used Cox proportional hazards models to calculate RRs, approximated by HRs, and 95% CIs for the association between each diet quality score and frailty, adjusting for potential confounders updated at each 4-y time period. Person-years were calculated from baseline until the occurrence of frailty, death, or the end of the study period (1 June 2014), whichever came first. Multivariable models were adjusted for age (1-y increment), BMI (<25.0, 25.0–29.9, ≥30.0), smoking status (never, past, and current 1–14, 15–24, and ≥25 cigarettes/d), and energy intake (kcal/d; quintiles). We added medication use, including postmenopausal hormone replacement therapy, aspirin, diuretics, β-blockers, calcium channel blockers, angiotensin-converting enzyme inhibitors, other antihypertensive medication, statins and other cholesterol-lowering drugs, insulin, and oral hypoglycemic medication (yes or no), in a separate model to address the fact that persons with risk factors for chronic disease are possibly at greater risk of developing frailty, although some over-adjustment might exist. Also leisure-time physical activity (MET-h/wk; quintiles) was included in a separate model because this variable is strongly related to the outcome. To test for a linear dose–response relation and for better comparability between the diet quality scores, we considered each diet quality score as a continuous variable and calculated the risk of frailty associated with a 1-SD increase in the AMED (SD: 2), DASH (SD: 4), and AHEI-2010 (SD: 10) scores.

The sample for the main analyses included all participants with <3 frailty criteria at baseline (nonfrail participants). We also replicated these analyses among those with none of the criteria at baseline (robust participants) to understand whether the effect of the diet patterns on frailty may differ depending on the baseline status. We performed additional analyses assessing the associations between the diet quality scores and each criterion of the FRAIL scale. Moreover, we examined the association of each component of the diet quality indexes with the risk of frailty by using multivariable models that were also adjusted for each of the other food components of the scores. Analyses were repeated excluding the alcohol component from the AMED and AHEI-2010 scores. To assess bias caused by the possibility that women with early signs of frailty may have changed their diet, 6-, 10-, and 14-y lagged analyses were conducted. Finally, a sensitivity analysis was performed excluding women with diabetes, cardiovascular disease, or cancer at baseline or those who developed these diseases during the follow-up to assess the independence of this association from the main chronic diseases. Analyses were performed with SAS software, version 9.4 (SAS Institute Inc.). This article follows the STROBE recommendations (23).

Results

Table 1 presents the age-standardized baseline characteristics of the population by quartiles of the AMED, DASH, and AHEI-2010 scores. Women with a greater adherence to any of the 3 diet quality scores, indicating better diet quality, had a lower BMI, were less likely to be current smokers, and were more physically active. Total energy intake increased over the quartiles of the AMED and DASH scores, whereas it remained relatively stable across the quartiles of the AHEI-2010. The use of medication was relatively similar across categories of the 3 diet quality scores although the intakes of postmenopausal hormone replacement therapy and statins were higher among women with a greater adherence to each diet pattern.

During >22 y of follow-up we identified 11,564 incident frailty cases (**Table 2**). Higher adherence to the AMED was associated with a lower risk of incident frailty after adjustment for lifestyle factors and medication use (RR Q4 compared with Q1: 0.55; 95% CI: 0.52, 0.58; *P*-trend < 0.001). Additional adjustment for physical activity somewhat attenuated the association (RR Q4 compared with Q1: 0.78; 95% CI: 0.74, 0.83; *P*-trend < 0.001). A higher adherence to the DASH and AHEI-2010 diets also showed a substantially lower risk of frailty in the fully adjusted models (DASH: RR Q4 compared with Q1: 0.82; 95% CI: 0.78, 0.87; *P*-trend < 0.001; AHEI-2010: RR Q4 compared with Q1: 0.77; 95% CI: 0.73, 0.82; *P*-trend < 0.001). The continuous analysis per 1-SD increase in the diet quality scores showed comparable results across the 3 diet quality scores. The risk of frailty decreased by 13% (95% CI: 10%, 15%), 7% (95% CI: 5%, 9%), and 10% (95% CI: 8%, 12%) per 1-SD increase in the AMED, DASH, and AHEI-2010 scores in the full multivariable models, respectively. After repeating the analyses among the robust individuals, the corresponding figures were 11% (95% CI: 8%, 14%), 6% (95% CI: 4%, 9%), and 8% (95% CI: 6%, 11%) (**Supplemental Table 2**).

Table 3 shows the associations between the diet quality scores and each frailty criterion. All 3 diet quality scores were associated with a lower risk of the individual frailty criteria fatigue, reduced resistance, reduced aerobic capacity, and weight loss. The association between the AMED and DASH and having several illnesses was borderline significant and attenuated to nonsignificance after also adjusting for physical activity. Additional analyses showed that several individual components of the diet quality scores were significantly associated with frailty, including lower consumption of red and processed meat (AMED, DASH), lower sodium intake (DASH, AHEI-2010), higher ratio of monounsaturated to saturated fat (AMED), vegetables (DASH and AHEI-2010), and moderate alcohol intake (AMED, AHEI-2010) (**Supplemental Tables 3–5**). Analyses excluding the alcohol component from the AMED and AHEI-2010 scores, as well as 6-, 10-, and 14-y lagged analyses,

TABLE 1 Age-standardized baseline characteristics according to quartiles of the diet quality scores among women aged ≥60 y in the Nurses' Health Study[1]

	AMED				DASH				AHEI-2010			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Diet quality score, range	0–2	3–4	5	6–9	8–21	22–25	26–28	29–38	16–47	47–54	54–62	62–95
Diet quality score	2.09 ± 0.72	3.68 ± 0.43	4.95 ± 0.28	6.46 ± 0.71	18.9 ± 2.1	23.3 ± 1.0	26.2 ± 1.0	29.9 ± 1.9	41.9 ± 4.7	51.1 ± 2.0	57.7 ± 2.0	67.3 ± 5.0
Participants, *n*	17,155	21,012	15,944	17,830	20,035	20,280	16,563	15,063	19,313	18,157	17,620	16,851
Age, y	62.3 ± 2.1	62.8 ± 2.4	62.5 ± 2.2	62.7 ± 2.3	62.3 ± 2.1	62.7 ± 2.3	62.6 ± 2.3	62.8 ± 2.4	62.5 ± 2.2	62.6 ± 2.2	62.6 ± 2.3	62.7 ± 2.3
BMI, kg/m^2	27.2 ± 5.5	26.7 ± 5.2	26.5 ± 5.1	25.9 ± 4.8	27.0 ± 5.5	26.8 ± 5.2	26.5 ± 5.0	25.8 ± 4.8	27.2 ± 5.6	26.7 ± 5.2	26.5 ± 5.0	25.8 ± 4.7
Current smoker, %	16	11	9	6	18	10	7	5	15	12	9	6
Energy intake, kcal/d	1508 ± 463	1666 ± 480	1823 ± 439	2001 ± 494	1667 ± 516	1708 ± 515	1791 ± 511	1863 ± 493	1795 ± 508	1744 ± 519	1729 ± 520	1722 ± 508
Leisure-time physical activity, MET-h/wk	14.4 ± 19.2	18.0 ± 22.0	21.2 ± 23.8	26.3 ± 27.4	14.5 ± 19.3	18.4 ± 21.5	21.7 ± 24.5	27.2 ± 28.3	15.0 ± 19.9	18.1 ± 22.0	21.2 ± 23.7	26.1 ± 27.5
Medication use[2]												
Aspirin, %	47	49	50	51	48	50	51	50	49	50	51	49
Postmenopausal hormone replacement therapy, %	32	34	36	38	30	35	37	39	31	34	36	39
Diuretics, %	11	11	11	11	11	12	11	11	12	12	11	10
β-Blockers, %	14	15	14	14	15	14	14	13	16	15	14	12
Calcium channel blockers, %	10	11	10	10	10	11	11	10	11	11	10	10
Other blood pressure medication, %	9	9	8	8	9	9	9	8	10	9	9	7
ACE inhibitors, %	10	10	10	10	10	10	10	10	10	10	10	9
Statins, %	18	18	19	19	19	19	19	18	18	19	19	18
Other cholesterol-lowering drugs, %	4	4	4	4	4	4	4	4	4	4	4	4
Insulin, %	2	2	2	1	1	2	2	2	2	2	2	2
Oral hypoglycemic drugs, %	4	3	3	2	3	3	3	3	4	3	3	2
Number of frailty criteria,[3] %												
0	69	74	75	79	69	74	76	79	69	73	76	79
1	25	22	21	17	24	22	20	17	24	22	20	17
2	6	5	4	4	6	5	4	4	6	5	4	4

[1] $n = 71{,}941$. Values are means ± SDs unless otherwise indicated. Data, except age, were directly standardized to the age distribution of the entire cohort. ACE, angiotensin-converting enzyme; AHEI-2010, alternate Healthy Eating Index-2010; AMED, alternate Mediterranean diet; DASH, Dietary Approaches to Stop Hypertension; MET, metabolic equivalent task.

[2] One or more times per week.

[3] Frailty criteria are fatigue, reduced resistance, reduced aerobic capacity, having several illnesses, and a significant weight loss during the previous year.

TABLE 2 RRs (95% CIs) of frailty according to quartiles of the diet quality scores among women aged ≥60 y in the Nurses' Health Study[1]

	Q1	Q2	Q3	Q4	*P*-trend	RR (95% CI) for 1-SD increase in the diet score[2]
AMED						
Participants, *n*	17,155	21,012	15,944	17,830		
Person-years	249,646	270,205	252,124	268,950		
Frailty cases	3592	3217	2654	2101		
Age-adjusted	Reference	0.85 (0.81, 0.89)	0.70 (0.67, 0.74)	0.54 (0.51, 0.57)	<0.001	0.73 (0.71, 0.75)
Multivariable model[3]	Reference	0.86 (0.82, 0.90)	0.72 (0.68, 0.76)	0.57 (0.53, 0.60)	<0.001	0.74 (0.72, 0.76)
Multivariable model[4]	Reference	0.84 (0.80, 0.88)	0.70 (0.67, 0.74)	0.55 (0.52, 0.58)	<0.001	0.73 (0.71, 0.75)
Multivariable model[5]	Reference	0.95 (0.90, 0.99)	0.87 (0.82, 0.91)	0.78 (0.74, 0.83)	<0.001	0.87 (0.85, 0.90)
DASH						
Participants, *n*	20,035	20,280	16,563	15,063		
Person-years	252,256	273,788	255,118	259,762		
Frailty cases	3270	3068	2818	2408		
Age-adjusted	Reference	0.81 (0.77, 0.85)	0.72 (0.69, 0.76)	0.56 (0.53, 0.59)	<0.001	0.80 (0.78, 0.81)
Multivariable model[3]	Reference	0.83 (0.79, 0.87)	0.76 (0.72, 0.79)	0.61 (0.58, 0.64)	<0.001	0.83 (0.81, 0.84)
Multivariable model[4]	Reference	0.81 (0.77, 0.85)	0.73 (0.70, 0.77)	0.59 (0.56, 0.63)	<0.001	0.82 (0.80, 0.83)
Multivariable model[5]	Reference	0.92 (0.87, 0.96)	0.91 (0.86, 0.96)	0.82 (0.78, 0.87)	<0.001	0.93 (0.91, 0.95)
AHEI-2010						
Participants, *n*	19,313	18,157	17,620	16,851		
Person-years	257,835	259,748	260,855	262,486		
Frailty cases	3641	3114	2727	2082		
Age-adjusted	Reference	0.82 (0.78, 0.85)	0.71 (0.67, 0.74)	0.53 (0.50, 0.55)	<0.001	0.77 (0.76, 0.79)
Multivariable model[3]	Reference	0.82 (0.78, 0.86)	0.72 (0.69, 0.76)	0.57 (0.53, 0.60)	<0.001	0.79 (0.77, 0.81)
Multivariable model[4]	Reference	0.82 (0.78, 0.86)	0.72 (0.68, 0.76)	0.57 (0.53, 0.60)	<0.001	0.79 (0.77, 0.81)
Multivariable model[5]	Reference	0.91 (0.86, 0.95)	0.87 (0.82, 0.91)	0.77 (0.73, 0.82)	<0.001	0.90 (0.88, 0.92)

[1]AHEI-2010, alternate Healthy Eating Index-2010; AMED, alternate Mediterranean diet; DASH, Dietary Approaches to Stop Hypertension.

[2]SDs of the diet scores: AMED score SD was 2, DASH score SD was 4, AHEI-2010 score SD was 10.

[3]Adjusted for age (1-y increment), BMI (<25.0, 25.0–29.9, ≥30.0 kg/m^2), smoking status (never, past, and current 1–14, 15–24, and ≥25 cigarettes/d), and energy intake (kcal/d; quintiles). The DASH score is also adjusted for alcohol intake (0, 1.0–4.9, 5.0–14.9, ≥15.0 g/d).

[4]Also adjusted for medication use (aspirin, postmenopausal hormone replacement therapy, diuretics, β-blockers, calcium channel blockers, angiotensin-converting enzyme inhibitors, other blood pressure medication, statins and other cholesterol-lowering drugs, insulin, oral hypoglycemic medication).

[5]Also adjusted for leisure-time physical activity (MET-h/wk; quintiles).

were consistent in showing an inverse association between the diet patterns and frailty risk (**Supplemental Tables 6–9**). Finally, in analyses only among women without the main chronic diseases, the inverse association between diet and frailty risk remained significant for the 3 diet quality scores (**Supplemental Table 10**).

Discussion

In this study, we found that the AMED, DASH, and AHEI-2010 scores were inversely associated with the risk of frailty, as well as with 4 out of 5 individual criteria of the FRAIL scale (fatigue, reduced resistance, reduced aerobic capacity, and unintentional weight loss). Specifically, a 1-SD increase in adherence to any of these healthy diet quality scores was associated with a 7–13% reduced risk of frailty. Lower consumption of red and processed meat, lower sodium intake, higher ratio of monounsaturated to saturated fat, vegetables, and moderate alcohol intake were important components of the diet quality scores that might partly drive the observed associations, although overall healthy diets had a stronger impact on frailty than any of their individual food or nutrient components.

Frailty is a geriatric syndrome which places individuals at increased vulnerability to adverse health outcomes. Owing to the lack of a universal operational definition of frailty, there are different approaches to identifying it. Among the most frequently used approaches are the Fried scale and the FRAIL scale (5, 17). An important difference is that the Fried scale is based on performance-based measures (grip strength, gait speed) as well as self-reported components (fatigue, physical activity, and

TABLE 3 RRs (95% CIs) of each frailty criterion for a 1-SD increase in the diet score among women aged ≥60 y in the Nurses' Health Study[1]

	AMED	DASH	AHEI-2010
Fatigue, 30,761 cases			
Age-adjusted	0.89 (0.88, 0.90)	0.90 (0.89, 0.91)	0.89 (0.88, 0.90)
Multivariable model[2]	0.89 (0.88, 0.91)	0.91 (0.90, 0.92)	0.90 (0.89, 0.91)
Multivariable model[3]	0.89 (0.87, 0.90)	0.91 (0.90, 0.92)	0.91 (0.89, 0.92)
Multivariable model[4]	0.94 (0.93, 0.96)	0.95 (0.94, 0.96)	0.95 (0.94, 0.96)
Reduced resistance, 10,955 cases			
Age-adjusted	0.78 (0.76, 0.80)	0.86 (0.84, 0.87)	0.86 (0.84, 0.87)
Multivariable model[2]	0.81 (0.79, 0.84)	0.89 (0.88, 0.91)	0.88 (0.86, 0.90)
Multivariable model[3]	0.81 (0.78, 0.83)	0.89 (0.87, 0.90)	0.88 (0.86, 0.90)
Multivariable model[4]	0.93 (0.90, 0.95)	0.98 (0.96, 1.00)	0.98 (0.96, 1.00)
Reduced aerobic capacity, 22,875 cases			
Age-adjusted	0.80 (0.79, 0.81)	0.85 (0.84, 0.86)	0.83 (0.82, 0.85)
Multivariable model[2]	0.83 (0.81, 0.84)	0.88 (0.87, 0.89)	0.86 (0.85, 0.87)
Multivariable model[3]	0.82 (0.81, 0.84)	0.88 (0.86, 0.89)	0.86 (0.85, 0.87)
Multivariable model[4]	0.93 (0.91, 0.94)	0.96 (0.95, 0.97)	0.94 (0.93, 0.96)
≥5 illnesses, 4420 cases			
Age-adjusted	0.96 (0.93, 1.00)	0.95 (0.92, 0.98)	0.88 (0.85, 0.90)
Multivariable model[2]	0.98 (0.94, 1.02)	0.98 (0.95, 1.01)	0.90 (0.87, 0.93)
Multivariable model[3]	0.95 (0.92, 1.00)	0.96 (0.93, 0.99)	0.90 (0.87, 0.93)
Multivariable model[4]	1.01 (0.97, 1.05)	1.00 (0.97, 1.03)	0.93 (0.90, 0.97)
Weight loss, 25,277 cases			
Age-adjusted	0.92 (0.90, 0.93)	0.94 (0.93, 0.95)	0.93 (0.92, 0.94)
Multivariable model[2]	0.89 (0.87, 0.90)	0.93 (0.91, 0.94)	0.92 (0.90, 0.93)
Multivariable model[3]	0.89 (0.88, 0.91)	0.93 (0.92, 0.94)	0.92 (0.91, 0.93)
Multivariable model[4]	0.92 (0.90, 0.93)	0.95 (0.94, 0.96)	0.94 (0.93, 0.95)

[1] $n = 71{,}941$. SDs of the diet scores: AMED score SD was 2, DASH score SD was 4, AHEI-2010 score SD was 10. AHEI-2010, alternate Healthy Eating Index-2010; AMED, alternate Mediterranean diet; DASH, Dietary Approaches to Stop Hypertension.

[2] Adjusted for age (1-y increment), BMI (<25.0, 25.0–29.9, ≥30.0 kg/m^2), smoking status (never, past, and current 1–14, 15–24, and ≥25 cigarettes/d), and energy intake (kcal/d; quintiles). The DASH score is also adjusted for alcohol intake (0, 1.0–4.9, 5.0–14.9, ≥15.0 g/d).

[3] Also adjusted for medication use (aspirin, postmenopausal hormone replacement therapy, diuretics, β-blockers, calcium channel blockers, angiotensin-converting enzyme inhibitors, other blood pressure medication, statins and other cholesterol-lowering drugs, insulin, oral hypoglycemic medication).

[4] Also adjusted for leisure-time physical activity (MET-h/wk; quintiles).

weight loss), whereas all criteria in the FRAIL scale are self-reported. Despite the absence of performance-based measures in the FRAIL scale, the Fried scale and the FRAIL scale are well correlated ($r = 0.617$, $P < 0.001$) (24). Moreover, self-reported items produce higher estimates of frailty than performance-based measures do (25).

This is the first study to our knowledge to investigate the association of different diet quality scores, based on food consumption guidelines, and risk of frailty in a large US population. The results are in line with a recent meta-analysis of 4 studies, conducted in France, Spain, Italy, and China, which concluded that greater adherence to a Mediterranean diet was associated with a lower risk of frailty (10). Other diet quality scores investigated in association with frailty are the Dutch Healthy Diet-Index and the Dietary Quality Index-Revised, which also showed a protective association with frailty incidence (11, 26). These diet quality scores share a high intake of fruits, vegetables, and whole grains.

The results from studies using a posteriori dietary patterns (derived from collected data using statistical methods) were more inconclusive, in part because the main component foods differed substantially between patterns. In a study of middle- and older-aged individuals in the Netherlands, the Rotterdam study, adherence to an a posteriori "traditional" pattern high in legumes, eggs, and savory snacks was associated with lower risk of a frailty status over time (11). Also in a Spanish cohort, the Seniors-ENRICA, an a posteriori "prudent" pattern, characterized by high intakes of olive oil, vegetables, potatoes, legumes, blue fish, pasta, and meat, showed a significant inverse association with the risk of frailty (12). Finally, in the Three-City Bordeaux study, compared with participants in the "healthy" pattern, characterized by higher consumption of fish in men and fruits and vegetables in women, those in the "unhealthy" patterns had higher risk of frailty over the 12-y follow-up (13). On the other hand, in the Hong Kong study, no statistically significant association was found between any of the 3 dietary patterns derived, including a "vegetables and fruits" diet, and risk of frailty (14).

Strengths of this study are the large sample size and the use of updated information on dietary factors and covariates over >22 y of follow-up. However, several limitations need to be acknowledged. First, only 1 definition of frailty was used. Our results should be confirmed in studies using other definitions such as the Fried scale (5) or the Rockwood index (2). Second, because dietary information was self-reported, measurement error and misclassification could occur. However, the FFQ used here has been extensively validated against diet records and biomarkers, showing good correlations (16). Third, although we were able to adjust for many potential confounders, residual and unmeasured confounding cannot be completely ruled out. Fourth, reverse causation might also contribute to our results, although it is unlikely to completely explain them because the study associations held in lagged analyses and among robust individuals at baseline. Finally, given that the study was conducted among female health professionals that were predominantly Caucasian with good access to health care, extrapolation of results to the general population should be made with caution.

In conclusion, adherence to a healthy diet, as defined by the AMED, DASH, and AHEI-2010 scores, was associated with reduced risk of frailty. Our findings extend the well-known benefits of healthy diets to include the retardation of functional decline, and suggest that old adults adhering to such diets can prevent frailty and its subsequent adverse health outcomes.

The authors' responsibilities were as follows—FBH: acquired the data; EAS: drafted the manuscript; EAS and EL-G: contributed statistical expertise; EL-G and FBH: procured the funding and provided administrative, technical, or material support; EL-G: supervised the study; and all authors: conceived and designed the study, analyzed and interpreted the data, critically revised the manuscript for important intellectual content, and read and approved the final manuscript. The authors report no conflicts of interest.

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