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No association between diet quality scores and risk of hip fracture in post-menopausal women and men aged 50 and older

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Abstract

Background—Although a number of studies showed a lower risk of hip fractures with high quality diets, few of them were conducted in the U.S.

Objective—This prospective analysis examined the association between several diet quality indexes and risk of hip fractures in U.S. men and women.

Design—This is a prospective cohort study.

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Authors contributions:
TTF, DF, and WCW designed the study. TTF and DF conducted the analysis, TTF wrote the first draft of the manuscript with from DF. All authors reviewed, commented, and approved subsequent drafts of the manuscript.

None of the authors have conflicts of interests to declare.

Research snapshot
Research question: Does high quality diet reduce the risk of hip fracture in men and women?
Research findings: In these two prospective cohorts of 74,446 post menopausal women and 36,602 men 50 years of age and older with up to 32 years of follow-up, higher Alternate Healthy Eating Index-2010 scores were associated with a lower risk of hip fractures in women.

Participants/setting—The participants were 74,446 post menopausal women from the Nurses' Health Study and 36,602 men 50 years of age and older from the Health Professionals Follow-Up Study in the U.S.

Main outcome measure—Hip fractures were self-reported on biennial questionnaires between 1980–2012 in women, and between 1986–2012 in men.

Statistical analysis—Diet was assessed every 4 years with a validated Food Frequency Questionnaire. Relative risks (RR) were computed for hip fracture by quintiles of the Alternate Mediterranean Diet score (aMed), the Alternate Healthy Eating Index-2010 (AHEI-2010), and the Dietary Approaches to Stop Hypertension (DASH) score using Cox proportional hazards models, adjusting for potential confounders.

Results—2,143 incident hip fractures in women and 603 in men were reported during follow-up. A significant inverse trend was observed with the cumulative AHEI-2010 score in women (RR comparing extreme quintiles=0.87, 95% CI=0.75-1.00, p trend=0.02). There was also a suggestion of an inverse association with the DASH score (p trend=0.03). In addition, significant inverse trends were observed between all three diet quality scores and hip fractures in women under 75 years but not older women. There was no clear association between diet quality indexes and hip fracture in men.

Conclusion—In conclusion, higher AHEI-2010 scores were associated with a lower risk of hip fractures in U.S. women. The inverse associations with diet quality may be more apparent among those younger than 75 years.

Keywords

Diet quality; hip fractures; nutrition; diet

Introduction

Multiple nutritional factors are known to play a role in bone remodeling [1, 2] and have been linked to the development of osteoporosis or fractures. [3] Calcium, vitamin D, and vitamin K are established nutrients in bone remodeling [1]. Recent data suggest protein is associated with lower risk of fractures. [4] On the other hand, sugar sweetened beverages have been associated with fracture risk [5] and coffee consumption might be associated with an increased risk in women but not in men. [6]

Previous studies have used diet quality indexes to examine whether overall healthfulness of the diet is associated with bone mineral density (BMD) or fractures. Among these indexes, the Mediterranean diet was used most frequently. Studies generally found a higher score, which reflects a closer resemblance to the Mediterranean diet, was associated with a lower risk of hip fractures [7–11]. The Alternate Healthy Eating Index was also associated with a lower risk of hip fracture but in fewer number of studies [10, 12]. Because of the differences in the types of food that are prevalent around the world and the inherent structure of the various diet quality indexes, the same score could result from diets with substantial differences in specific food choices and quantity consumed. In addition, few studies on diet quality indexes were conducted in the U.S. [11] or separately examined the association in men [7, 8, 12].

Therefore, this analysis aimed to prospectively examine the association between several diet quality indexes and risk of hip fracture in U.S. men and women.

Methods

Participants

Women in this analysis were participants of the U.S. Nurses' Health Study (NHS). This ongoing cohort began in 1976 with 121,700 nurses aged 30–55 y in 11 states [13]. Participants self-reported lifestyle and disease information through a questionnaire every 2 years. In addition, a food-frequency questionnaire (FFQ) was sent in 1980, 1984, 1986, and every 4 y thereafter to collect dietary information. Men in this analysis were participants of the U.S. Health Professionals Follow-up Study (HPFS), an ongoing cohort similar to the NHS. HPFS began in 1986 with 51,529 male U.S. health professionals aged 40–75 [14]. Lifestyle, health, and dietary information were collected through self-administered questionnaires similar to the NHS. In each questionnaire cycle for each cohort, at least 90% of the participants were successfully tracked.

In this analysis, only white men and women were included because of the small number of non-white participants and different rates of fractures in some minority groups. For women, follow-up began in 1980 if they were already postmenopausal in 1980. Otherwise, they entered into follow-up when they reported reaching menopause, including surgical menopause, on a subsequent questionnaire. For men, follow-up began in 1986 if they were at least 50 years old, otherwise, they entered into follow-up when they reached age 50 at each questionnaire cycle. In addition, individuals without a recent dietary assessment or who had previously reported a hip fracture or a diagnosis of cancer or osteoporosis at entry to follow-up were excluded. Participants with cancer at entry to follow-up were excluded because cancer patients may receive medications that adversely affect bone mineral density. Individuals with diagnosed osteoporosis are at high risk of fractures and may have changed their diet, therefore these participants are also excluded from the analysis. In total, this analysis included 74,446 women and 36,602 men. This study was approved by the Institutional Review Boards of the Brigham and Women's Hospital and the Harvard TH Chan School of Public Health, Boston MA. Participants in both cohorts indicated implied consent by completing and returning study questionnaires.

Dietary assessment and computation of diet quality scores

In NHS, a total of 9 FFQs[15] were administered between 1980 and 2010 [16]. In HPFS, a similar FFQ was administered 7 times between 1986 and 2010 [14, 17]. Both FFQs were validated and designed to assess intake in the past 12 months [14, 18]. The average correlation coefficient between foods assessed on the FFQ and multiple weeks of weighed food records was 0.57 and ranged from 0.23 for fruit punch and 0.93 for beer [18]. Each FFQ contained approximately 135 items except for the 1980 FFQ which contained 61 items. Standard portion size was provided for each item and nine frequency choices, ranging from <1 time/month to ≥6 times/day were available. Diet quality scores were computed for each participant for each time the FFQ was administered.

The Alternate Healthy Eating Index-2010 (AHEI-2010) consists of 11 food and nutrient components and was previously associated with a lower risk of chronic diseases [19]. It awards points for: higher intakes of vegetables, whole fruits, nuts and legumes, whole grains, polyunsaturated fat, and long chain n-3 fatty acids; for lower intakes of red and processed meats, sugar sweetened beverages and fruit juice, trans fat, and sodium; and for moderate intake of alcohol. Each component ranges from 0 to 10 points with the total possible score ranging from zero to 110 points.

The Alternate Mediterranean Diet Score (aMed) was modified from a version by Trichopoulou et al [20]. It contains 9 components and 1 point is awarded for consumption above the sex-specific median of vegetables, fruits, whole grains, nuts, legumes, fish, monounsaturated-to-saturated fat ratio; and for consumption below the sex-specific median of red and processed meat [21]. Otherwise, the participant receives 0 point for those components. For the alcohol component, 1 point is awarded to women who consume 5–15g/d and men 10–25g/d and zero points for consumption outside these ranges. The aMed has a possible range of 0–9 points.

The DASH score was developed to measure conformance to dietary characteristics emphasized in the Dietary Approaches to Stop Hypertension trial [22]. The score contains 8 components which are ranked into quintiles based on sex-specific intake levels. Quintile rankings are used as points for fruits, vegetables, nuts and legumes, whole grains, and low-fat dairy products. Reverse scoring for the quintile ranks are used for red and processed meats, sodium, and sugar sweetened beverages. Possible score ranges from 8 to 40 points.

Assessment of hip fractures

Hip fractures, including information on month and year of occurrence, were self-reported by participants on biennial questionnaires. Participants also reported the circumstances of fracture occurrence which was used for categorizing the level of trauma. Fractures caused by high impact trauma such as motor vehicle accidents, horseback riding, skiing, and other similar events were excluded as they are likely unavoidable even in individuals with high bone mineral density. It is likely that self-reporting of hip fractures was highly accurate, as all participants were health professionals. In a validation study in the NHS, medical record review confirmed each reported fracture in all 30 sampled cases. [13] Hip fractures were also identified from death records in both cohorts.

Assessment of other lifestyle characteristics

Participants self-reported height at baseline which was used to calculate updated BMI with weight reported at each biennial questionnaire. Smoking, use of thiazide diuretics, lasix, and anti-inflammatory steroids (yes or no), use of brand-specific multivitamins (yes or no), use of calcium, vitamin D, and retinol supplements (no or daily amount), diagnosis of osteoporosis and diabetes (yes or no), and in women, postmenopausal hormone use were also assessed every 2 years. Leisure-time physical activity was assessed with 10 activities and reported as hours per week and were assigned a metabolic equivalent score [23]. These scores were then summed over all activities to create a value in metabolic equivalent task hours per week.

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Statistical analysis

For women, the earliest FFQ used was from 1980 for those who already reached menopause at that time. However, for analysis of the AHEI-2010, the earliest follow-up began in 1984 as that was when the FFQ contained sufficient details for its computation. In men, the earliest FFQ used was from 1986 for those who were at least age 50 at the time. For this analysis, participants were censored on the date of hip fracture, death from hip fracture, last questionnaire response, or in 2012 (June 1 for women and January 1 for men). Follow-up time at each 2-year cycle was excluded if participants have missing data for the two most recent FFQs.

Cumulative averages were computed for each diet quality score from each FFQ cycle to reduce within-person variation and represent long-term intake. [24] For example, if a participant entered into follow-up in 1994, the score in 1998 was calculated as the mean of 1994 and 1998. Cohort participants were ranked according to their cumulative average diet scores and were then classified into five groups in 20% increment (quintiles). The lowest quintile was designated as the reference group. A sensitivity analysis was also conducted using specific cut points to assign categories for each diet quality score. The association between each diet quality score and risk of hip fracture was examined using Cox proportional hazard models. Proportional hazards assumption was tested by fitting a model with an interaction term between calendar time and a diet score. This was repeated for each diet score for each cohort. There was no evidence of violation of the proportional hazards assumption. Trend tests were conducted by modeling the diet quality scores as continuous variables. Departure from linearity was tested using the likelihood ratio test comparing the linear model with a model that included a cubic spline term [25]. Stratified analyses were also conducted to examine whether the association between diet quality scores and hip fracture differ by age, BMI, and leisure-time physical activity. Test for interaction between these factors and diet quality indexes was conducted using the likelihood ratio test comparing regression models with and without an interaction term. As an alternative to the temporal relation represented by cumulative analysis, recent diet was also examined by using the mean of the two most recent questionnaires as exposure.

Multivariable analysis was adjusted for age (in months), BMI (8 categories), height (continuous), leisure-time physical activity (5 categories), use of thiazides, Lasix or oral anti-inflammatory steroids (yes or no), smoking (10 categories to represent smoking status and number of cigarettes per day), postmenopausal hormone use (women only, never/past/current), history of diabetes (yes/no), caffeine intake (quintiles), multivitamin use (yes/no), and supplemental intakes of calcium, retinol, and vitamin D. Models of the DASH score were also adjusted for alcohol intake (5 categories) as it was not part of the score. In addition, sugar-sweetened beverages (5 categories) was adjusted for in the analysis of aMed, as this score does not contain this component, and it was associated with a higher risk of hip fracture in a previous analysis in NHS. [5] All of these variables were updated at each questionnaire cycle. For categorical variables, missing data were assigned as a separate category. Self-reported diagnosis of osteoporosis after entry to follow-up was not included in regression models as it may have been in the causal pathway. Analysis was conducted using SAS v9.4 (Cary, NC) [26]. Statistical significance was set at $p<0.05$.

Results

In up to 32 years of follow-up, 2143 cases of hip fractures were reported in women and 603 in men. Descriptive statistics showed that individuals with higher diet quality scores tended to be leaner and less likely to be current smokers, but were more physically active and more likely to use vitamin supplements (table 1). Individuals with higher diet quality scores generally consumed more fruits and vegetables and whole grains, and less red and processed meats, refined grains, and sugar sweetened beverages. Diet quality generally improved over follow-up. The AHEI-2010 score increased from a mean of 49.1 (SD=11.0) to 62.2 (SD=12.0) between 1984 and 2010 in women and 53.9 (SD=11.5) to 61.9 (SD=11.8) between 1986 and 2010 in men.

In women, the aMed score was inversely associated with hip fracture after adjusting for age and energy (RR comparing top to bottom quintile=0.81, 95% CI=0.70-0.94, p trend<0.001) (table 2). The association was attenuated after adjusting for leisure-time physical activity and BMI and was no longer evident after adjusting for all other potential confounders. For the AHEI-2010, a significant inverse association was observed after adjusting for age and energy in women (RR comparing top and bottom quintile=0.76, 95% CI=0.67-0.87, p trend<0.001) but was attenuated after adjusting for potential confounders although a significant trend remained (RR comparing extreme quintiles=0.87, 95% CI=0.75-1.00, p trend=0.02). For the DASH score, a significant inverse association was observed after adjusting for age and energy (RR comparing top and bottom quintiles=0.82, 95% CI=0.71-0.95, p trend<0.001) and the inverse linear trend remained significant after adjusting for all potential confounder (p=0.03). In men, none of the diet quality scores were associated with risk of hip fracture. Test for non-linearity for the diet quality scores was not significant except for the DASH score in women (p for non-linearity =0.03).

Potential differential associations of the cumulative average diet scores with hip fracture by age was examined and significant inverse associations was found for all three diet scores among women under 75 years (table 3) but not among older participants. In men the association did not appear to differ by age. Stratified analyses by BMI and leisure-time physical activity did not show clear differences in risk (tables 4 and 5, online only).

When current diet was considered, results for AHEI-2010 for women were comparable with the cumulative analysis but the trend in men reached statistical significance (RR comparing extreme quintiles=0.85, 95% CI=0.65-1.10, p trend=0.03) (table 6, online only). The aMed and DASH score also reached statistical significantly in women (RR comparing extreme quintiles for aMed=0.83, 95% CI=0.72-0.96, p trend=0.002; DASH=0.79, 95% CI=0.69-0.90, p=0.001) but these scores remained not associated with hip fractures in men.

Results of sensitivity analysis on cumulative diet quality scores using specific cut points for categories assignment was not substantially different from results from quintile categories (table 7, online only). For comparison with other studies that used baseline data, an alternate analysis was conducted using only diet and lifestyle data at entry to follow-up, without considering changes in these factors over follow-up. For women, all three baseline scores were also inversely associated with risk of hip fracture (data not shown). However, when the analysis was adjusted with updated lifestyle factors, no significant association was observed in women, indicating baseline analysis can be confounded when lifestyle factors were not updated. No associations were observed using baseline data in men.

Discussion

In these two U.S. cohorts of middle-aged and older men and women, a long term overall healthy diet as reflected by the AHEI-2010 and DASH score were inversely associated with the risk of hip fracture in women after controlling for BMI, leisure-time physical activity and other confounders. Although there was no significant association with men, there was some signs of an inverse association. However, the smaller number of cases did not confer the same level of statistical power as in the analysis among women.

Several studies have shown that higher diet quality scores or healthy eating patterns were associated with lower risk of fracture. [7, 8, 10–12] In particular, some studies[7, 8] showed an inverse association was observed with the Mediterranean diet but this was less clear in this analysis. There are some significant differences between this study and others. The most paramount difference is the accounting for changes in diet and risk factors during follow-up in this study.[7, 8, 10–12] Previous studies that were conducted in European[7, 8] or Asian[10, 12] populations also differed in the specific foods within each food group and the median and quantile cutpoints for component scores could differ considerably. However, intake levels of similar food groups (e.g. vegetables) in these studies did not appear to be dramatically different from the cohorts in this study. The age of the participants in previous studies was mostly comparable to ours[8, 9, 12] except for the study in EPIC cohort which they were younger. [7] BMI among the European studies [7–9] were comparable to ours but was lower in the Asian studies.[10, 12] Data from the U.S. Women’s Health Initiative showed no clear evidence of a lower risk of hip fracture with higher baseline AHEI-2010 and DASH scores although the Mediterranean Diet Score did appear to show an inverse association. [11] In the same group of women, a higher Dietary Inflammatory Index, which reflected an unhealthy diet, also showed no association with fracture risk [27].

The significant inverse association between the diet scores and risk of hip fracture appeared to be stronger among women younger than 75 years. Although bone mineral density declines with age, women experience an accelerated loss during the early post menopausal years while a gradual decline occurs in men [28]. Reducing the loss of bone mineral density earlier could be more effective in preventing fracture than later in the elderly years. Despite similarities between diet quality scores in their emphasis of higher fruits, vegetables, whole grain intake, and less red and processed meats, and refined carbohydrates intake, the inverse association in the younger participants was stronger for the AHEI-2010. This may be due to its wider range of scores, which allowed it to better distinguish healthy vs less healthy diets and therefore detect potential associations. In addition to cumulative diet, these results also showed that current diet may be associated with a lower risk of hip fractures in women. A number of studies have linked better diet quality with higher muscle mass or better physical functioning [29–31], these may affect balance and may change faster than bone strength.

Osteoporosis develops gradually, and with a follow-up of up to 32 years in this analysis there was ample time to detect any association between diet and fracture. In addition, there was a substantial number of incident fractures, even in men, which allowed for distinguishing between high versus low scoring individuals for comparison. Besides having detailed and updated control of potential confounders, the participants in this study had a wide range of intake for each food which provided good contrasts of diet quality to detect a potential association. Diet quality improved in these cohorts during follow-up. The cumulative analysis and the current analysis examined different time points of influence of diet and hip fracture risk. While none of the diet quality scores were designed specifically for prevention of hip fractures, the aim was to examine whether a healthy diet has an influence on hip fracture risk. Even though the most consistent inverse association was observed with the AHEI-2010, it is possible that other food combinations would show an even stronger association with hip fracture risks. Although individuals with higher diet quality scores tended to have lower BMI, they also tended to have higher levels of leisure-time physical activity. In this analysis, physical activity was a stronger confounder than BMI. Theoretically, it is possible that better diet could results in better well being which in turn may allow individuals to be more physically activity. However, this is more likely in low resource areas and these cohorts generally have adequate protein and energy intake. On the other hand, data on hip fracture, lifestyle, and diet were self-reported, but a previous validation study with medical records showed cohort participants were able to accurately report disease incidence [13]. Other validation studies have also shown that the lifestyle and dietary questionnaires used in this study were able to collect reasonably valid information, although some error inevitably exists [13, 14, 16]. Nevertheless, while the FFQ can rank individuals according to levels of intake, it does not represent absolute intake and therefore, the absolute number of points in the diet quality scores cannot directly translate into the amount of each food group needed to reach a particular number of points of a score. To better to represent absolute intake, food data from FFQ requires calibration [32, 33]. Finally, only white participants of NHS and HPFS were included in this study, therefore, this may limit generalizability to other races.

Conclusion

In conclusion, higher AHEI-2010 scores were associated with a lower risk of hip fractures in U.S. women. A suggestion of an inverse association was also observed with the DASH score (p trend=0.03) among women. In addition, the inverse association with hip fractures appeared to be more apparent for all three diet quality scores among women younger than 75 years.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Lifestyle and dietary characteristics (means and sd) of Nurses' Health Study (n=74,446) and Health Professionals Follow-up Study (n=36,602) participants at time of entry[a] to study according to low and high quintiles of diet quality scores.

	Alternate Mediteranean Diet Score[b]		Alternative HealthyEating Index-2010[c]		Dietary Approaches to Stop Hypertension score[d]	
	Q1	**Q5**	**Q1**	**Q5**	**Q1**	**Q5**
			WOMEN			
Age at entry to study (years)	52.6 ± 4.4	53.8 ± 3.9	52.8 ± 4.9	53.7 ± 4.0	52.3 ± 4.5	54.0 ± 3.9
Menopausal hormone use (%)	30.1	32.8	27.8	39.4	31.5	29.2
BMI (kg/m^2)	25.5 ± 5.0	25.1 ± 4.4	25.9 ± 5.2	25.1 ± 4.3	25.7 ± 5.2	24.8 ± 4.3
Leisure-Time Physical activity (MET-hours/wk)	11 ± 13	20 ± 17	11 ± 12	21 ± 18	11 ± 12	21 ± 18
Current smoker (%)	31.3	15.7	27.4	13.4	34.1	15.0
History of diabetes (%)	2.7	3.1	3.1	3.6	2.4	3.3
Anti-inflammatory steroids (%)	1.8	1.4	1.7	1.3	1.8	1.5
Thiazide (%)	12.9	13.7	12.9	14.5	13.9	13.2
Lasix (%)	1.6	1.1	1.6	0.8	1.3	1.2
Multivitamin supplement (%)	32.3	45.8	34.0	48.6	31.2	46.9
aMed score	1.6 ± 0.6	6.6 ± 0.7	2.8 ± 1.4	5.6 ± 1.6	2.3 ± 1.3	5.9 ± 1.3
AHEI-2010 score	42.1 ± 8.8	58.4 ± 9.8	35.8 ± 4.3	66.7 ± 5.4	40.9 ± 8.3	60.1 ± 9.4
DASH score	19.6 ± 3.6	28.3 ± 3.4	19.4 ± 3.9	27.9 ± 3.7	17.0 ± 2.0	30.7 ± 1.7
Energy (kcal/d)	1475 ± 473	1855 ± 514	1879 ± 503	1638 ± 507	1700 ± 511	1665 ± 490
Alcohol (g/d)	6 ± 12	7 ± 8	7 ± 15	6 ± 7	7 ± 12	6 ± 9
Caffeine (mg/d)	361 ± 258	317 ± 245	323 ± 234	270 ± 216	368 ± 257	304 ± 248
Total calcium (mg/d) [e]	832 ± 457	954 ± 429	840 ± 408	1133 ± 546	712 ± 400	1055 ± 438
Supplemental calcium (mg/d)	116 ± 287	193 ± 370	155 ± 313	341 ± 442	128 ± 298	166 ± 354
Total vitamin D (IU/d) [e]	303 ± 255	388 ± 285	280 ± 211	419 ± 303	259 ± 216	427 ± 314
Supplemental vitamin D (IU/d)	104 ± 194	163 ± 263	111 ± 193	186 ± 259	97 ± 185	173 ± 281
Total retinol (IU/d) [e]	4091 ± 4986	5233 ±6213	3519 ± 3594	5526 ± 6470	3381 ± 3984	6106 ± 6973
Supplemental retinol (IU/d)	1650 ± 3862	2900 ± 5949	1645 ± 3411	3187 ± 5770	1435 ± 3437	3280 ± 6326
Fruits (servings/d)	1.4 ± 1.0	3.2 ± 1.6	1.9 ± 1.1	2.7 ± 1.6	1.3 ± 0.9	3.4 ± 1.7

	Alternate Mediteranean Diet Score[b]		Alternative HealthyEating Index-2010[c]		Dietary Approaches to Stop Hypertension score[d]	
	Q1	Q5	Q1	Q5	Q1	Q5
Vegetables (servings/d)	1.4 ± 0.9	3.4 ± 2.0	2.3 ± 1.2	4.1 ± 2.1	1.6 ± 1.1	3.3 ± 2.0
Red meat (servings/d)	0.7 ± 0.4	0.6 ± 0.4	0.8 ±0.4	0.3 ± 0.3	0.8 ± 0.5	0.5 ± 0.3
Processed meat (servings/d)	0.3 ± 0.3	0.2 ± 0.3	0.4 ± 0.4	0.1 ± 0.2	0.5 ± 0.4	0.1 ± 0.2
Poultry (servings/d)	0.2 ± 0.2	0.4 ± 0.3	0.2 ± 0.1	0.4 ± 0.3	0.3 ± 0.2	0.4 ± 0.3
Whole grains (servings/d)	0.5 ± 0.7	1.5 ± 1.1	0.7 ± 0.9	1.4 ± 1.3	0.4 ± 0.6	1.6 ± 1.2
Refined grains (servings/d)	1.5 ± 1.2	1.4 ± 1.2	2.2 ± 1.6	1.4 ± 1.1	1.9 ± 1.4	1.0 ± 1.0
Sugar sweetened beverages (servings/d)	0.8 ± 1.1	0.7 ± 0.9	0.8 ± 1.1	0.7 ± 1.0	1.0 ± 1.2	0.6 ± 0.9
Low fat dairy (servings/d)	0.7 ± 1.0	1.0 ± 0.9	0.9 ± 1.0	1.2 ± 1.0	0.6 ± 0.9	1.2 ± 1.0
MEN						
Age at entry (years)	56.0 ± 6.1	57.7 ± 6.6	56.2 ± 6.2	57.6 ± 6.6	55.5 ± 5.8	58.3 ± 6.7
BMI (kg/m^2)	26.1 ± 3.3	25.1 ± 2.9	26.1 ± 3.4	25.1 ±2.9	26.1 ± 3.3	25.0 ± 3.0
Leisure-Time Physical activity (MET-hours/wk)	19 ± 24	30 ± 29	19 ± 24	30 ± 29	19 ± 24	30 ± 29
Current smoker (%)	13.0	3.6	13.4	3.9	14.1	3.2
History of diabetes (%)	2.1	2.6	2.0	3.1	1.4	3.7
Anti-inflammatory steroids (%)	0.01	0.004	0.005	0.003	0.005	0.005
Thiazide (%)	8.1	8.4	8.2	8.8	7.4	9.3
Lasix (%)	0.6	0.8	0.6	0.6	0.7	0.7
Multivitamin supplement (%)	37.6	51.4	37.8	50.1	36.3	51.3
aMed score	1.5 ±0.6	7.4 ±0.6	2.6 ±1.4	6.1 ± 1.5	2.5 ±1.4	6.2 ±1.3
AHEI-2010 score	42.7 ± 8.9	64.9 ± 9.0	37.7 ±4.7	70.0 ± 5.4	43.4 ±8.8	63.8 ± 9.5
DASH score	18.6 ±3.7	30.0 ±3.9	19.5 ± 4.2	29.2 ± 4.3	16.8 ±2.1	31.5 ±2.3
Energy (kcal/d)	1757 ± 538	2249 ± 602	2119 ± 593	1888 ± 580	1827 ± 571	2158 ± 594
Alcohol (g/d)	12 ± 18	12 ± 11	14 ± 21	10 ± 10	12 ± 16	10 ± 14
Caffeine (mg/d)	267 ± 239	188 ± 201	272 ± 241	194 ± 206	281 ± 239	180 ± 203
Total calcium (mg/d)[e]	892 ± 447	939 ± 406	851 ± 401	984 ± 479	750 ± 364	1083 ±464
Supplemental Calcium (mg/d)	68 ± 210	152 ± 327	66 ± 206	159 ± 339	63 ± 198	158 ± 338
Total vitamin D (IU/d)[e]	360 ± 290	497 ± 328	337 ± 251	506 ± 363	323 ± 276	511 ± 341
Supplemental vitamin D (IU/d)	114 ± 231	195 ± 286	113 ± 210	191 ± 289	108 ± 211	194 ± 289

	Alternate Mediteranean Diet Score[b]		Alternative HealthyEating Index-2010[c]		Dietary Approaches to Stop Hypertension score[d]	
	Q1	**Q5**	**Q1**	**Q5**	**Q1**	**Q5**
Total retinol (IU/d)[e]	4784 ± 5784	6168 ± 6824	3427 ± 4753	6436 ± 7660	4335 ± 5364	6422 ± 7259
Supplemental retinol (IU/d)	2006 ± 4559	4064 ± 6900	1928 ± 4306	3961 ± 6876	1866 ± 4304	4038 ± 7102
Fruits (servings/d)	1.1 ± 0.8	3.2 ± 1.8	1.4 ± 1.0	2.9 ± 1.8	1.0 ± 0.7	3.3 ± 1.9
Vegetables (servings/d)	1.7 ± 0.9	4.3 ± 2.0	2.0 ± 1.1	3.9 ± 2.1	1.8 ± 1.0	4.1 ± 2.1
Red meat (servings/d)	0.8 ± 0.5	0.4 ± 0.4	0.1 ± 0.5	0.3 ± 0.3	0.8 ± 0.5	0.4 ± 0.4
Processed meat (servings/d)	0.4 ± 0.5	0.2 ± 0.3	0.6 ± 0.6	0.1 ± 0.2	0.5 ± 0.5	0.2 ± 0.3
Poultry (servings/d)	0.3 ± 0.2	0.5 ± 0.3	0.3 ± 0.2	0.4 ± 0.3	0.3 ± 0.2	0.4 ± 0.3
Whole grains (servings/d)	0.7 ± 0.8	2.4 ± 1.7	1.1 ± 1.1	2.1 ± 1.8	0.7 ± 0.8	2.5 ±1.7
Refined grains (servings/d)	1.6 ± 1.3	1.7 ± 1.2	2.0 ± 1.5	1.3 ± 1.1	1.7 ± 1.4	1.5 ± 1.2
Sugar sweetened beverages (servings/d)	0.4 ± 0.6	0.2 ± 0.4	0.5 ± 0.8	0.1 ± 0.3	0.5 ± 0.7	0.1 ±0.3
Low fat dairy (servings/d)	0.8 ± 1.1	1.0 ± 1.0	0.9 ± 1.1	0.9 ± 0.9	0.5 ± 0.7	1.4 ± 1.2

[a] menopause for women, age 50 or older for men

[b] The components of the Alternate Mediterranean Diet Score are (possible range 0–9 points): high intakes of vegetables, fruits, whole grains, nuts, legumes, fish, monounsaturated-to-saturated fat ratio, low intake of red and processed meats, moderate alcohol consumption.

[c] The components of the Alternate Healthy Eating Index-2010 (possible range 0–110 points) awards points for: higher intakes of vegetables, whole fruits, nuts and legumes, whole grains, polyunsaturated fat, and long chain n-3 fatty acids; for lower intakes of red and processed meats, sugar sweetened beverages and fruit juice, trans fat, and sodium; and for moderate intake of alcohol

[d] The Dietary Approaches awards points for (possible range 8–40 points) higher intakes of fruits, vegetables, nuts and legumes, whole grains, and low-fat dairy products, low intake of red and processed meats, sodium, sugar sweetened beverages.

[e] energy adjusted

Table 2

Relative risks (95% CI) for hip fractures according quintiles of cumulative dietary quality scores in the Nurses' Health Study (n=74,446, postmenopausal) and Health Professionals Follow-up Study (n=36,602, age 50+) participants

	Q1	Q2	Q3	Q4	Q5	P trend
Alternate Mediterranean Diet Score [a]						
WOMEN						
Median index score	2.0	3.3	4.1	5.0	6.2	
No. of cases	402	484	455	414	388	
Age and energy adjusted	1	1.01 (0.88, 1.15)	0.90 (0.78, 1.03)	0.80 (0.69, 0.91)	0.81 (0.70, 0.94)	<0.001
Age, energy, physical activity adjusted	1	1.05 (0.92, 1.20)	0.97 (0.85, 1.12)	0.89 (0.77, 1.03)	0.94 (0.81, 1.10)	0.03
Above + BMI	1	1.06 (0.92, 1.21)	0.98 (0.86, 1.13)	0.89 (0.77, 1.03)	0.92 (0.79, 1.07)	0.01
Multivariable adjusted [b]	1	1.06 (0.93, 1.22)	1.01 (0.87, 1.16)	0.92 (0.79, 1.07)	0.96 (0.81, 1.12)	0.08
MEN						
Median index score	2.0	3.3	4.3	5.3	6.7	
No. of cases	100	120	132	128	123	
Age and energy adjusted	1	1.00 (0.76, 1.31)	0.97 (0.74, 1.27)	0.87 (0.66, 1.15)	0.92 (0.69, 1.21)	0.34
Age, energy, physical activity adjusted	1	1.02 (0.78, 1.25)	1.02 (0.77, 1.33)	0.93 (0.70, 1.23)	0.93 (0.70, 1.23)	0.78
Above + BMI	1	1.02 (0.77, 1.34)	1.00 (0.76, 1.31)	0.91 (0.69, 1.21)	0.94 (0.70, 1.26)	0.50
Multivariable adjusted [b]	1	1.04 (0.78, 1.36)	1.01 (0.76, 1.33)	0.92 (0.69, 1.22)	0.92 (0.69, 1.22)	0.56
Alternate Healthy Eating Index-2010 [c]						
WOMEN						
Median index score	40.3	47.7	53.0	58.4	66.2	
No. of cases	423	406	390	323	316	
Age and energy adjusted	1	0.94 (0.83, 1.06)	0.91 (0.80, 1.03)	0.81 (0.71, 0.92)	0.76 (0.67, 0.87)	<0.001
Age, energy, physical activity adjusted	1	0.98 (0.87, 1.11)	0.97 (0.86, 1.00)	0.90 (0.79, 1.02)	0.87 (0.76, 1.00)	0.02
Above + BMI	1	1.00 (0.88, 1.14)	1.00 (0.88, 1.13)	0.91 (0.80, 1.04)	0.85 (0.74, 0.98)	0.01
Multivariable adjusted [b]	1	1.00 (0.88, 1.14)	1.01 (0.89, 1.14)	0.93 (0.81, 1.06)	0.87 (0.75, 1.00)	0.02
MEN						
Median index score	40.9	48.8	54.5	60.4	68.5	
No. of cases	106	115	126	120	136	
Age and energy adjusted	1	0.86 (0.66, 1.13)	0.90 (0.69, 1.18)	0.79 (0.60, 1.04)	0.86 (0.66, 1.12)	0.22

	Q1	Q2	Q3	Q4	Q5	P trend
Age, energy, physical activity adjusted	1	0.88 (0.67, 1.16)	0.94 (0.72, 1.23)	0.84 (0.64, 0.10)	0.93 (0.71, 1.22)	0.58
Above + BMI	1	0.89 (0.68, 1.17)	0.94 (0.71, 1.23)	0.83 (0.63, 1.10)	0.89 (0.68, 1.17)	0.35
Multivariable adjusted [b]	1	0.88 (0.67, 1.16)	0.93 (0.71, 1.22)	0.83 (0.63, 1.09)	0.88 (0.67, 1.17)	0.34
Dietary Approaches to Stop Hypertension score [d]						
WOMEN						
Median index score	18.6	22.0	24.1	26.4	29.5	
No. of cases	333	471	468	434	437	
Age and energy adjusted	1	1.10 (0.95, 1.27)	0.98 (0.85, 1.13)	0.85 (0.73, 0.98)	0.82 (0.71, 0.95)	<0.001
Age, energy, physical activity adjusted	1	1.16 (1.00, 1.33)	1.06 (0.92, 1.23)	0.95 (0.82, 1.10)	0.95 (0.82, 1.11)	0.03
Above + BMI	1	1.19 (1.03, 1.37)	1.11 (0.96, 1.28)	0.98 (0.85, 1.14)	0.95 (0.82, 1.11)	0.02
Multivariable adjusted [b]	1	1.19 (1.03, 1.37)	1.12 (0.96, 1.29)	0.99 (0.85, 1.15)	0.95 (0.81, 1.11)	0.03
MEN						
Median index score	18.0	21.7	24.1	27.0	30.7	
No. of cases	88	122	121	123	149	
Age and energy adjusted	1	1.00 (0.76, 1.33)	0.93 (0.70, 1.23)	0.88 (0.66, 1.17)	0.97 (0.73, 1.28)	0.52
Age, energy, physical activity adjusted	1	1.03 (0.77, 1.36)	0.97 (0.73, 1.29)	0.94 (0.70, 1.25)	1.05 (0.79, 1.40)	0.98
Above + BMI	1	1.03 (0.78, 1.37)	0.96 (0.73, 1.29)	0.93 (0.69, 1.24)	1.00 (0.75, 1.33)	0.65
Multivariable adjusted [b]	1	1.04 (0.78, 1.38)	0.97 (0.72, 1.29)	0.92 (0.68, 1.23)	0.98 (0.73, 1.31)	0.50

[a]Possible range 0–9 points, higher score represents better adherence to the Mediterranean diet.

[b]adjusted for age, energy intake, BMI, height, smoking, leisure-time physical activity, post menopausal hormone use (women), thiazides, lasix, anti-inflammatory steroids, multivitamin supplements, supplemental intakes of calcium, retinol, and vitamin D, intake of caffeine, sugar sweetened beverages (Alternate Mediterranean Diet Score only), and alcohol (Dietary Approaches to Stop Hypertension Score only), history of diabetes.

[c]Possible range 0–110 points, higher score represents a healthier diet.

[d]Possible range 8–40 points, higher score represents better adherence to the DASH diet.

Table 3

Multivariable [a] relative risks for cumulative diet quality scores for hip fractures stratified by age in the Nurses' Health Study (n=74,446, postmenopausal) and Health Professionals Follow-up Study (n=36,602, age 50+) participants [b].

	Q1	Q2	Q3	Q4	Q5	P trend	P interaction
aMed [c]							
WOMEN							
Age <75 y	1	1.00 (0.84, 1.19)	0.93 (0.78, 1.12)	0.80 (0.66, 0.97)	0.86 (0.70, 1.05)	0.01	0.02
Age >= 75y	1	1.19 (0.95, 1.48)	1.14 (0.91, 1.43)	1.12 (0.89, 1.42)	1.14 (0.88, 1.48)	0.77	
MEN							
Age <75 y	1	1.07 (0.71, 1.69)	0.81 (0.53, 1.24)	1.02 (0.67, 1.56)	0.92 (0.58 1.47)	0.99	0.96
Age >= 75y	1	1.03 (0.70, 1.51)	1.19 (0.82, 1.73)	0.89 (0.60, 1.32)	1.02 (0.68, 1.53)	0.57	
AHEI-2010 [d]							
WOMEN							
Age <75 y	1	0.94 (0.79, 1.11)	0.97 (0.81, 1.15)	0.90 (0.76, 1.08)	0.73 (0.60, 0.88)	0.001	0.04
Age >= 75y	1	1.09 (0.90, 1.32)	1.07 (0.88, 1.30)	0.96 (0.78, 1.17)	1.07 (0.87, 1.32)	0.97	
MEN							
Age <75 y	1	0.81 (0.55, 1.20)	0.61 (0.39, 0.93)	0.76 (0.51, 1.14)	0.76 (0.50, 1.15)	0.19	0.45
Age >= 75y	1	0.96 (0.65, 1.42)	1.28 (0.88, 1.85)	0.93 (0.63, 1.37)	1.04 (0.71, 1.54)	0.99	
DASH [e]							
WOMEN							
Age <75 y	1	1.05 (0.88, 1.25)	1.05 (0.88, 1.26)	0.88 (0.73, 1.07)	0.84 (0.68, 1.02)	0.01	0.15
Age >= 75y	1	1.52 (1.18, 1.95)	1.30 (1.00, 1.67)	1.24 (0.96, 1.61)	1.19 (0.92, 1.55)	0.75	
MEN							
Age <75 y	1	0.99 (0.67, 1.46)	0.79 (0.51, 1.20)	0.70 (0.45, 1.09)	1.01 (0.65, 1.55)	0.60	0.75
Age >= 75y	1	1.14 (0.75, 1.73)	1.18 (0.78, 1.78)	1.16 (0.76, 1.75)	1.05 (0.69, 1.59)	0.73	

[a] adjusted for age, energy intake, BMI, height, smoking, leisure-time physical activity, post menopausal hormone use (women), thiazides, lasix, anti-inflammatory steroids, multivitamin supplements, supplemental intakes of calcium, retinol, and vitamin D, intake of caffeine, sugar sweetened beverages (aMed only), and alcohol (DASH only), history of diabetes.

[b] Women: 1233 cases in age <75y, 910 cases in age >=75 y; Men: 245 cases in age<75y, 386 cases in age>=75.

[c] Alternate Mediterranean Diet Score

[d] Alternate Healthy Eating Index-2010

[e] Dietary Approaches to Stop Hypertension Score