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Dietary patterns and risk of hip fractures in postmenopausal women and men over 50 years

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Abstract

Purpose—We examined the association between predominant dietary patterns and risk of hip fractures in postmenopausal women and men over 50 years.

Methods—We used data from 74,540 women in the Nurses' Health Study followed between 1980 and 2010, and 35,451 men from the Health Professionals Follow-up Study followed between 1986 and 2012 for this analysis. Health and lifestyle information was assessed every two years. Diet was assessed approximately every four years with a food frequency questionnaire. Two major dietary patterns were previously derived using principal component analysis. The Prudent pattern is characterized by higher intakes of fruits, vegetables, whole grains, and poultry, and the Western pattern is characterized by higher intakes of red and processed meats, sweets, and refined grains. We computed relative risks (RR) for hip fracture by dietary pattern scores using Cox proportional hazards models, adjusting for potential confounders.

Results—During follow-up, there were 1891 hip fractures in women and 596 in men. No association was observed between the Prudent or Western pattern and risk of hip fractures in either men or women. We also did not find an association among lean (BMI<25) or overweight (BMI ≥25) individuals or among those with higher or lower levels of physical activity.

Conclusion—Neither the Prudent nor the Western dietary pattern was associated with risk of hip fractures in postmenopausal women or men over 50 years of age.

Keywords

fractures; diet; dietary pattern; postmenopause

Introduction

In the U.S., hip fractures in the elderly are a major cause of morbidity. Although incidence has been declining recently, rates in 2007 for individuals above age 65 remained high at 832

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Teresa T. Fung and Diane Feskanich declare that they have no conflict of interest.

per 100,000 in women and 523 per 100,000 in men [1]. In addition, the mortality rate one year after hip fractures was over 30% in men and over 20% in women [2].

Dietary strategies for prevention primarily focused on adequate consumption of calcium and vitamin D [3]. However, other nutrients may also play role, such as vitamin K because of its role in osteocalcin synthesis and vitamin C in collagen synthesis. On the other hand, there is mixed evidence on the role of excess vitamin A intake in enhancing osteoblast activity and fracture risk [4]. Dietary factors may also interact with each other to influence nutrient absorption and metabolism. For example, excess phosphorous or oxalate intake may reduce calcium absorption, and excess sodium intake may increase calcium excretion.

Therefore, one approach to study the relationship between diet and hip fractures is through examining the multiple components of the diet simultaneously. A number of investigators have used principal component analysis to capture predominant dietary patterns in a population and examined their association with fracture risk. Among these, a study on Singaporean Chinese found a dietary pattern that was high in vegetables, fruits, and soy was associated with lower risk of hip fractures in both men and women [5]. In Canada, a nutrient dense pattern characterized by higher intakes of fruits, vegetables, and whole grains was associated with a lower risk of total non-traumatic fractures in women [6].

Previously, we derived predominant dietary patterns in large cohorts of men and women using principal component analysis and found significant associations with cardiovascular disease and diabetes [7, 8]. We identified two major dietary patterns: the Prudent pattern which was characterized by higher intakes of fruits, vegetables, whole grains, poultry, and low fat dairy products, and the Western pattern which was characterized by higher intakes of red and processed meats, refined grains, sweets, and high fat dairy products. In this analysis, we prospectively assessed the association between these dietary patterns and risk of hip fractures in post-menopausal women and men 50 years and older.

Methods

Population

The Nurses' Health Study (NHS) is a prospective cohort established in 1976 with 121,701 women registered nurses aged between 30 and 55 years at enrollment [9]. The Health Professionals Follow-up Study (HPFS) is comprised of 51,529 male health professionals aged between 40 and 75 years that began in 1986 and paralleled the NHS in data collection [10]. In both cohorts, a self-administered questionnaire was mailed to the study participants every 2 years to collect medical history, diet (every 4 years) and lifestyle information. Follow-up rates were close to 90% in both cohorts. This analysis was approved by the Institutional Review Board at Brigham and Women's Hospital.

Analytic population

In this analysis, follow-up for women began in 1980 with the first administration of the food frequency questionnaire. Women who were postmenopausal in 1980 entered follow-up at that time; others entered at the biennial questionnaire when they reached menopause, including surgical menopause. Men entered follow-up if they were 50 years old in 1986 or

when they reached 50 years. Participants were excluded at entry if they did not have the most recent dietary assessment, had previously reported a hip fracture or diagnosis of cancer or osteoporosis, or were non-Caucasian (<3% of the cohort). We stopped follow-up with hip fracture incident, death, or the date of last questionnaire response. Therefore, 74,540 women and 38,305 men were included in this analysis and followed through 2010 for women and 2012 for men.

Ascertainment of Hip Fractures

Participants self-reported hip fractures on each biennial questionnaire, including bone site and month and year of the fracture. Only fractures of the proximal femur were classified as a hip fracture for this analysis. We excluded fractures due to motor vehicle accidents, horseback riding, skiing, and other severe trauma events because these events could result in fracture even in the absence of osteoporosis. As all participants were health care professionals, self-reporting of fractures was likely highly accurate. In a validation study in the NHS, medical record review confirmed all reported fractures in all 30 sampled cases [9].

Covariate assessment

Height was assessed at baseline. Weight and the calculated body mass index (BMI; in kg/m²), recreational activity, smoking, use medications and vitamin/mineral supplements, postmenopausal hormone use (women only), and diagnosis of osteoporosis and diabetes were assessed on all biennial questionnaires. Recreational physical activity was assessed with 10 activities that were assigned a metabolic equivalent (MET) score for energy expenditure in relation to sitting, and reported hours per week were multiplied by these scores and summed over all activities to create a value in MET-hours/week.

Diet assessment

Diet was assessed by self-administered, semi-quantitative food frequency questionnaires (SFFQ) was in 1980 and 1984 (women only), 1986, 1990, 1994, 1998, 2002 and 2006, with approximately 130 items. A standard portion size and 9 possible frequency-of-consumption responses were provided for each item. Total energy and nutrient intakes were calculated by summing up energy or nutrients from all foods. Prior validation studies showed reasonably good correlations between food assessed by the FFQ and multiple weeks of food records completed over the preceding year in both the HPFS [11] and the NHS cohorts [12].

Dietary patterns derivation

Dietary patterns were previously derived by principal component analysis (PCA) [13]. Foods from the FFQ were first classified into 38 food groups based on nutrient profiles or culinary usage. Each alcoholic beverage (wine, liquor, beer) type was included separately as food groups. PCA identifies dietary patterns primarily based on the correlations between food groups. We used an orthogonal rotation procedure to generate uncorrelated factors, or patterns. Factor scores were standardized to having a mean of 0 and standard deviation of 1. Each participant received a factor score for each identified pattern and higher score represents closer adherence to that pattern. We identified two major dietary patterns which reflect the predominant eating pattern in our population. The Prudent pattern is characterized

by higher intake of fruits, vegetables, whole grains, poultry, and low fat dairy products. The Western pattern is characterized by higher intake of red and processed meats, refined grains, sweets and desserts, and full fat dairy products.

Statistical analysis

We used Cox proportional hazards models to examine the relationship between dietary patterns and risk of hip fractures. Assumption for proportional hazard was assessed and no evidence of violation was noted. We computed cumulative averages for dietary patterns to reduce within-person variation and to represent long-term intake [14]. For example, for a woman who became post-menopausal in 1984, the dietary pattern score in 1994 was calculated as the average of the 1984, 1990, and 1994 scores. In multivariable analysis, we adjusted for age (in months), physical activity (5 categories), thiazide use (yes/no), lasix use (yes/no), oral anti-inflammatory steroids (yes/no), BMI (8 categories), smoking (10 categories to represent smoking history and number of cigarettes per day), energy intake (quintiles), calcium supplement (yes/no), multivitamin supplement (yes/no), and post menopausal hormone use (never/past/current) in women. All covariates were time-varying. We did not adjust for self reported diagnoses of osteoporosis or diabetes as they may be in the causal pathway of dietary patterns and fracture development. In secondary analyses, we stratified by BMI ($<25 \text{ kg/m}^2$ vs. $>25 \text{ kg/m}^2$), and physical activity (above or below median).

Results

In up to 20 years of follow-up, there were 1,891 cases of hip fractures in women and 596 cases in men. In both men and women, those in the highest quintile of the Prudent pattern had higher levels of physical activity, consumed more calcium, fruits and vegetables, and are more likely multivitamin users (table 1). Conversely, men and women at the highest quintile of the Western pattern score had lower level of physical activity and consumed more refined grains, sugar-sweetened beverages, and red and processed meats. BMI were higher among those in the top quintile of the Western pattern score. In men, alcohol intake was also higher among those in the top quintile of the Western score. Energy intake also increased with both dietary pattern score.

After adjusting for age and energy intake, the prudent pattern was significant associated with lower risk of hip fractures in women (relative risk comparing top to bottom quintiles = 0.83, 95% CI=0.70–0.99, p trend=0.002) and the western pattern a higher risk (RR=1.30, 95% CI=1.08–1.55, p trend=0.01) (table 2). However, after adjusting for physical activity, the association attenuated and was no longer significant. No significant association was observed with the prudent or western pattern after further adjustment for other potential confounders. In men, neither the prudent nor the Western pattern was associated with fracture risk. As BMI is a strong predictor of fracture risk, we stratified our analysis by this factor but did not find any association between either dietary pattern and hip fracture risk among those with BMI below or above 25 kg/m^2 in men or women. BMI may also be a mediator in this association, however, results remained null without adjustment for BMI. Similarly, neither dietary pattern was associated with hip fractures among those with higher

or lower levels of physical activity when stratified by the median, among those with or without a history of diabetes, or among smokers, past smokers or never smokers. Energy intake was not associated with hip fracture risk in men or women when modeled in quintiles, as a continuous variable or in spline regression. Results of dietary patterns and hip fractures remained essentially the same with or without energy adjustment.

Discussion

In this analysis with up to 20 years of follow-up, we did not find any association between the Prudent or the Western pattern and hip fracture risk in either men or women. In contrast, several previous prospective studies had shown healthful dietary patterns derived from principal component analysis were associated with a lower risk of hip fractures. Among middle-aged Singapore Chinese with 10 years of follow-up, a dietary pattern high in fruits, vegetables, soy products, was associated with lower risk of hip fractures in both men and women [5]. However, a less healthful pattern, the Meat-Dim-Sum pattern, which was high in meats, sodium, and refined grains, had no association. In a Canadian study in individuals over age 50 with over 6 years of follow-up, two major dietary patterns were identified [6]. The nutrient dense pattern, which was similar to our Prudent pattern, was associated with a lower risk of total non-traumatic fractures in women but not in men. The energy dense pattern, which was similar to our Western pattern, had no association. In addition, a Chinese case-control study which derived a healthy pattern high in fruits and vegetables and a prudent pattern high in healthy traditional foods such as mushroom, seafood, algae, and nuts, found both were associated lower hip fracture risks among the elderly[15]. However, no association was observed with the less healthy patterns.

Therefore, our results were similar to existing literature that a less healthful dietary pattern did not seem to influence hip fracture risk, however, our null result on the Prudent pattern differ from others despite largely similar adjustment for potential confounders. In the Singapore Chinese study, soy intake was higher and calcium intake was lower than this present study. And in both studies in Chinese populations, mean BMI was lower than in our cohorts. Specific food intakes, such as the types of vegetables, were most likely different in American populations. In the Canadian study, dietary characteristics were largely similar to this analysis, however, BMI was somewhat higher than our cohorts. These differences may have contributed to the different results in this study.

The strongest confounder in our cohorts was physical activity, followed by BMI and smoking status. Higher levels of physical activity [16] or BMI [17] is associated with lower risk of fractures. In this analysis, women at the highest quintile of the prudent pattern score also had higher levels of physical activity and the attenuation of the inverse association observed in the age and energy adjusted model indicated that physical activity was driving the association. On the other hand, it is possible that that a healthier diet would lead to less frailty and enables individuals to have higher levels of physical activity. Thus physical activity may in part be a proxy for frailty. BMI can influence the association between dietary patterns and hip fracture risk as a confounder and/or mediator. Results remained null when we adjusted for BMI to control for the confounding effect or removed from the regression model to avoid over controlling the mediating effect.

Because of the long follow-up time in our cohorts, we were able to examine the long term association of dietary patterns and fractures risk. Incidence of non-traumatic fractures is lower in men than women, but because of the large cohort size, we had a large number of cases to examine this association in men. We also had detailed information on potential confounders to control for them in the analysis. In addition, repeated measurement of both diet and lifestyle data allowed us to update these information in the statistical models. However, because lifestyle information was obtained from self-administered questionnaires, some level of error is unavoidable although we expect them to be small because the cohort participants were health care professionals. The food frequency questionnaire may underestimate intake, but it is validated for this population and is sufficient in ranking individuals. The Western pattern has been associated with higher mortality and therefore premature death may preclude fracture occurrence [18]. Vice versa would be possible for the prudent pattern which is associated with lower mortality. Therefore, the competing risks may limit our ability to detect an association between dietary patterns and fracture risk. In addition, our analysis was limited to Caucasian population, and more studies in different ethnic groups are needed.

In conclusion, our data do not support an association between the Prudent and Western dietary patterns and hip fracture risk in middle-aged and older men or women.

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Lifestyle and dietary characteristics (means) of study participants at time of entry* to study according to quintiles of dietary patterns.

Table 1

	Prudent pattern			Western pattern		
	Q1	Q3	Q5	Q1	Q3	Q5
WOMEN						
Age at entry to study	53	53	54	54	53	52
Menopausal hormone use (%)	34	29	29	32	30	30
Energy (kcal/d)	1534	1587	1908	1389	1571	2140
BMI	25.5	25.2	25.5	24.8	25.3	26.0
Physical activity (METs/wk)	11	16	20	19	15	13
Current smoker (%)	31	23	17	18	24	28
Thiazide use (%)	6	3	4	4	4	5
Lasix (%)	0.2	0.1	0.2	0.1	0.2	0.3
Anti-inflammatory steroids (%)	0.3	0.2	0.2	0.2	0.2	0.2
Multivitamin supplement (%)	35	38	45	46	38	34
Calcium supplement (%)	38	42	50	51	41	35
Alcohol (g/d)	7	6	6	7	6	6
Calcium (mg/d)**	860	852	977	1099	850	735
Fruits (servings/d)	0.9	1.5	2.5	2.1	1.5	1.3
Vegetables (servings/d)	1.4	1.9	4.3	2.8	2.2	2.4
Red/processed meats (servings/d)	0.9	1.0	0.9	0.5	0.9	1.5
Poultry (servings/d)	0.2	0.3	0.5	0.4	0.3	0.3
Whole grains (servings/d)	0.6	0.9	1.4	1.3	0.9	0.8
Refined grains (servings/d)	1.7	1.3	1.3	0.8	1.3	2.3
Sugar sweetened beverages (servings/d)	0.4	0.3	0.2	0.1	0.2	0.7
Low fat dairy (servings/d)	0.7	0.9	1.3	1.2	0.9	0.7
Full fat dairy (servings/d)	1.0	1.0	1.1	0.8	1.0	1.4
MEN						
Age at entry	56	57	58	58	57	56
Energy (kcal/d)	1653	1964	2419	1508	1868	2634
BMI	25.9	25.6	25.4	25.0	25.7	26.1

	Prudent pattern			Western pattern		
	Q1	Q3	Q5	Q1	Q3	Q5
Physical activity (METs/wk)	19	24	31	28	23	22
Current smoker (%)	12	7	4	3	7	13
Thiazide use (%)	7	9	9	9	9	7
Lasix (%)	0.6	0.7	0.6	0.5	0.6	0.6
Anti-inflammatory steroids (%)	0.4	0.3	0.5	0.3	0.1	0.6
Multivitamin supplement (%)	39	43	49	49	45	38
Calcium supplement (%)	12	17	23	22	17	13
Alcohol (g/d)	12	11	12	7	12	15
Calcium (mg/d)**	856	924	968	1066	903	809
Fruits (servings/d)	1.1	2.0	3.5	2.6	2.0	1.8
Vegetables (servings/d)	1.3	2.6	5.3	3.1	2.8	2.9
Red/processed meats (servings/d)	1.2	1.1	1.0	0.3	1.0	2.0
Refined grains (servings/d)	1.5	1.6	1.8	1.0	1.5	2.5
Poultry (servings/d)	0.2	0.4	0.5	0.4	0.4	0.4
Whole grains (servings/d)	0.8	1.5	2.3	1.8	1.4	1.5
Sugar sweetened beverages (servings/d)	0.4	0.3	0.3	0.1	0.3	0.6
Low fat dairy (servings/d)	0.7	0.9	1.1	1.0	0.9	0.9
Full fat dairy (servings/d)	1.0	0.9	0.9	0.4	0.8	1.6

* menopause for women, age 50 for men

** energy adjusted

Table 2

Relative risk (95% CI) for hip fractures according quintiles of dietary patterns

	Q1	Q2	Q3	Q4	Q5	P trend
Prudent pattern						
WOMEN						
No. of cases	320	430	393	396	352	
Age and energy adjusted	1	1.04 (0.90, 1.21)	0.86 (0.74, 1.00)	0.87 (0.75, 1.02)	0.83 (0.70, 0.99)	0.002
Age, energy, physical activity adjusted	1	1.10 (0.94, 1.27)	0.94 (0.80, 1.09)	0.98 (0.84, 1.14)	0.97 (0.82, 1.15)	0.23
Above + BMI	1	1.14 (0.98, 1.32)	1.00 (0.86, 1.17)	1.06 (0.90, 1.24)	1.06 (0.89, 1.26)	0.97
Multivariable adjusted *	1	1.29 (1.02, 1.38)	1.06 (0.91, 1.24)	1.13 (0.97, 1.33)	1.14 (0.96, 1.36)	0.38
MEN						
No. of cases	113	121	108	126	128	
Age and energy adjusted	1	0.84 (0.65, 1.10)	0.73 (0.55, 0.97)	0.79 (0.60, 1.04)	0.81 (0.61, 1.08)	0.27
Age, energy, physical activity adjusted	1	0.87 (0.66, 1.14)	0.77 (0.58, 1.01)	0.84 (0.64, 1.12)	0.88 (0.66, 1.18)	0.60
Above + BMI	1	0.87 (0.66, 1.14)	0.76 (0.57, 1.01)	0.83 (0.62, 1.09)	0.84 (0.63, 1.13)	0.39
Multivariable adjusted *	1	0.88 (0.67, 1.15)	0.77 (0.58, 1.02)	0.84 (0.64, 1.12)	0.86 (0.64, 1.16)	0.46
Western pattern						
WOMEN						
No. of cases	362	422	381	403	323	
Age and energy adjusted	1	1.17 (1.02, 1.35)	1.11 (0.96, 1.29)	1.27 (1.09, 1.49)	1.30 (1.08, 1.55)	0.01
Age, energy, physical activity adjusted	1	1.13 (0.98, 1.30)	1.03 (0.88, 1.20)	1.14 (0.97, 1.33)	1.10 (0.92, 1.33)	0.50
Above + BMI	1	1.14 (0.99, 1.32)	1.06 (0.91, 1.23)	1.18 (1.01, 1.38)	1.16 (0.96, 1.39)	0.15
Multivariable adjusted *	1	1.12 (0.97, 1.29)	1.01 (0.87, 1.18)	1.10 (0.94, 1.30)	1.05 (0.87, 1.26)	0.65
MEN						
No. of cases	121	117	143	108	107	
Age and energy adjusted	1	1.01 (0.77, 1.32)	1.29 (0.99, 1.68)	1.00 (0.74, 1.34)	1.05 (0.75, 1.46)	0.93
Age, energy, physical activity adjusted	1	0.98 (0.75, 1.28)	1.24 (0.95, 1.62)	0.94 (0.70, 1.27)	0.97 (0.69, 1.36)	0.67
Above + BMI	1	1.05 (0.80, 1.37)	1.34 (1.03, 1.75)	1.02 (0.76, 1.38)	1.08 (0.77, 1.51)	0.87
Multivariable adjusted *	1	1.05 (0.80, 1.38)	1.33 (1.01, 1.74)	0.99 (0.73, 1.35)	1.03 (0.73, 1.46)	0.92

* adjusted for age, energy intake, BMI, smoking, physical activity, post menopausal hormone use (women), thiazides, lasix, anti-inflammatory steroids, calcium supplements, multivitamin supplements