DIETARY PROTEIN INTAKE AND FALLS IN OLDER PEOPLE:

A LONGITUDINAL COHORT STUDY IN THE OSTEOARTHRITIS INITIATIVE

Running title: proteins and falls

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ABSTRACT

Objectives: Literature regarding dietary protein intake and risk of falls is limited to a few studies with relatively small sample sizes and short follow-ups, which have reported contrasting findings. Thus, we investigated whether dietary protein intake is associated with risk of falls in a large cohort of North American adults.

Design: Data were drawn from the Osteoarthritis Initiative, a cohort study, with 8 years of follow-up,

Setting and participants: Community-dwelling adults with knee osteoarthritis or at high risk for this condition.

Methods: Dietary protein intake was recorded using the Block Brief 2000 food frequency questionnaire and categorized using gender-specific quartiles (Q). Falls were self-reported in response to the question "Did you fall during the past year?", categorized as yes vs. no and made during the 6 visits over 8 years of follow-up. Results are reported as relative risks (RRs), with their 95% confidence intervals (CIs), using a multivariable Poisson regression.

Results: The final sample consisted of 4,450 adults (mean age 61.2 years, females=59.6%). Higher dietary protein intake was significantly associated with higher frequency of falls during the year before baseline. After adjusting for 17 potential confounders, people with the greatest amount of protein intake (Q4) had a significantly higher risk of falling over the 8-year follow-up period (RR=1.112; 95%CI: 1.027-1.211; p=0.009) than those with the lowest protein intake (Q1).

Conclusions and implications: In this cohort of people affected by knee osteoarthritis or at high risk for this condition, high dietary protein intake may increase the risk of falls in older people, but further research is needed to confirm or refute these findings.

INTRODUCTION

Falls are a major public health concern in older people, associated with adverse quality of life, increased physical comorbidity, healthcare use and premature mortality.[1] Given this, it is essential that potential risk factors for future falls can be identified and target in clinical practice and with interventions. A wide range of risk factors have been associated with falls including advancing age, depression, polypharmacy, poor physical performance, pain, some medications, and (orthostatic) hypotension.[2-6]

There is emerging interest in the potential of dietary determinants of falls in older people which would provide an easy target for treatment. [7] Despite this little research to date that has investigated associations between dietary factors and risk of falls. [2] Of particular interest is the relationship between dietary protein and falls. [7] Dietary protein is essential for building muscles mass, preventing sarcopenia and maintain lower limb function [8], all of which are established risk factors for future falls.[5] However, limited literature exists regarding a possible association between dietary protein intake and falls.[9-11]

Even if these studies have advanced our knowledge regarding the potential association between protein intake and falls, they suffer on some limitations, such as short follow-up. Given this background, the present study therefore aimed to investigate the association between dietary protein intake and risk of falls in a large cohort of North American adults followed up over 8 years, accounting for relevant confounders.

MATERIALS AND METHODS

Data source and subjects

Data were obtained from the Osteoarthritis Initiative (OAI) database. Participants were recruited across four clinical sites in the United States of America (Baltimore, MD; Pittsburgh, PA; Pawtucket, RI; and Columbus, OH) between February 2004 and May 2006. Participants were included if they: (1) had knee osteoarthritis (OA) with knee pain for a 30-day period in the past 12 months or (2) were at high risk of developing knee OA (e.g. overweight/obese (body mass index, BMI ≥25kg/m^2), family history of knee OA).[12] The data of this longitudinal cohort study were collected at baseline and during subsequent evaluations, with a follow-up of 8 years. All participants provided written informed consent. The OAI study was given full ethics approval by the institutional review board of the OAI Coordinating Center, at the University of California in San Francisco.

Dietary protein intake

Participants' dietary patterns were analyzed using the Block Brief 2000 food frequency questionnaire (FFQ) only during the baseline appointment.[13] The validated tool, containing a food list of 70 items, was designed to assess the individual's food and beverage consumption over the past year. Frequency of food consumption was reported at nine levels of intake from "never" to "every day". There were also seven dietary behavior questions on food preparation methods and fat intake, one question on fiber intake, and 13 questions on vitamin and mineral intakes. Using these data, dietary total protein intake was calculated and categorized in gender-specific quartiles using the following cut-offs: 44, 59, 76 g/day in men and 38, 51, 67 g/day in women, respectively.

Outcome: falls

A fall was defined as "*an event which resulted in a person coming to rest inadvertently on the ground or floor or other lower level*."[14]

The assessment of the outcome was made at baseline and during the V01 (12 months), V03 (24 months), V05 (36 months), V06 (48 months), V08 (72 months) and V10 (96 months) follow-up assessments. At the end of each wave, including baseline evaluation, participants reported the number of falls experienced in the preceding year by answering this question: "Did you fall during the past year?". This variable was categorized as yes vs. no in the analyses. The number of falls was also recorded. On the contrary, no information was available regarding the date of falling.

Covariates

Several covariates at baseline (other than age and sex) were identified as potential confounding factors based on previous literature.[4] These included: ethnicity (white vs. other); education (college or higher vs. other); body mass index, BMI (as continuous); yearly income ($< \text{vs} \geq$ \$50,000 and missing data); depressive symptoms assessed using the Center for Epidemiologic Studies Depression Scale (CES-D)[15]; smoking habits (never vs. previous/actual); physical activity evaluated using the total score for the Physical Activity Scale for the Elderly scale (PASE) [16]; Charlson Comorbidity Index score[17]; the number of medications used; the use of analgesic medications (yes vs. no); pain, stiffness, and physical functioning of the joints assessed through the Western Ontario and McMaster Universities Osteoarthritis (WOMAC) Index [18], as the maximum value between the assessments made between right and left knee; daily energy intake; alcohol intake (asking how many alcoholic drinks were drunk in a typical week); the presence of radiographical OA on fixed flexion radiograph and based on the presence of tibiofemoral osteophytes (correspondent to Osteoarthritis Research Society International atlas grades 1-3, clinical center reading) [19]; adherence to Mediterranean diet assessed using a validated tool. [20-22] The changes of covariates during follow-up period were also considered.

Statistical analyses

Data on continuous variables were normally distributed according to the Kolmogorov-Smirnov test. Data were presented as means and standard deviation values (SD) for quantitative measures, and percentages for all categorical variables by dietary protein intake. P values for trends were calculated using the Jonckheere-Terpstra test for continuous variables and the Mantel-Haenszel Chi-square test for categorical ones.

To assess the relationship between dietary protein intake at baseline and the risk of falls during the follow-up period, a multivariable Poisson regression analysis with robust variance estimators, was applied. The fully adjusted model included the covariates mentioned before. Multi-collinearity among covariates was assessed through variance inflation factor (VIF) [23], taking a cut-off of 2 as the criterion for exclusion. However, no covariates were excluded using this criterion. Adjusted relative risks (RRs) and 95% confidence intervals (CI) were calculated to estimate the strength of the associations between dietary protein intake and the risk of falls during follow-up period.

A $p<0.05$ was deemed statistically significant. Analyses were performed using STATA® software version 14.1 (Stata Corp LP, College station, Texas).

RESULTS

Sample selection

The OAI dataset initially included a total of 4,796 individuals. At the baseline, 84 individuals were excluded since they did not have data regarding falls, 92 since they did not have information regarding proteins as well as 170 for implausible calorie intake (i.e. greater than 2 SD from the mean of the population included in the OAI). Therefore, 4,450 people were included in our analyses.

Descriptive characteristics

The cohort included 2,652 women (59.6%). The mean age was 61.2 years (±9.3 years; range: 45-79 years). The mean dietary protein intake was significantly higher in men than in women (62±24 vs. 54±22 g/day, $p<0.0001$).

Table 1 illustrates the baseline characteristics by dietary protein intake. People who consumed a higher amount of dietary proteins (i.e. Q4) were significantly younger, had a higher adherence to Mediterranean diet, were more physically active, were more frequently whites and wealthy, were more obese and drank alcohol more frequently than those who consumed less proteins (Q1). No significant differences across quartiles were present regarding the presence of co-morbidities, knee OA or number of medications, as reported in **Table 1,** even if people introducing more proteins reported a significant higher use of analgesic medications than those introducing less proteins ($p=0.02$).

Finally, people with a higher dietary protein intake reported significant higher frequency of falls in the year prior to the baseline evaluation than those with a lower protein intake (36.4 vs. 29.8%, $p<0.0001$).

Dietary protein intake and risk of falls

Over a mean follow-up of 8 years, 2,994 (=67.3%) of the included participants reported a fall. During the follow-up period, people with a higher dietary protein intake reported a significant higher rate of falls (71.3% in Q4 vs. 59.7% in Q1) (**Table 2**).

Table 2 shows the association between dietary protein intake at baseline and risk of falls in the sample as whole during the follow-up period. In the basic model, taking Q1 (i.e. people consuming less proteins) as reference, all the other quartiles reported a significant higher proportion of falls. After adjusting for 17 potential confounders, people who consumed more dietary protein reported a significant higher risk of falls (RR=1.112; 95%CI: 1.027-1.211; p=0.009).

The stratification by sex (p for interaction=0.28), by history of previous falls at baseline (p for interaction=0.37) or by median age (p for interaction=0.28) did not modify our results.

DISCUSSION

In this large longitudinal study, over an 8-year follow-up period, higher dietary protein intake was associated with a higher risk of falls, after adjusting for several potential confounders. It should, however, acknowledged that the overall strength of the association between dietary protein intake and incident falls is weak after adjusting for potential confounders.

In the fully-adjusted model, in fact, other factors (such as male gender, non-whites, depression, low physical activity and the use of analgesic medications) mostly attenuated the association between our exposure and incident falls, being important predictors of falls not only in our research, but also in other studies. For example, low physical activity level is a strong predictor of falls, as shown in a large meta-analysis regarding this topic[24] as well as the use of analgesic medications significantly increases the risk of falls in older people. [25] Depression is another important risk factor for falls for several reasons, including the use of antidepressants, medications commonly associated with falls. [26]

A first important result of our investigation is the high proportion of people falling at baseline and during the follow-up period. In this cohort of people with knee OA or at high risk of this condition, more than two thirds people fell. From an epidemiological point of view, falls are the second leading cause of accidental or unintentional injury deaths worldwide and this figure particularly affects older people, among whom the rate of fatal falls is significantly higher than for younger people. [14]

Compared with the other studies that have examined the association between dietary protein and falls [9-11], we observed a higher rate of falls, probably because we had a longer follow-up period (8 years) and because the people included in the OAI either have a diagnosis of knee OA or are at high risk of this condition (e.g. they were obese/overweight), which are strong risk factors for falls. [27,28] Even if we adjusted our analyses, for BMI, a possible hypothesis is that people introducing more proteins are more obese than those introducing less and increasing research is reporting the importance of obesity

associated with low muscle mass (i.e. sarcopenic obesity). [29] In particular, sarcopenic obesity seems to be a stronger risk factor for falls than obesity alone, as also evidenced in a recent paper. [30] Unfortunately, data regarding body composition were not recorded in the OAI and so the diagnosis of sarcopenia is not possible.

Contrary to our findings, a previous cross-sectional study did not observe any association between dietary protein intake and increased risk of falls.[31] Similar findings were obtained by cohort studies. In the Framingham study, in 807 participants with a mean age of 75 years, people who consumed more dietary protein were at higher risk of falls, but after adjusting for potential covariates this association disappeared.[9] In the Study of Osteoporotic Fractures, which comprised more than 4,000 very old postmenopausal women with a relatively low protein intake, dietary protein intake was not associated with incident falls. [10] Finally, another more recent study found this lack of association in the sample as whole and a protective effect of dietary protein only in people reporting significant weight loss. [11] There are several factors that may explain these different findings. First, there were some methodological differences between the studies, including the sample size and follow-up period (which, in previous studies, was generally shorter than ours). Second, as our study evidenced, people consuming more protein were significantly younger and more physically active. Therefore, the higher rate of falls in this group may reflect people moving more than their counterparts. Finally, people who consumed more dietary proteins also reported higher alcohol intake, which is an important risk factor for falls in older people. [32] However, the role of these factors is probably limited since we adjusted our analyses for these factors.

Our findings should be interpreted considering the study's limitations. First, the OAI includes only individuals who already have or are at high risk of knee OA. Thus, our results may be not extendable to the general population. Second, dietary protein intake was assessed only at the baseline. Thus, the effect of inherent changes in diet can affect our results, but we cannot say in which direction. Third, in the OAI, dietary protein intake was not divided in animal and vegetable intake and so we cannot

229 determine the effect of these two components. Fourth, at baseline, previous weight loss was not
230 recorded, but in two studies this factor seems to be associated with a protective effect of protein intake
231 on falls.[9,11] Finally, falls were only self-reported. In this sense, retrospective recall of falls each year
232 over the past 12 months is an inferior way to ascertain falls rather than prospective monitoring (e.g.
233 monthly calendars) and the agreement between these two tools is often poor. [33,34]
234
235 **CONCLUSIONS AND IMPLICATIONS**
236 Our data suggest that, in this cohort of people affected by knee osteoarthritis or at high risk for this
237 condition, higher dietary protein intake may be associated with an increased risk of falls. Contrary to
238 the previous literature, a significant association between dietary protein intake and increased risk of
239 falling was found, indicating that other studies are needed to confirm or refute our findings.

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Table 1. Descriptive findings of the participants by total dietary protein intake.

	Q1 (n=1109)	Q2 (n=1103)	Q3 (n=1124)	Q4 (n=1114)	P value*
Age (years)	62.1 (9.2)	61.8 (9.3)	61.5 (9.1)	60.5 (8.9)	0.0001
aMED (points)	27 (5)	28 (5)	28 (5)	28 (5)	<0.0001
Alcoholic drinks in a typical week (number)	1.52 (1.38)	1.71 (1.49)	1.81 (1.44)	1.77 (1.53)	<0.0001
PASE (points)	154 (83)	156 (79)	160 (78)	166 (86)	0.004
WOMAC (points)	13 (15)	12 (15)	12 (14)	12 (14)	0.11
CESD (points)	6.9 (7.5)	6.2 (6.49	6.5 (7.1)	6.6 (6.6)	0.11
Females (n, %)	60.6	59.1	59.4	59.3	0.89
White race (n, %)	70.6	81.9	82.2	83.9	<0.0001
Smoking (previous/current)	45.1	47.3	47.0	49.3	0.25
Graduate degree (n, %)	30.9	29.5	31.8	29.7	0.61
Yearly income (< 50,000 $)	56.5	62.8	64.0	61.0	0.002
BMI (Kg/m^2)	28.4 (4.8)	28.4 (4.8)	28.4 (4.6)	29.4 (5.0)	<0.0001
Charlson co-morbidity index (points)	0.44 (0.95)	0.39 (0.78)	0.35 (0.81)	0.39 (0.80)	0.08
Knee OA (%)	57.0	57.4	56.4	58.9	0.67

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	Q1 (n=1109)	Q2 (n=1103)	Q3 (n=1124)	Q4 (n=1114)	P value*
Number of medications	3.69 (2.53)	3.69 (2.41)	3.66 (2.56)	3.64 (2.58)	0.98
Use of analgesic medications (%)	39.3	38.2	40.4	44.2	0.02
Fallers (%)	29.8	32.4	33.2	36.4	<0.0001

Notes: The data are presented as means (with standard deviations) for continuous variables and number (with percentage).

[a] P values for trends were calculated using the Jonckheere-Terpstra test for continuous variables and the Mantel-Haenszel Chi-square test for categorical ones.

Abbreviations: aMED: adherence to Mediterranean diet; PASE: Physical Activity Scale for the Elderly; BMI: body mass index; OA: osteoarthritis; CESD: Center for Epidemiological Studies Depression; WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index.

Table 2. Association between dietary protein intake and falls during follow-up.

	Events during follow-up /participants at baseline	Not adjusted model (RR, 95%CI)	p-value	Fully-adjusted model[1] (RR, 95%CI)	p-value
Q1	662/1109	1 [reference]	-	1 [reference]	-
Q2	739/1103	1.122 (1.053-1.196)	<0.0001	1.089 (1.010-1.171)	0.026
Q3	798/1124	1.189 (1.119-1.264)	<0.0001	1.084 (0.976-1.203)	0.133
Q4	795/1114	1.196 (1.125-1.270)	<0.0001	1.112 (1.027-1.211)	0.009

Notes:

All the data are presented as relative ratios (RRs) with their 95% confidence intervals (CIs).

Protein intake was categorized in gender-specific quartiles using in men 44, 59, 76 and in women 38, 51, 67 g/day, as cut-offs.

[1] Fully adjusted model included as covariates: age (as continuous); sex; race (whites vs. others); education (degree vs. others); body mass index (as continuous); yearly income (categorized as ≥ or < 50,000$ and missing data); Center for Epidemiologic Studies Depression Scale; smoking habits (current and previous vs. others); Physical Activity Scale for Elderly score (as continuous); Western Ontario and McMaster Universities Osteoarthritis Index score (as continuous); use of analgesic medications (yes vs. no); Charlson co-morbidity index; number of medications used; daily energy intake; alcohol intake; adherence to Mediterranean diet; presence of knee osteoarthritis.

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