Original Article

Relationships among falls and dietary patterns, nutritional inadequacy and prefrailty in community-dwelling older Japanese females: A cross-sectional study

Tatsumi Hayashi RD, BS[1,2], Rumi Sato RD, BS[3], Kazuo Tamura MD, PhD[4,5]

[1]*Faculty of Economics, Shimonoseki City University, Yamaguchi, Japan*
[2]*Faculty of Food and Nutrition, Kyushu Nutrition Welfare University, Fukuoka, Japan*
[3]*Council of Social Welfare, Bungo Ono city, Oita, Japan*
[4]*Research Promotion Division, Fukuoka University, Fukuoka, Japan*
[5]*NPO Clinical Hematology Oncology Treatment Study Group, Fukuoka, Japan*

Background and Objectives: Falls are common among older females. This study investigated the relationships among falls and dietary patterns, nutritional inadequacy and prefrailty in community-dwelling older Japanese females. **Methods and Study Design:** This cross-sectional study involved 271 females aged 65 and over. Prefrailty was defined as exhibiting one or two of the five Japanese version of the Cardiovascular Health Study criteria. Frailty was excluded (n=4). Energy, nutrient and food intakes were estimated using a validated FFQ. Dietary patterns were determined from intakes of 20 food groups assessed with FFQ, by cluster analysis. Nutritional inadequacy for the selected 23 nutrients in each dietary pattern was examined based on DRIs. Binomial logistic regression was applied to examine the relationships among falls and dietary patterns, prefrailty, and inadequate nutrients. **Results:** Data from 267 participants were included. The incidence of falls was 27.3%, and 37.4% of participants were classified as prefrailty. Three dietary patterns identified were namely; 'rice and fish and shellfish' (n=100); 'vegetables and dairy products' (n=113); and 'bread and beverages' (n=54). A binomial logistic regression analysis revealed that dietary patterns of 'rice and fish and shellfish' (OR, 0.41; 95% CI, 0.16–0.95), and 'vegetables and dairy products' (OR, 0.30; 95% CI, 0.12–0.78) were negatively correlated with falls, and falls was positively associated with prefrailty. **Conclusions:** Dietary patterns characterized by 'rice and fish and shellfish', and 'vegetables and dairy products' were associated with a reduced incidence of falls in community-dwelling older Japanese females. Larger prospective studies are needed to validate these results.

Key Words: dietary patterns, falls, prefrailty, nutritional adequacy, older Japanese females

INTRODUCTION

30–60% of community-dwelling older populations experience at least one fall in a year, and approximately half of these individuals experience multiple falls.[1] The risk of falls is higher in older females than in males;[2] therefore, studies on this specific population are needed. Falls are associated with injuries and fractures and may result in a fear of falling. They have also been implicated in adverse effects including decreased physical activity, the limitation or avoidance of activities, decreased social contact, and decreased quality of life.[3,4]

Falls in the older population are associated with various risk factors, such as previous falls, balance impairment, decreased muscle strength (upper or lower extremity), medications (>4 or psychoactive medication use), gait impairments and walking difficulties, and depression.[5] Previous studies demonstrated that the incidence of falls was reduced by the screening of older populations to identify modifiable risk factors and implement appropriate interventions.[6] Therefore, falls in the older population are considered to be preventable.[7]

An inadequate nutrient intake is a well-known risk factor for frailty in the older population.[8] A systematic review also showed that falls were associated with frailty.[9] Nutrition is an important factor associated with the risk of falls.[10,11] However, there have been few studies in Asians on the relationships among falls and diet, nutritional inadequacy and prefrailty. Therefore, a more detailed understanding of the relationships of the risk of falls and daily diets is needed. Recently, the impact of dietary patterns rather than the traditional single nutrient or food approach, on health outcomes is increasingly recognized.[12] Assessment of dietary patterns has been validated as an

Corresponding Author: Tatsumi Hayashi, Faculty of Economics, Shimonoseki City University, 4-20-301 Dannoura-cho, Shimonoseki, Yamaguchi 751-0814, Japan.
Tel: +81-90-5747-0849; +81-83-233-6715; Fax: +81-83-233-6715
Email: tatsumi-hayashi@eco.shimonoseki-cu.ac.jp; thayashi0814@gmail.com
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alternative method of measuring dietary exposure in nutritional epidemiology.[13]

This cross-sectional study analyzed dietary patterns in healthy community-dwelling older females in Japan, to examine the prevalence of nutritional inadequacy based on DRIs,[14] and to elucidate the relationships among falls and dietary patterns, nutritional inadequacy, and prefrailty.

METHODS

Study design and participants

In total, 271 healthy community-dwelling older females (age range: 65–84 years) from the Elders College in Kitakyushu city, Japan were recruited in 2016 for this cross-sectional study. Participants were excluded if they had the following health-related issues: the need for assistance or care under the Japanese public long-term care insurance system, an inability to independently perform the activities of daily living, frailty, severe neurological disease (such as dementia or cerebrovascular disease), medical contraindications to exercise, and a history of other serious health issues. Participants had not received instructions from a doctor to implement any dietary restrictions. Measurements and surveys were performed over several sessions August and October 2016 at a university facility within Kitakyushu city. Individual variables were measured and surveyed on the same day by multiple registered dietitians and health fitness programmers.

This study was reviewed and approved by the Ethics Committee of the Elders College in Kitakyushu (Approval no. 1601). All participants provided consent in writing before the initiation of the present study.

Assessment of falls and fracture

The following internationally-agreed definition of falls was used: ‘an unexpected event in which a participant rests on the ground, floor, or lower level’.[15] Participants who experienced at least one fall in the past 12 months were classified into the falls group, while those with no falls in the past 12 months were classified into the non-falls group. Participants were also asked to report the time and number of previous fractures in a questionnaire.

Frailty assessment

The Japanese version of the Cardiovascular Health Study[16] was used to identify prefrailty. This tool, which is based on Cardiovascular Health Study standards developed for frailty phenotypes by Fried et al,[17] has been modified to screen for frailty among Japanese individuals. Participants were classified into prefrailty (1–2 deficits) or non-frailty (0 deficits) groups based on the following set criteria: shrinking, weight loss of ≥2 kg over the past 6 months; low activity, not engaging in moderate-level exercise or sports and also not engaging in low-level exercise for health purposes; exhaustion, feeling fatigued for no particular reason in the past 2 weeks; weakness, grip strength cut-off value <18 kg for females; slowness, gait speed cut-off value <1.0 m/s.[16]

In the present study, only non-frailty and prefrailty participants were included in the analysis. Four frailty participants were excluded.

Physical function

Height and weight were simultaneously measured using a height/weight measurement device (AD-6350; A&D Co., Ltd., Japan), and these data were used to calculate BMI. A Smedley handheld dynamometer (Grip-D; Takei Ltd., Japan) was used to measure grip strength as an index of muscle strength. To measure gait speed, markers were placed at the start and end points of a 6-m walking route. Participants asked to walk for at least 2 m before the start point and after the end point to ensure that they walked at their usual pace. Measurements were performed once and the distance walked per second (m/s) was used in the analysis.

Other variables

Age and physical activity levels (PAL), alcohol drinking habits, and dietary supplement use were evaluated based on the responses of participants to questions in the FFQ Based on Food Groups (FFQg)[18] (Ver.5. 2016; KENPAKUSHA Corp., Japan). Intake from supplements was not included in the calculation for nutrient intakes due to the lack of a reliable composition table of dietary supplements in Japan. Supplements were treated as the presence or absence of use. Regarding PAL, participants were asked how they spent the 24 hours of each day. The responses were calculated automatically based on DRIs, which were classified as low (I), medium (II), or high (III), and were used to calculate the estimated energy requirement.[14] To measure exercise habits, participants were asked to record habitual exercise times for the past week to establish whether they engaged in habitual exercise. Participants were also questioned on whether they had any diseases that were being treated, whether they lived with anyone, had comorbidities, and were current smokers.

Evaluation of nutrient intake and intake by food groups

Nutrient and food intakes were estimated and evaluated using the validated FFQg,[18] which is software developed to estimate mean daily nutrient intake levels over the past 1–2 months for individuals. It questions portion sizes and food frequencies over 1 week or 1 time intake, in a survey format. Energy and nutrient intake levels were estimated using nutrient value estimation software (Excel Eiyou version 8.0; KENPAKUSHA Corp. Japan) based on the 2015 version (7th rev.) of the Standard Tables of Food Composition in Japan.[19]

Among diet variables, energy-adjusted intake, calculated using the method of residuals,[20] was used for daily nutrient and food intakes.

Evaluation of an inadequate nutrient intake

An inadequate nutrient intake was evaluated based on comparisons with each dietary reference value according to Japanese DRIs 2020. Nutrient intake used energy-adjusted intake for each nutrient, as calculated with the method of residuals.[20] Among the 33 nutrients indicated in DRIs, five (i.e. biotin, iodine, selenium (Se), chromium, and molybdenum) lack sufficient food composition tables in Japan.[19] However, Se is calculated as a reference value when it is necessary to consider it from the viewpoint of antioxidant properties. Therefore, four nutrients were excluded from the present analysis.

The intakes of the following 16 nutrients: protein, vitamin A, vitamin B-1 (V.B-1), vitamin B-2, niacin, vitamin B-6 (V.B-6), vitamin B-12 (V.B-12), folate, vitamin C (V.C), sodium (Na), calcium, magnesium (Mg), iron (Fe), zinc, copper (Cu), and Se, were considered to be inadequate if they were below the estimated average requirements (EAR).[14] The EAR cut-off point method cannot be used for Fe in females because the distribution of the required amount of iron varies.[21] Participants were confirmed to have entered menopause and Fe was evaluated in a similar manner based on EAR.

Provisional dietary goals (DG)[14] for preventing lifestyle related diseases have been established for protein, fat, SFA, carbohydrates, dietary fiber, salt equivalent, and potassium (K). The intakes of these nutrients were considered to be inadequate when the amount was outside of the range of the corresponding DG.

Adequate intake (AI)[14] levels were established for n-6 PUFA, n-3 PUFA, vitamin D (V.D), vitamin E, vitamin K, pantothenic acid, phosphorus, and manganese because there are insufficient grounds for the establishment of EAR for these nutrients. If an intake level of AI or higher was confirmed, there was a very low risk that intake was inadequate. Moreover, even if the intake level was below AI, intake was considered to be adequate if an insufficiency or risk of such was not proven.[14] AI is of limited value in assessing nutrient adequacy, and cannot be used to assess the prevalence of inadequacy.[22] Accordingly, data were excluded from the analysis.

Statistical analysis

All statistical analyses were performed using SPSS Statistics (version 22.0, IBM Corporation, Armonk, NY, USA). All tests were two-tailed, and $p<0.05$ was considered to be significant. Data were subjected to the Kolmogorov-Smirnov test in order to evaluate the normality of their distribution. Measured values for continuous variables were compared using the Mann-Whitney U test, and those for categorical variables using Fisher's exact test or the chi-square test. Continuous variables are presented as median values (50th percentile) and categorical variables as percentages (%) and 95%CI. Participants were divided into falls and non-falls groups.

Subsequently, to determine the number of clusters using the cluster analysis of large files (K-means), the analysis was repeated at specified times with the number of clusters preliminarily set to 2-5 for the 20 food groups from the FFQg. The numerical values of all variables in the final cluster center were determined, and each cluster was characterized, thus setting the number of clusters to 3 as most appropriate.

The median differences in intakes of energy-adjusted food group and nutrient across clusters were examined by the Kruskal-Wallis test, after which, a multiple comparison test by Dunn-Bonferroni's method was performed to clarify significant differences ($p<0.05$). In addition, age, body height, body weight, BMI, and blood pressure were normally distributed between clusters, and ANOVA was performed.

Individual numbers need to be counted in order to estimate the prevalence of an inadequate nutrient intake.[21,22] We estimated the percentages of participants for whom DRIs were not fulfilled for the 16 EAR and seven DG nutrients. The chi-square test was then used to compare these results between clusters. The numbers of EAR and DG nutrients for which DRIs were not fulfilled were tabulated and compared using the Mann-Whitney U test.

Finally, binomial logistic regression analysis (forward selection) was performed to examine the relationships among the history of falls and dietary patterns, nutritional inadequacy, and prefrailty. With the history of falls and dietary patterns as dependent and independent variables, respectively, nutritional inadequacy (continuous quantity) and non-frailty/prefrailty were used as significant variables. In model 2, age (continuous quantity) was set as an adjusting variable.

RESULTS

Data were analyzed for 267 older community-dwelling females aged 65–84 years. Table 1 shows intakes by food group for the three clusters of identified dietary patterns. We descriptively named them as 'rice and fish and shellfish' (n=100), 'vegetables and dairy products' (n=113) and 'bread and beverages' (n=54) patterns, based on the food groups predominant in each cluster. The 'rice and fish and shellfish' pattern was characterized by high intakes of rice, potatoes, fruits, algae, fish and shellfish, and meat other than those in the other two patterns. The 'vegetables and dairy products' pattern was characterized by high intakes of other vegetables and mushrooms, eggs, and dairy products. The 'bread and beverages' pattern was characterized by high intakes of bread, sugar and sweeteners, soy products, eggs, favorite beverages, and alcoholic beverages. It was also characterized by a lack of animal products. Supplementary table 1 shows the median and interquartile range of energy-adjusted food intake using residual method[20] in falls and non-falls groups. The median intakes of total vegetables and fish and shellfish were significantly lower in the falls groups, while the intake of alcoholic beverages was significantly higher.

Table 2 shows the characteristics of participants according to the three dietary patterns. Supplementary table 2 shows the basic characteristics of participants according to a history of falls. The incidence of falls among participants over 12 months was 27.3% (95% CI, 17.5–39.1), a single fall 20.6% (95% CI, 10.8–33.8), and multiple falls 6.7% (95% CI, 0.2–29.6). The incidence of fracture was 8.2% (95% CI, 0.6–28.8), occurring only in the falls group. Prefrailty was 37.4% (95% CI, 27.9–47.7). The 'bread and beverages' patterns show a prevalence of 72.2% (95% CI, 55.4–85.5) for both falls and prefrailty, a significantly high value compared with other dietary patterns, with the combined prevalence of 79.5% (95% CI, 60.9–92.0), they more frequently being treated for disease. Among participants in the non-falls and falls groups, those with falls were significantly older, they more frequently had a BMI <21.5 kg/m^2, and were more frequently being treated for disease. All participants had entered menopause (data not shown).

Table 3 shows the median and interquartile range of the energy-adjusted[20] nutrient intakes and nutrient ratios for

Table 1. Comparison of food intake by the three dietary patterns among community-dwelling older Japanese females†

Food groups (g/day)	Overall (n=267)	Dietary pattern			p-value§
		Rice and fish and shellfish (n=100, 37.5%)	Vegetables and dairy products (n=113, 42.3%)	Bread and beverages (n=54, 20.2%)	
Rice‡§	321 (288, 401)	397 (324, 443)^{BC}	249 (201, 299)^{AC}	311 (259, 377)^{AB}	<0.001
Bread‡§	37 (14, 57)	28 (13, 47)^{C}	36 (15, 57)^{C}	64 (39, 90)^{AB}	<0.001
Noodles‡§	50 (24, 86)	51 (26, 89)	46 (21, 86)	55 (29, 92)	0.107
Potatoes‡§	54 (27, 88)	66 (42, 91)^{B}	48 (19, 95)^{A}	57 (25, 87)	0.046
Sugar and sweeteners‡§	11 (9, 14)	12 (9, 14)^{B}	10 (6, 12)^{AC}	13 (9, 18)^{B}	<0.001
Soy products‡§	77 (49, 102)	75 (49, 89)^{C}	77 (35, 101)^{C}	88 (71, 107)^{AB}	0.022
Green and yellow vegetables‡§	100 (79, 124)	92 (79, 125)	103 (84, 128)	99 (77, 123)	0.848
Other vegetables and mushrooms‡§	198 (157, 219)	197 (132, 206)^{BC}	211 (179, 237)^{AC}	172 (128, 198)^{AB}	<0.001
Fruits‡§	150 (78, 203)	191 (105, 222)^{C}	154 (87, 236)^{C}	134 (67, 150)^{AB}	0.001
Algae‡§	7 (5, 10)	7 (6, 12)^{BC}	6 (4, 10)^{A}	6 (3, 8)^{A}	0.002
Fish and shellfish‡¶	77 (62, 88)	83 (68, 100)^{BC}	77 (68, 84)^{AC}	65 (47, 77)^{AB}	<0.001
Meat‡¶	59 (38, 72)	66 (55, 86)^{B}	46 (24, 67)^{AC}	61 (49, 67)^{B}	<0.001
Eggs‡¶	30 (17, 49)	23 (15, 31)^{BC}	45 (17, 51)^{A}	46 (31, 52)^{A}	<0.001
Dairy products‡¶	184 (120, 230)	166 (113, 244)^{BC}	210 (182, 246)^{AC}	125 (104, 183)^{AB}	<0.001
Fats and oils‡	15 (11, 17)	15 (11, 17)	13 (10, 17)	16 (12, 17)	0.777
Nuts and seeds‡§	3 (1, 5)	3 (0, 5)	3 (1, 5)	3 (1, 5)	0.897
Confectioneries‡	51 (28, 60)	46 (28, 61)	53 (41, 60)	54 (31, 62)	0.492
Favorite beverages‡ (excluding alcoholic beverages)	17 (1, 100)	3 (0, 41)^{BC}	21 (1, 94)^{AC}	146 (51, 246)^{AB}	<0.001
Alcoholic beverages‡	2 (-1, 6)	0 (0, 3)^{BC}	2 (0, 3)^{AC}	6 (2, 15)^{AB}	<0.001
Seasonings and spices‡	19 (16, 28)	17 (15, 29)	19 (17, 27)	21 (15, 33)	0.149
Plant foods§††	980 (889, 1112)	1081 (1022, 1221)^{BC}	920 (814, 980)^{A}	952 (891, 1046)^{A}	<0.001
Animal foods¶††	351 (304, 407)	367 (267, 403)^{C}	350 (306, 418)^{C}	308 (259, 338)^{AB}	<0.001
Total foods††	1474 (1341, 1641)	1617 (1445, 1648)^{B}	1406 (1269, 1504)^{A}	1494 (1386, 1599)	<0.001

†Values are medians (interquartile range).
‡Intakes of food group were energy-adjusted according to the residual method.[20]
§Plant foods, g/day = (Rice‡ + Bread‡ + Noodles‡ + Potatoes‡ + Sugar and sweeteners‡ + Soy products‡ + Total vegetables‡ + Fruits‡ + Algaes‡ + Nuts and seeds‡), g/day.
¶Animal foods, g/day = (Fish and shellfish‡ + Meat‡+ Eggs‡+ Dairy products‡), g/day.
††Total foods, g/day = (Plant foods§ + Animal foods¶ + Fats and oils‡ + Confectioneries‡ + Favorite beverages‡ + Alcohol beverages‡ + Seasonings and spices‡), g/day.
‡‡Kruskal-Wallis test. ^{ABC}After the Kruskal-Wallis test, a multiple comparison test by Dunn-Bonferroni's method was performed to find significant differences (p<0.05). ^{A} Rice and fish and shellfish, ^{B} Vegetables and dairy products, ^{C} Bread and beverages.

Table 2. Basic characteristics of participants classified according to the three dietary patterns among community-dwelling older Japanese females†

Characteristics	Overall (n=267)	Dietary pattern			p-value‡‡
		Rice and fish and shellfish (n=100)	Vegetables and dairy products (n=113)	Bread and beverages (n=54)	
Falls history [Yes]	27.3 (17.5-39.1)	17.0 (3.0-43.4)	15.0 (2.6-40.1)	72.2 (55.4-85.5)	<0.001
Fracture history [Yes]	8.2 (0.6-28.8)	3.0 (0.0-70.8)	2.7 (0.0-70.8)	29.6 (9.7-57.4)	<0.001
Age (years)	74±4	73±4	73±4	76 ±5	<0.001
65-74	55.1 (46.6-63.3)	62.0 (48.7-74.1)	54.0 (40.7-66.9)	44.4 (24.2-66.1)	0.108
75+	44.9 (35.8-54.3)	38.0 (22.6-55.3)	46.0 (32.0-60.5)	55.6 (36.2-73.8)	
Frailty criteria‡ of J-CHS					
Shrinking	-		-	-	-
Low activity	27.0 (17.1-38.8)	27.0 (11.7-47.7)	21.2 (7.6-42.8)	38.9 (18.5-62.6)	0.056
Exhaustion	12.4 (3.5-28.6)	8.0 (0.0-48.6)	10.6 (0.3-42.4)	24.1 (5.3-55.3)	0.012
Weakness§	4.9 (0.0-33.0)	0	0	24.1 (5.3-55.3)	<0.001
Slowness¶	7.9 (0.6-28.6)	0	3.5 (0.0-60.2)	31.4 (11.2-58.3)	<0.001
Grip strength (kg)	22.2±3.1	22.5±2.6	22.3±3.2	21.4±3.6	0.092
Gait speed (m/sec)	1.35±0.26	1.41±0.25	1.37±0.24	1.19±0.28	<0.001
Exercise time (min/day)	46±45	39±37	57±56	36±35	0.004
Frailty‡					
Non-frailty	62.6 (54.7-69.9)	73.0 (61.3-82.8)	69.9 (58.5-79.8)	27.8 (8.2-56.6)	<0.001
Prefrailty	37.4 (27.9-47.7)	27.0 (11.7-47.7)	30.1 (15.5-48.3)	72.2 (55.4-85.5)	
Frailty score (0–5)‡					
1 deficit	22.8 (13.0-35.5)	17.0 (3.0-43.4)	23.0 (8.5-44.0)	33.3 (13.3-59.0)	<0.001
2 deficits	14.6 (5.3-29.8)	10.0 (0.3-44.5)	7.1 (0.0-47.2)	38.9 (18.5-62.6)	
Body height (cm)	156±7	157±7	156±7	155±6	0.308
Body weight (kg)	53.6±7.3	53.1±6.7	54.5±7.8	52.4±6.9	0.147
BMI (kg/m^2)	22.0±2.2	21.6±2.0	22.4±2.4	21.8±2.3	0.032
SBP (mmHg)	136±17	135±15	136±18	139±18	0.384
DBP (mmHg)	79±11	78±10	78±11	80±13	0.467
Living alone [Yes]	19.9 (10.2-33.1)	18.0 (3.9-43.4)	16.8 (3.6-41.2)	29.6 (9.7-57.4)	0.128
Alcohol intake [Yes]	40.5 (31.1-50.4)	28.0 (12.6-48.3)	38.1 (23.6-54.2)	68.5 (51.1-82.8)	<0.001
Dietary supplement use [Yes]	23.2 (13.3-35.8)	25.0 (9.8-46.5)	25.7 (11.1-45.5)	16.7 (1.2-54.4)	0.403
Current smoker [Yes]	5.6 (0.0-32.1)	4.0 (0.0-60.2)	2.7 (0.0-70.8)	7.4 (0.0-60.2)	0.689
Presence of disease during treatment [Yes]	54.3 (45.8-62.6)	50.0 (35.5-64.5)	46.0 (32.0-60.4)	79.6 (64.5-90.5)	<0.001

J-CHS: Japanese version of the Cardiovascular Health Study;[16] SBP: systolic blood pressure; DBP: diastolic blood pressure.
†Values are percentage of participants (95%CI) or mean ± standard deviation.
‡Frailty scores (0–5) were defined as shrinking (one point), low activity (one point), exhaustion (one point), weakness (one point), and slowness (one point). A score of 1 or 2 was classified as indicating prefrailty.
§Weakness, grip strength <18 kg.[16]
¶Slowness, gait speed <1.0 m/s.[16]
††Categorization is according to DRIs for Japanese, 2020.[14]
‡‡For continuous variables, ANOVA was used; for categorical variables, chi-square test was used to test differences across the dietary patterns.

Table 2. Basic characteristics of participants classified according to the three dietary patterns among community-dwelling older Japanese females† (cont.)

Characteristics	Overall (n=267)	Dietary pattern: Rice and fish and shellfish (n=100)	Vegetables and dairy products (n=113)	Bread and beverages (n=54)	*p*-value‡‡
Comorbidities					
Osteoporosis	11.6 (2.9-28.4)	9.0 (0.0-47.4)	5.3 (0.0-45.9)	27.8 (8.3-55.7)	<0.001
Diabetes mellitus	14.6 (5.3-29.8)	9.0 (0.0-47.4)	6.2 (0.0-41.0)	42.6 (22.3-64.9)	<0.001
Hypertension	28.5 (18.7-40.0)	26.0 (10.7-47.0)	23.9 (9.4-44.4)	42.6 (22.3-64.9)	0.039
Ophthalmology	18.0 (8.3-31.8)	14.0 (1.1-43.7)	13.2 (1.0-41.5)	35.2 (14.9-60.3)	<0.001
History of cancer	8.2 (0.6-28.8)	4.0 (0.0-60.2)	8.9 (0.01-45.0)	14.8 (0.4-56.2)	0.127
Physical activity level††					
Low (I)	31.5 (21.7-42.6)	35.0 (20.0-53.1)	23.9 (9.4-44.4)	40.7 (20.2-63.7)	0.192
Medium (II)	63.3 (55.5-70.6)	59.0 (45.4-71.7)	70.8 (59.5-80.5)	55.6 (36.3-73.8)	
High (III)	5.2 (0.0-32.4)	6.0 (0.0-45.9)	5.3 (0.0-45.9)	0	

J-CHS: Japanese version of the Cardiovascular Health Study;[16] SBP: systolic blood pressure; DBP: diastolic blood pressure.
†Values are percentage of participants (95%CI) or mean ± standard deviation.
‡Frailty scores (0–5) were defined as shrinking (one point), low activity (one point), exhaustion (one point), weakness (one point), and slowness (one point). A score of 1 or 2 was classified as indicating prefrailty.
§Weakness, grip strength <18 kg.[16]
¶Slowness, gait speed <1.0 m/s.[16]
††Categorization is according to DRIs for Japanese, 2020.[14]
‡‡For continuous variables, ANOVA was used; for categorical variables, chi-square test was used to test differences across the dietary patterns.

Table 3. Comparison of nutrient intake by the three dietary patterns among community-dwelling older Japanese females†

Variables	Overall (n=267)	Dietary pattern			*p*-value§
		Rice and fish and shellfish (n=100)	Vegetables and dairy products (n=113)	Bread and beverages (n=54)	
Energy (kcal)	1772 (1576, 1896)	1857 (1797, 2004)BC	1717 (1523, 1943)A	1762(1536, 1923)A	<0.001
Protein‡ (g)	69.5 (64.2, 72.4)	69.5 (65.5, 72.3)C	70.2 (63.9, 73.0)C	66.1 (60.2, 70.8)AB	0.014
Animal protein‡ (g)	38.3 (33.3, 42.4)	40.2 (36.0, 42.4)C	37.8 (33.1, 42.7)C	34.5 (29.1, 38.3)AB	<0.001
Fat‡ (g)	58.3 (50.6, 62.7)	59.2 (52.0, 64.7)	56.2 (51.5, 62.5)	57.3 (48.8, 62.4)	0.056
SFA‡ (g)	17.28 (14.91, 19.54)	17.35 (16.23, 20.15)	16.31 (14.53, 19.38)	16.99 (14.89, 18.69)	0.237
n-6 PUFA‡ (g)	10.00 (9.01, 11.53)	10.41 (9.05, 12.20)	9.84 (8.32, 11.53)	10.09 (9.29, 11.31)	0.097
n-3 PUFA‡ (g)	2.64 (2.15, 3.02)	2.97 (2.49, 3.28)BC	2.56 (2.08, 2.96)A	2.29 (2.02, 2.73)A	<0.001
Carbohydrates‡ (g)	246 (203, 273)	255 (244, 295)BC	239 (218, 282)A	238 (215, 280)A	0.002
Dietary fiber‡ (g)	15.8 (13.6, 18.0)	15.2 (13.6, 18.9)	15.9 (14.1, 18.0)	15.0 (13.4, 16.5)	0.138
Vitamin A‡ (μg RAE)	730 (590, 929)	708 (578, 993)	749 (617, 905)C	641 (588, 828)B	0.022
Vitamin D‡ (μg)	8.4 (7.4, 10.1)	8.8 (8.2, 12.3)BC	8.4 (6.4, 9.7)A	7.5 (6.7, 10.4)A	<0.001
Vitamin E‡ (μg)	7.3 (6.5, 8.2)	7.8 (6.7, 9.2)C	7.4 (6.7, 8.0)C	6.7 (6.1, 7.3)AB	<0.001
Vitamin K‡ (μg)	260 (217, 324)	258 (204, 359)	266 (216, 314)	248 (227, 291)	0.602
Vitamin B-1‡ (mg)	0.89 (0.76, 0.97)	0.89 (0.77, 0.95)	0.90 (0.76, 0.98)	0.83 (0.73, 0.97)	0.277
Vitamin B-2‡ (mg)	1.27 (1.01, 1.39)	1.32 (1.01, 1.67)C	1.28 (1.00, 1.37)	1.14 (1.03, 1.29)A	0.007
Niacin‡ (mg NE)	28.7 (25.7, 34.2)	31.9 (26.5, 39.2)BC	28.3 (25.9, 32.1)A	26.7 (24.9, 30.3)A	<0.001
Vitamin B-6‡ (mg)	1.30 (1.08, 1.55)	1.31 (1.03, 1.67)C	1.33 (1.22, 1.50)C	1.18 (1.03, 1.23)AB	<0.001
Vitamin B-12‡ (μg)	8.2 (6.6, 10.9)	10.4 (7.2, 13.3)BC	8.2 (7.1, 9.4)A	7.0 (5.4, 8.3)A	<0.001
Folate‡ (μg)	351 (312, 452)	358 (313, 475)	387 (311, 452)	344 (312, 373)	0.059
Pantothenic acid‡ (mg)	5.80 (5.24, 6.19)	6.21 (5.45, 6.89)C	6.08 (5.51, 6.27)C	5.60 (4.94, 5.85)AB	<0.001
Vitamin C‡ (mg)	110 (93, 134)	107 (85, 130)BC	124 (99, 153)AC	96 (81, 117)AB	<0.001
Sodium‡ (mg)	3550 (2900, 4434)	3422 (3013, 5292)	3583 (2748, 4398)	3597 (3026, 4311)	0.627
Salt equivalent‡ (g)	9.0 (7.3, 11.1)	8.4 (7.3, 11.7)C	9.0 (6.8, 11.1)C	9.8 (8.6, 11.5)AB	0.002
Potassium‡ (mg)	2362 (2233, 2473)	2301 (2191, 2451)B	2441 (2355, 2643)AC	2319 (2137, 2404)B	<0.001
Calcium‡ (mg)	718 (622, 828)	705 (600, 899)B	808 (721, 869)AC	684 (599, 759)B	<0.001
Magnesium‡ (mg)	244 (221, 282)	270 (226, 299)C	258 (236, 301)C	231 (215, 242)AB	<0.001
Phosphorus‡ (mg)	1127 (1001, 1228)	1229 (1076, 1459)C	1222 (1084, 1295)C	1072 (1002, 1129)AB	<0.001
Iron‡ (mg)	7.5 (6.9, 8.7)	7.6 (6.8, 8.7)	7.8 (7.2, 8.8)C	7.2 (6.9, 8.2)B	0.035
Zinc‡ (mg)	8.5 (8.0, 8.9)	9.1 (8.5, 9.3)BC	8.4 (8.0, 8.8)A	8.5 (7.7, 9.1)A	<0.001
Copper‡ (mg)	1.14 (1.06, 1.29)	1.19 (1.09, 1.30)	1.11 (1.09, 1.20)	1.14 (1.10, 1.29)	0.097
Manganese‡ (mg)	3.49 (3.24, 3.81)	3.65 (3.41, 3.95)BC	3.41 (3.18, 3.79)A	3.35 (3.08, 3.67)A	0.004
Selenium‡ (μg)	60 (55, 65)	58 (54, 64)	60 (55, 65)	62 (55, 66)	0.223
Protein‡ energy ratio (% energy)	15.3 (14.0, 17.2)	15.0 (13.7, 16.1)	15.6 (14.0, 17.7)C	14.8 (13.4, 16.5)B	0.018
Animal protein‡ ratio (%)	54.8 (49.4, 60.3)	57.5 (53.7, 60.6)BC	53.0 (49.0, 61.5)A	51.5 (47.2, 56.9)A	<0.001
Fat‡ energy ratio (% energy)	29.1 (26.3, 32.0)	28.6 (25.9, 31.5)	27.8 (24.8, 33.0)	28.4 (26.3, 32.8)	0.571
SFA‡ energy ratio (% energy)	8.7 (7.4, 10.9)	7.9 (7.6, 9.5)	9.2 (65.5, 11.8)	8.6 (7.0, 10.6)	0.297
Carbohydrate‡ energy ratio (% energy)	55.1 (50.2, 58.8)	55.4 (53.8, 58.6)	57.4 (52.5, 60.5)	55.3 (51.9, 59.7)	0.850

RAE: retinol activity equivalent; NE: niacin equivalents.
†Values are medians (interquartile range).
‡Nutrient intakes were energy-adjusted according to the residual method.[20]
§Kruskal-Wallis test. ABC After the Kruskal-Wallis test, a multiple comparison test by Dunn-Bonferroni's method was performed to find significant differences (p<0.05). A Rice and fish and shellfish, B Vegetables and dairy products, C Bread and beverages.

the three clusters of identified dietary patterns. Supplementary table 3 shows the energy-adjusted nutrient intakes of the falls and non-falls groups. In terms of the overall level of nutrient intake, V.B-1 and Mg concentrations were below RDA, the V.D concentration was below AI (in the falls group only), dietary fiber and K concentrations were below DG, and the salt equivalent concentration and SFA energy ratio were above the standard. In the falls group, significant differences were observed in n-3 PUFA, V.D, V.B-6,

Table 4 shows the percentages of participants who did not meet DRIs (unit/day). V.C, Mg, and K were significant depending on the dietary patterns (*p*=0.017, *p*<0.001, and *p*=0.002, respectively). An inadequate intake below EAR was not detected for protein, niacin, V.B-12, folate, Na, Fe, Cu, or Se.

The median numbers (interquartile ranges) of nutrients with an inadequate intake below EAR or outside DG were 5.0 (4.0, 7.0) overall, 5.0 (4.0, 7.0) in the 'rice and fish and shellfish' pattern, 5.0 (5.0, 6.0) in the 'vegetables and dairy products' pattern, and 6.0 (5.0, 7.0) in the 'bread and beverages' pattern; a significant difference was observed (*p*=0.007).

Table 5 shows the results of the binomial logistic regression model (forward selection) used to identify factors associated with a history of falls. When adjusted for age (Model 2), the dietary patterns, i.e., 'rice and fish and shellfish' (OR, 0.41; 95% CI, 0.16–0.95, *p*=0.036), 'vegetables and dairy products' (OR, 0.30; 95% CI, 0.12–0.78, *p*=0.014), and V.C intake (OR, 0.96; 95% CI, 0.95–0.97, *p*<0.001) was negatively correlated with falls, whereas prefrailty (OR, 1.95; 95% CI, 1.03–3.99, *p*=0.034) showed a significant positive relationship.

DISCUSSION

This cross-sectional study was performed to clarify the relationship between dietary patterns using cluster analysis and falls in community-dwelling older Japanese females, as well as the relationships among falls and nutritional inadequacy and prefrailty. The main finding of this study was that 'rice and fish and shellfish' and 'vegetables and dairy products' patterns were inversely associated with falls and had better profile than the 'bread and beverages' pattern.

In our study cohort, the estimated incidence of at least one fall in the past 12 months was 27.3%. A recent study reported that the incidence of falls in a community-dwelling older population was 26.6% (n=447, 54.6% males, age 65–85 years).[23] In addition, a large-scale study in Japan and abroad using data from the Behavioral Risk Factor Surveillance System demonstrated that the estimated incidence of falls in females ≥65 years was 29.1%.[6] Therefore, the incidence of falls in our cohort was consistent with previous findings.

The relationship observed falls and prefrailty was in accordance with the findings reported by Umegaki et al.[23] Prefrailty is a reversible health condition.[24] Since physical injuries from falls are more severe in females,[25,26] there is an urgent need for the regular screening of this older population as well as appropriate preventive interventions for falls in the prefrailty older population.

To the best of our knowledge, this study is the first study to report the relationship between dietary patterns using cluster analysis and falls, in Japan. As a result, the prevalence of falls in 'rice and fish and shellfish' and 'vegetables and dairy products' patterns were much lower than in 'bread and beverages' pattern. Previous studies showed that the high intakes of fish, vegetables, fruits, and soybean products, as common dietary patterns, had beneficial effects on cognitive functions[27] and sarcopenia[28] in Japanese older populations, even though the dietary patterns among studies were determined by different analytic methods. In our study, 'rice and fish and shellfish', negatively correlated with falls, represents a traditional Japanese dietary pattern, while 'vegetables and dairy products' indicate a health-conscious dietary pattern. These two patterns are also characterized by the high intakes of animal products. However, 'bread and beverages' is characterized by the significantly lower intakes of protein, animal protein, and animal foods despite the significant high intakes of tofu as compared with other dietary patterns. Relatively soft foods and drinks are more likely to be selected because of health conditions, such as oral functions, including tooth loss.

A longitudinal study by Nguyen et al. first demonstrated that higher intakes of foods, including fruits and vegetables (healthy dietary pattern) are associated with the lower risk of falls in overall cohorts and older females.[29] Other studies in Asia demonstrated that healthy dietary patterns were associated with the lower risks of frailty[30,31] and muscle weakness.[32]

In this study, the 'vegetables and dairy products' pattern met the DRIs for many nutrients other than salt equivalent. In the 'bread and beverages' pattern, intakes of vitamins and minerals other than Na were lower than the median intakes of the overall in this study. Cluster analysis is useful for focusing attention on groups with good or poor nutritional status.[33]

The results of our study on nutritional inadequacy due to dietary patterns revealed that V.C intakes were negatively correlated with falls and positively correlated with prefrailty. The InCHIANTI study showed that daily intake of antioxidants, particularly V.C, in the older population correlated with higher knee extension strength and physical performance.[34]

Sim et al. showed that high intakes of total vegetables and cruciferous vegetables were associated with a reduced risk of falls, concluding that this effect may be related to the anti-inflammatory properties of vegetables.[35]

Aging is associated with the accumulation of cellular damage,[36] and oxidative stress (OS) is one of the known factors that promote the aging of cells.[37] Aging is associated with elevated OS, which may, in turn, activate a number of inflammation-inducing pathways.[38] Since OS is elevated in frailty and prefrailty, antioxidant parameters may be lower under these conditions.[39]

The loss of muscle strength during the aging process is an important risk factor for falls.[40] Therefore, it is important to identify dietary factors that effectively prevent or reduce the loss of muscle mass and function in middle and early old age.

The present study had several limitations. First, since this was a cross-sectional study, we were unable to estab-

Table 4. Percentage of participants with inadequate nutrients based on EAR and DG according to DRIs for Japanese, 2020, using the cut-point method by the three dietary patterns among community-dwelling older Japanese females

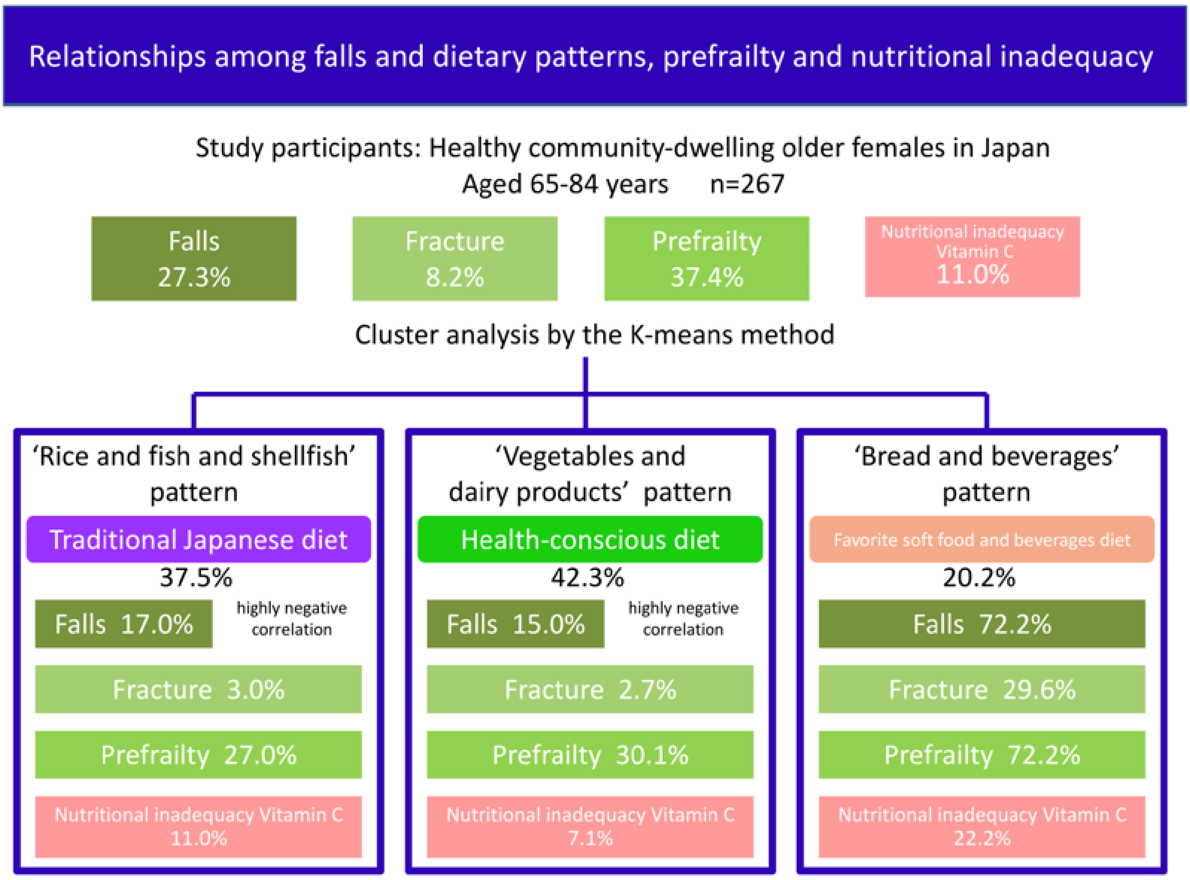
Variables	Reference value†	Overall (n=267)	Dietary pattern: Rice and fish and shellfish (n=100)	Dietary pattern: Vegetables and dairy products (n=113)	Dietary pattern: Bread and beverages (n=54)	*p*-value
Nutrients with EAR‡						
Vitamin A (µg RAE)	65-74 years: ≥500, 75 years+: ≥450	6.7 (0.2-29.7)	9.0 (0.0-47.4)	5.3 (0.0-45.9)	5.6 (0.0-70.8)	0.714¶
Vitamin B-1 (mg)	65-74 years: ≥0.9, 75 years+: ≥0.8	45.3 (36.2-54.6)	48.0 (33.3-63.0)	39.8 (25.4-55.6)	51.9 (32.2-71.2)	0.273¶
Vitamin B-2 (mg)	65-74 years: ≥1.0, 75 years+: ≥0.9	19.9 (10.2-33.1)	25.0 (0.02-80.7)	19.5 (5.6-42.2)	11.1 (0.0-60.1)	0.113¶
Vitamin B-6 (mg)	65 years+: ≥1.0	9.4 (1.2-28.5)	12.0 (0.3-44.5)	2.7 (0.0-70.8)	18.5 (1.5-55.8)	0.002¶
Vitamin C (mg)	65 years+: ≥80	11.6 (2.9-28.4)	11.0 (0.3-46.4)	7.1 (0.0-47.3)	22.2 (4.0-53.6)	0.017¶
Calcium (mg)	65-74 years: ≥550, 75 years+: ≥500	5.2 (0.0-32.4)	5.0 (0.0-52.2)	2.7 (0.0-70.8)	11.1 (0.0-60.1)	0.124¶
Magnesium (mg)	65-74 years: ≥230, 75 years+: ≥220	22.5 (12.6-35.2)	30.0 (14.7-49.4)	10.6 (0.3-42.4)	33.3 (12.8-59.3)	<0.001¶
Zinc (mg)	65-74 years: ≥7.0, 75 years+: ≥6.0	5.2 (0.0-32.4)	4.0 (0.0-60.2)	4.4 (0.0-52.2)	9.3 (0.0-52.2)	0.554¶
Nutrients with DG§						
Dietary fiber (g)	65 years+: ≥17.0	66.3 (58.8-73.2)	66.0 (53.2-77.3)	61.1 (48.5-72.6)	77.8 (62.1-89.3)	0.102¶
Salt equivalent (g)	65 years+: <6.5	86.9 (81.8-91.0)	86.0 (76.8-92.6)	83.2 (74.0-90.2)	96.3 (86.4-99.7)	0.060¶
Potassium (mg)	65 years+: ≥2600	83.9 (78.4-88.5)	90.2 (82.6-95.3)	72.0 (60.1-82.0)	92.6 (81.4-98.2)	0.002¶
Protein (% energy)	65 years+: 15-20	54.3 (45.8-62.6)	52.0 (37.7-66.1)	49.6 (35.9-63.3)	68.5 (51.1-82.8)	0.059¶
Fat (% energy)	65 years+: 20-30	48.3 (39.4-57.3)	50.0 (35.5-64.5)	50.4 (36.8-64.0)	40.7 (20.2-63.7)	0.459¶
SFA (% energy)	65 years+: <7.0	78.3 (72.1-83.7)	84.0 (74.3-91.2)	74.3 (63.6-83.3)	75.9 (59.9-88.0)	0.209¶
Carbohydrates (%energy)	65 years+: 50-65	18.7 (9.0-32.4)	17.0 (3.0-43.4)	18.6 (4.8-41.9)	22.2 (4.0-53.6)	0.570¶
Number of nutrients with an inadequate intake††		5.0 (4.0-7.0)	5.0 (4.0-7.0)	5.0 (5.0-6.0)B	6.0 (5.0-7.0)A	0.007††

EAR: estimated average requirement; RAE: retinol activity equivalent; DG: tentative dietary goals for preventing lifestyle-related diseases (LRDs).
†DRIs (units/d), 2020 for Japanese females aged 65-74 and 75+ years old.[14]
‡EAR is the average daily nutrient intake level required in a population, calculated based on the distribution of the measured requirements in a study population. To prevent inadequate intake, EAR was assessed.[14]
§DGs required for the prevention of LRDs were set as the current goals for Japanese individuals to reach the average daily intake of nutrients, and, thereby, prevent LRDs.[14]
¶Chi-square test.
††Kruskal-Wallis test. ABAfter the Kruskal-Wallis test, a multiple comparison test by Dunn-Bonferroni's method was performed to find significant differences ($p<0.05$). A Vegetables and dairy products, B Bread and beverages.

Table 5. Logistic regression analysis of factors associated with a history of falls

Independent variables	Model 1 Crude OR		Model 2 Adjusted[†] OR	
	OR (95% CI)	*p*-value	OR (95% CI)	*p*-value
Dietary patterns				
Bread and beverages	1.00 Reference		1.00 Reference	
Rice and fish and shellfish	0.25 (0.10-0.41)	<0.001	0.41 (0.16-0.95)	0.036
Vegetables and dairy products	0.28 (0.10-0.45)	<0.001	0.30 (0.12-0.78)	0.014
Nutrient intake				
Vitamin C (mg/day, continuous)	0.97 (0.96-0.99)	0.007	0.96 (0.95-0.97)	<0.001
Magnesium (mg/day, continuous)	0.99 (0.99-1.01)	0.164	-	-
Potassium (mg/day, continuous)	-	-	-	-
Frailty[‡]				
Non-frailty	1.00 Reference		1.00 Reference	
Prefrailty	1.87 (1.13-3.07)	0.014	1.95 (1.03-3.99)	0.034

[†]Adjusted for age as continuous quantity.
[‡]Frailty scores (0–5) were defined as shrinking (one point), low physical activity (one point), exhaustion (one point), weakness (one point), and slowness (one point). A score of 1 or 2 was classified as indicating prefrailty.



Graphical abstract.

lish a causal relationship falls and the nutritional state. Second, self-reports of the incidence of falls rely on a subject's ability to recall past events. This may lead to a recall bias and the under- or overestimation of the incidence of falls.[41] However, we note that the incidence of falls in our study cohort was equivalent to those recently reported in Japan and internationally.[6,23] Third, since our sample size was small, we had to limit the inclusion of variables for adjustments in the binomial logistic regression analysis. This may have resulted in residual confounders. Fourth, we were unable to take into account the intake of dietary supplements in the nutrition calculation because the current the Standard Tables of Food Composition in Japan[19] does not have reliable data on dietary supplements. Fifth, participants were students at the Elders College and were not randomly selected from the community. Since participants were healthy older females, data on the incidence of falls and prefrailty may be an underestimation. As such, it is not entirely clear whether the results obtained from our study cohort may be generalized to populations living in other communities. Finally, we were unable to obtain data on medications that were prescribed by physicians and dental professionals. Therefore, we did not evaluate the impact of the type and number of medications that are considered to be risk factors for falls. These limitations need to be carefully considered when interpreting the results of the present study.

Conclusion

This study confirmed that 'rice and fish and shellfish' and 'vegetables and dairy products' of dietary patterns were associated with a reduced falls in community-dwelling older Japanese females. Prospective studies with a larger sample size, including older males, are necessary to confirm whether these dietary patterns can prevent falls in older females.

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AUTHOR DISCLOSURES

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Supplementary table 1. Comparison of intakes by food groups in falls and non-falls groups

Food groups† (g/day)	Falls (n=73)	Non-falls (n=194)	*p*-value‡
	Median (IQR)	Median (IQR)	
Cereals	395 (335, 442)	413 (338, 470)	0.705
Potatoes	56 (30, 91)	51 (25, 86)	0.556
Sugar and sweeteners	12 (9, 16)	11 (9, 13)	0.115
Soy products	75 (54, 94)	81 (49, 106)	0.296
Total vegetables	264 (236, 323)	311 (278, 337)	0.011
Green and yellow vegetables	90 (64, 113)	101 (81, 114)	0.015
Fruits	136 (77, 197)	154 (85, 221)	0.124
Algae	6 (5, 9)	7 (5, 11)	0.366
Fish and shellfish	68 (56, 80)	78 (68, 90)	0.007
Meat	56 (38, 71)	60 (41, 73)	0.891
Eggs	31 (21, 49)	29 (17, 49)	0.299
Dairy products	163 (113, 227)	194 (126, 238)	0.054
Fats and oils	14 (12, 16)	16 (11, 17)	0.086
Nuts and seeds	2 (1, 4)	3 (1, 5)	0.079
Confectioneries	53 (36, 62)	49 (28, 60)	0.597
Favorite beverages (excluding alcoholic beverages)	30 (3, 146)	14 (0, 94)	0.106
Alcoholic beverages	2 (1, 8)	1 (-1, 5)	0.014
Seasonings and spices	19 (16, 28)	19 (17, 27)	0.489

IQR: interquartile range.
†Nutrient intakes were energy-adjusted according to the residual method.[20]
‡Mann-Whitney U test.

Supplementary table 2. Basic characteristics of participants classified according to a history of falls

Characteristics	Falls (n=73, 27.3%) Median (IQR) or % (95% CI)	Non-falls (n=194, 72.7%) Median (IQR) or % (95% CI)	*p*-value
Age (years)	76 (71, 79)	73 (70, 76)	<0.001‡‡
65-74	46.6 (29.2-64.5)	58.2 (48.6-67.5)	0.099§§
75+	53.4 (36.7-69.6)	41.8 (30.9-53.3)	
Frailty criteria† of J-CHS			
Shrinking	-	-	-
Low activity	34.3 (16.6-55.9)	24.2 (12.8-39.1)	0.122§§
Exhaustion	21.9 (5.6-49.4)	8.8 (0.2-34.2)	0.006§§
Weakness‡	9.6 (0.01-54.2)	3.1 (0.0-45.9)	0.049§§
Slowness§	19.2 (3.4-48.9)	3.6 (0.0-41.0)	<0.001§§
Frailty†			
Non-frailty	46.6 (29.2-64.5)	68.6 (59.9-76.4)	<0.001§§
Prefrailty	53.4 (36.7-69.6)	31.4 (20.1-44.7)	
Frailty score (0–5)†			
1 deficit	21.9 (5.6-49.4)	23.2 (11.8-38.3)	<0.001§§
2 deficits	31.5 (13.8-54.2)	8.2 (0.2-34.1)	
Grip strength (kg)	21.6 (19.0, 24.5)	22.1 (19.8, 25.1)	0.944‡‡
Gait speed (m/sec)	1.21 (1.02, 1.51)	1.33 (1.26, 1.43)	0.001‡‡
Exercise time (min/day)	30 (0, 60)	35 (15, 75)	0.052‡‡
Body height (cm)	155 (151, 162)	155 (150, 162)	0.942‡‡
Body weight (kg)	52.6 (48.6, 57.7)	53.9 (48.1, 57.9)	0.785‡‡
BMI (kg/m^2)	21.6 (20.4, 23.7)	21.9 (20.8, 23.8)	0.506‡‡
<21.5¶	49.3 (32.2-66.6)	26.8 (15.3-41.0)	0.002¶¶
21.5 - 24.9¶	42.5 (24.9-61.6)	66.5 (57.6-74.6)	
≥25.0¶	8.2 (0.0-45.9)	6.7 (0.01-36.5)	
SBP (mmHg)	138 (125, 150)	135 (126, 147)	0.430‡‡
DBP (mmHg)	78 (74, 88)	77 (72, 85)	0.134‡‡
Living alone [Yes]	26.3 (8.5-51.3)	17.5 (6.4-34.7)	0.125§§
Fracture history [Yes]	30.1 (12.6-53.4)	0	<0.001§§
Presence of disease during treatment [Yes]	80.8 (68.4-90.0)	44.3 (33.6-55.5)	<0.001§§
Comorbidities			
Osteoporosis	26.0 (8.5-51.3)	6.2 (0.01-36.9)	<0.001§§
Diabetes mellitus	38.4 (20.6-58.7)	5.7 (0.01-37.7)	<0.001§§
Hypertension	46.6 (29.2-64.5)	21.7 (10.4-37.1)	<0.001§§
Ophthalmology	35.6 (17.8-56.8)	11.3 (1.4-33.0)	<0.001§§
History of cancer	15.1 (1.1-49.0)	5.7 (0.01-37.7)	0.022§§
Alcohol intake [Yes]	48.0 (30.7-65.5)	37.6 (26.5-49.8)	0.162§§
Dietary supplement use [Yes]	28.7 (11.4-52.6)	21.1 (9.9-36.8)	0.196§§
Current smoker [Yes]	9.6 (0.01-54.2)	4.1 (0.0-36.9)	0.131§§
Physical activity level††			
Low (I)	42.5 (24.9-61.6)	27.3 (15.9-41.1)	0.020¶¶
Medium (II)	57.5 (41.3-72.7)	65.5 (56.5-73.7)	
High (III)	0	7.2 (0.2-34.2)	

IQR: interquartile range; J-CHS: Japanese version of the Cardiovascular Health Study;[16] SBP: systolic blood pressure; DBP: diastolic blood pressure.

†Frailty scores (0–5) were defined as shrinking (one point), low activity (one point), exhaustion (one point), weakness (one point), and slowness (one point). A score of 1 or 2 was classified as indicating prefrailty.

‡Weakness, grip strength <18 kg.[16]

§Slowness, gait speed <1.0 m/s.[16]

¶The BMI category was based on DRIs for Japanese, 2020.[14]

††Categorization is according to DRIs for Japanese, 2020.[14]

‡‡Mann-Whitney U test.

§§Fisher's exact test.

¶¶Chi-square test.

Supplementary table 3. Comparison of nutrient intakes and the nutritional ratio in falls and non-falls groups

Variables	Falls (n=73) Median (IQR)	Non-falls (n=194) Median (IQR)	*p*-value‡
Energy (kcal)	1721 (1507, 1893)	1797 (1580, 1914)	0.078
Energy/body weight (kcal/kg)	33 (28, 37)	35 (29, 42)	0.059
Protein† (g)	67.2 (61.0, 70.8)	70.2 (65.5, 72.9)	0.066
Animal protein† (g)	35.8 (32.4, 41.2)	39.7 (33.4, 42.7)	0.104
Fat† (g)	58.0 (50.7, 62.6)	58.4 (50.6, 62.7)	0.658
SFA† (g)	17.94 (15.02, 18.96)	16.58 (14.73, 19.55)	0.134
n-6 PUFA† (g)	9.84 (8.77, 11.28)	10.13 (9.02, 11.80)	0.412
n-3 PUFA† (g)	2.35 (2.06, 2.95)	2.84 (2.31, 3.10)	0.005
Carbohydrates† (g)	232 (204, 280)	249 (204, 270)	0.372
Dietary fiber† (g)	15.4 (13.3, 16.5)	16.0 (14.1, 18.3)	0.094
Vitamin A† (μg RAE)	691 (590, 872)	733 (592, 993)	0.156
Vitamin D† (μg)	8.0 (7.0, 8.9)	8.5 (7.7, 11.2)	0.004
Vitamin E† (μg)	7.2 (6.5, 7.8)	7.4 (6.5, 8.4)	0.056
Vitamin K† (μg)	250 (201, 291)	266 (218, 348)	0.076
Vitamin B-1† (mg)	0.89 (0.81, 1.02)	0.89 (0.76, 0.97)	0.429
Vitamin B-2† (mg)	1.19 (1.01, 1.32)	1.28 (1.00, 1.48)	0.056
Niacin† (mg NE)	27.7 (25.0, 30.9)	29.0 (25.9, 34.9)	0.310
Vitamin B-6† (mg)	1.20 (1.03, 1.33)	1.33 (1.13, 1.55)	0.003
Vitamin B-12† (μg)	7.4 (6.2, 8.4)	8.6 (6.7, 11.8)	0.002
Folate† (μg)	346 (310, 387)	365 (312, 461)	0.068
Pantothenic acid†(mg)	5.60 (4.94, 6.08)	6.08 (5.59, 6.51)	0.097
Vitamin C† (mg)	103 (79, 117)	118 (94, 142)	<0.001
Sodium† (mg)	3303 (2967, 3956)	3611 (2882, 4635)	0.154
Salt equivalent† (g)	9.2 (8.3, 10.3)	8.9 (7.2, 11.1)	0.137
Potassium† (mg)	2348 (2233, 2432)	2372 (2232, 2480)	0.140
Calcium† (mg)	694 (599, 782)	747 (656, 847)	0.012
Magnesium† (mg)	233 (213, 261)	249 (224, 286)	0.007
Phosphorus† (mg)	1122 (1040, 1264)	1131 (998, 1229)	0.655
Iron† (mg)	7.3 (6.7, 8.4)	7.7 (6.9, 9.3)	0.204
Zinc† (mg)	8.4 (7.9, 8.7)	8.5 (8.1, 9.1)	0.109
Copper† (mg)	1.13 (1.04, 1.27)	1.15 (1.07, 1.30)	0.107
Manganese† (mg)	3.45 (3.18, 3.79)	3.49 (3.27, 3.86)	0.487
Selenium† (μg)	59 (55, 65)	63 (55, 68)	0.077
Protein† energy ratio (% energy)	14.9 (13.6, 17.1)	15.9 (14.0, 17.2)	0.740
Animal protein† ratio (%)	54.5 (50.7, 57.5)	55.2 (49.3, 60.3)	0.403
Fat† energy ratio (% energy)	29.4 (26.7, 33.2)	29.0 (26.2, 31.9)	0.063
SFA† energy ratio (% energy)	9.3 (7.6, 11.0)	8.4 (7.2, 10.7)	0.166
Carbohydrate† energy ratio (% energy)	54.9 (50.6, 59.0)	55.1 (50.1, 58.8)	0.053

IQR: interquartile range; RAE: retinol activity equivalent; NE: niacin equivalents.
†Nutrient intakes were energy-adjusted according to the residual method.[20]
‡Mann-Whitney U test.