Original Article

Low vegetable intake increases the risk of fall-related fragility fracture in postmenopausal Taiwanese women, a prospective pilot study in the community

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ABSTRACT

Background: The aim of this prospective study was to investigate the relationship between lifestyle factors including nutrition intake and the incidence of fall-related fragility fractures in postmenopausal women.
Methods: A total of 1169 female volunteers were recruited from participants at the morning health examinations held at each local public health center in the West Chiayi County of Taiwan at the beginning of the study. Laboratory examinations, anthropometric measurements, and questionnaire interviews inquiring about lifestyle factors, including weekly nutrition intake, were performed. Subsequently, four follow-up telephone interviews at intervals of about 6–12 months were performed to inquire about instances of falls and fractures.
Results: Nine hundred and fifty-three subjects responded at least once to the four telephone interviews, and there were 183 postmenopausal women, with a mean age of 68.8 ± 8.3 (49–87) years, reporting falls. Of the 183 women, 25 had incurred new fractures from low-energy impacts. Statistical analysis revealed that older age and hypertension were associated with increased risks of falling. Intake of other deep-colored (nondark-green) vegetables and light-colored vegetables as well as total vegetable intake were associated with reduced risk of fall-related fragility fracture.
Conclusion: Among postmenopausal women, older age and the presence of hypertension were associated with increased risks of falls. Increased vegetable intake might be helpful to reduce the incidence of fall-related fragility fractures.

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At a glance commentary

Scientific background of the subject

Osteoporosis is a major public health issue. To identify modifiable risk factors and to develop corresponding strategies to help prevent osteoporosis is crucial, especially for postmenopausal women. There is increasing evidence suggesting a positive association between intake of vegetables and bone health. The results, however, have not been always consistent.

What this study adds to the field

This prospective study has yielded more evidence that adequate vegetable intake might reduce the risk of fall-related fragility fractures for Taiwanese post-menopausal women. It might be recommended that individuals consume vegetables at least 2 times a day for better bone health.

Osteoporosis is a major public health issue. An estimated 56 million cases of osteoporotic or fragility fractures were reported worldwide in 2000 [1]. Osteoporotic fractures lead to pain, functional limitation, and increased the risk of death. Elderly people, especially postmenopausal women are particularly at increased risk [2,3]. It was reported that the prevalence of osteoporosis in Taiwanese men and women over 50 years old was 23.9% and 38.3%, respectively [4]. Nearly one-third of Taiwanese women in their lifetime would have at least one fragility or osteoporosis fracture and the mortality rate within the 1st year of hip fracture is as high as 15% [5]. Thus, to identify modifiable risk factors and to develop corresponding strategies to help prevent osteoporosis is crucial.

The association between bone health and lifestyle factors, especially dietary intake has been highly discussed in literature. There is increasing evidence suggesting a positive association between intake of vegetables and bone health. The results, however, have not been always consistent. Some studies revealed a positive association between consuming vegetables and bone mineral density (BMD) [6−8] and reduced fracture risk [9,10], but other studies have not shown this same results [11−13]. A majority of the studies that have produced positive findings were either cross-sectional or had a case-control design. Few prospective or longitudinal studies have shown direct links between vegetable consumption and the incidence of fractures. Besides, most of these studies have been conducted in European or American countries, and the evidence in the Asian populations is still relatively lacking, especially in Taiwan. In addition, dietary patterns and lifestyle may be quite different between Asian and Western populations, and thus the current findings may not be totally applicable to the Asians. For example, the Taiwanese population consumes much less dairy products (0.8−0.9 servings/day) than those in Western countries, but most of them consume an adequate amount of vegetables (around three servings a day) [14]. Therefore, the aim of this prospective study was to investigate the relationship between lifestyle

factors, including nutrition intake, and the incidence of fall-related fragility fractures in the Taiwanese postmenopausal women.

Methods

This study was based on community geriatric medical research in the West Chiayi County, Taiwan. Female volunteers were recruited for this prospective observational study from participants in the morning health examinations held at each local public health center. All enrolled subjects underwent fasting blood sampling and anthropometric measurements. Trained research assistants then conducted in-person interviews with all subjects. All subjects were then interviewed by telephone to inquire about the occurrence of any falls or fractures; these interviews were conducted in 12 months, 18 months, 2 years, and 2½ years after the initial interviews. Informed consent was obtained from all participants, and the study was approved by the local Institutional Review Board of Chiayi Chang Gung Memorial Hospital, a regional teaching hospital.

Anthropometric and laboratory examinations

Body weight, height, and waist and hip circumference were measured with participants wearing light clothing and without shoes. Body mass index (BMI, kg/m²) was calculated from body weight and height. Brachial arterial blood pressure levels were obtained with an automatic blood pressure monitor after the subjects were at rest at least for 15 min. Three separate measurements were made. Left side brachial blood pressures were measured first, immediately followed by measurement on the right side, and then on the left once more. Mean systolic and diastolic pressures were established by calculating the mean of the three measurements. Laboratory studies included measurement of the levels of serum blood urea nitrogen, creatinine, total cholesterol, low-density lipoprotein cholesterol, high-density lipoprotein cholesterol, triglyceride, glucose, and glycohemoglobin (HbA1c).

Lifestyle questionnaire

All participants were interviewed with a comprehensive questionnaire. Dietary habits and lifestyle factors including lacto-ovo vegetarianism, vegetarianism, smoking, milk, coffee, tea and alcohol consumption, exercise, and employment as a manual laborer were recorded. Further information was collected about the amounts, frequencies, and duration of the individual's lifestyle habits if the subject exhibited certain dietary habits. Use of supplemental calcium and additional medicine for osteoporosis were also recorded with showing the samples or pictures of common anti-osteoporotic drugs including Fosamax, Evista, salmon calcitonin nasal spray, and Forteo to the subjects. Habitual tea or coffee drinkers were defined as those who had drunk tea or coffee for 4 or more days/week for 5 years or longer. Subjects with habitual milk consumption were defined as those who had drunk seven or more glasses per week for 5 years or longer. Habitual

exercisers were defined as those who had exercised 3.5 or more hours/week for 5 years or longer.

Each subject's past medical history (including hypertension, diabetes mellitus, hyperlipidemia, liver diseases, renal diseases, blurred vision, stroke, previous fracture, and menstrual status) was recorded. If the subject reported having liver or renal disease, the liver or renal disease was defined further. A supplemental questionnaire (also face to face) involving semi-quantitative nutrition intake was administered 6 months to 1 year later because these information not included in the initial questionnaire were found to be possibly helpful after initial analysis. In this questionnaire, subjects were asked about the frequency (the frequency per day and week were used to calculate the total weekly frequency) and duration of several kinds of food consumed. These foods included fruits (including fresh fruit juice); dark-green vegetables (including green peppers, broccoli, and dark-green leafy vegetables such as spinach, chrysanthemum, and bok choy); other deep-colored vegetables (including deep yellow vegetables such as carrots, pumpkin, sweet potatoes, tomatoes, and yellow pepper; dark-red vegetables such as red peppers, red phoenix vegetables, and red amaranth; and others such as eggplant); light-colored vegetables (such as kale, cabbage, bamboo shoots, radish, cauliflower, white gourd, cabbage, Chinese cabbage, and celery); algae (such as a variety of mushrooms, shiitake, fungus, kelp, wakame, and seaweed); soy products (such as bean bag, bean curd, and tofu); eggs (including chicken, duck, and quail eggs); fish; meats (including pork, chicken, and duck); and organ meats (such as liver, heart, kidney, and large and small intestine from a variety of animals).

Telephone interview on falls and fractures and the definition of fragility fracture

Participants were asked about any falls or fractures that had occurred since the interview. A fall was defined as "falling with landing on the ground or lower level." When a fracture was reported, the site and cause of fracture were also recorded. Fractures from accidental falls that occurred during standing, walking, running, jumping, or riding a bicycle at slow speed were defined as fragility fractures and were thought to be closely related to reduced bone strength. Meanwhile, fractures caused by falling from a height (falling more than one floor) and due to traffic accidents involving a car, motorcycle, or by riding a bicycle at high speed were defined as high-energy-impact fractures, these fractures are not attributed to bone strength but an irresistible trauma.

Data analysis

The variables between subjects with and without fall accident were analyzed. Among the subjects with at least once of fall accident, the variables between subjects with or without fragility fracture were also analyzed. The independent sample t-test or Mann–Whitney U-test (for variables not normally distributed) were used for continuous variables analysis while Pearson's Chi-square test or Fisher's exact test were used for categorical variables. Binary logistic regression analyses were used for multivariate analysis, and odds ratios were calculated with a 95% confidence interval (CI). A $p < 0.05$ was considered significant for all tests. Statistical analysis was carried out using SPSS 12.0 software (SPSS, Inc., Chicago, IL, USA).

Results

During the 3 years, from September 2008 to August 2011, a total of 1169 subjects were included in the beginning of the study and there were 1038 female completed the two comprehensive questionnaires. Among 1038 subjects, the number of participants who responded to the first to fourth telephone interviews was around 700–900 with a responsive rate of 71.9%, 67.9%, 85.0%, and 75.0%, respectively [Fig. 1]. After excluding participants who were not menopausal or those who had received anti-osteoporotic treatments, such as hormone replacement therapy, 953 subjects had responded at least once during the four telephone interviews. Among these, 183 women, with a mean age of 68.8 ± 8.3 (49–87) years, had experienced at least one fall [Fig. 1].

Older age and a past medical history of diabetes, hypertension, and lower weekly intake frequency of fruit were associated with a fall, but HbA1c level, mean systolic or diastolic blood pressure, and the other food items weekly intake frequencies were not related to an increased risk of falling. Subjects who had a previous history of fracture or shorter stature tended to have a greater risk of falling, although this did not reach statistical significance. Binary logistic regression included all of the variables that had an impact on accidental falls noted in univariate analysis and revealed that older age and the presence of hypertension were independently associated with falling. Subjects with diabetes or a previous history of fracture tended to have a higher risk of falling, although this did not reach statistical significance [Table 1, other variables not associated with fall were not shown].

Among 183 women who had falls, 25 had fragility fractures. The case number of each fragility fracture site is shown in Table 2. Table 3 provides a comparison of anthropometry, laboratory test results, lifestyle, and nutrition intake variables between subjects with and without fragility fractured. The weekly intake of other deep-colored vegetables, light-colored vegetables, and total amount of vegetables (including dark-green, other deep-colored, and light-colored vegetables) was significantly lower among women in the fragility fracture group than among those in the nonfragility fracture group. For some variables, the case numbers were so small that these variables were not considered to be valuable for statistical analysis and thus are not included. Some of these variables are smoking ($n = 6$), habitual coffee drinking ($n = 12$), alcohol consumption ($n = 17$), rheumatoid arthritis ($n = 5$) in the analysis for comparison of subjects with or without falling; and blurred vision ($n = 4$), stroke ($n = 1$), lacto-ovo vegetarianism ($n = 4$) and vegetarianism ($n = 1$) in the analysis for comparison of subjects with or without fragility fracture. None of the subjects reported having liver cirrhosis or severe renal disease. For variables reaching statistical significance, such as other deep-colored vegetables, light-colored vegetables, and total vegetable consumption, binary logistic

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┌─────────────────────────────────────────────────┐
│ Initial interview: anthropometric measurement,   │
│ blood sampling and 1st questionnaire interview:   │
│ female = 1169                                     │
└─────────────────────────────────────────────────┘
                      ↓
┌─────────────────────────────────────────────────┐
│ Nutrition intake frequency interview:             │
│ female = 1038                                     │
└─────────────────────────────────────────────────┘
                      ↓
┌─────────────────────────────────────────────────┐
│ 1st telephone interview in one year from initial  │
│ interview: 746                                    │
│ fall: 44, fragility fracture: 11, fracture from   │
│ high energy impact: 5                             │
└─────────────────────────────────────────────────┘

┌─────────────────────────────────────────────────┐
│ 2nd telephone interview in 1.5 years from initial │
│ interview: 705                                    │
│ fall: 68, fragility fracture: 5, fracture from    │
│ high energy impact: 3                             │
└─────────────────────────────────────────────────┘

┌─────────────────────────────────────────────────┐
│ 3rd telephone interview in 2 year from initial    │
│ interview: 882                                    │
│ fall:66, fragility fracture: 5, fracture from     │
│ high energy impact: 1                             │
└─────────────────────────────────────────────────┘

┌─────────────────────────────────────────────────┐
│ 4th telephone interview in 2.5 year from initial  │
│ inverview, 778;                                   │
│ fall:54, fragility fracture: 6, fracture from     │
│ high energy impact: 0                             │
└─────────────────────────────────────────────────┘
                      ↓
┌─────────────────────────────────────────────────┐      ┌─────────────────────────────┐
│ Subjects with at least response once in           │ ───→ │ No response to telephone    │
│ the four times of telephone interview:            │      │ at all: 13                  │
│ 953                                               │      │ Not postmenopausal: 68      │
└─────────────────────────────────────────────────┘      │ Hormone replacement         │
                      ↓                                    │ therapy: 1, other           │
                                                           │ anti-osteoporotic drugs: 0  │
                                                           └─────────────────────────────┘

                                                           ┌─────────────────────────────┐
                                                     ───→ │ No fall accident:           │
                                                           │ 770                         │
                                                           └─────────────────────────────┘
┌─────────────────────────────────────────────────┐
│ Subjects with fall accident: 183                  │
└─────────────────────────────────────────────────┘
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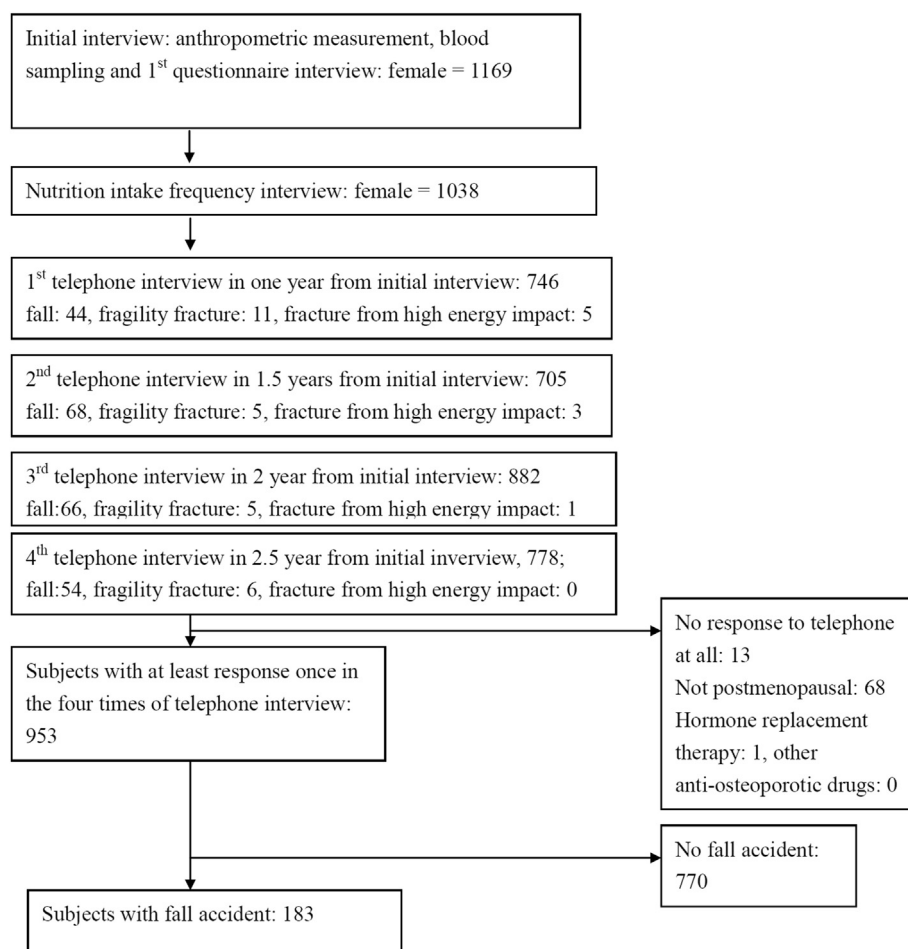
Fig. 1 – Subjects flow diagram showing the steps of the case enrollments.

regression was used to investigate the odds ratio, adjusted by age and BMI. Subjects were divided into two groups by different intake frequency for comparison. The results of all of the possible groupings by each intake frequency were analyzed. The highest statistical significant cut point of weekly intake frequency for other deep-colored vegetable and light-colored vegetable were both 6 times/week, and that for total vegetable was 15 times/week. For example, for light-colored vegetable, the *p* value of binary logistic regression in comparison of weekly intake frequency with six versus fewer than six, seven versus fewer than seven, eight versus fewer than eight were 0.029, 0.036, and 0.163, respectively. Therefore, 6 times was the cut point frequency of such kind of food. Each corresponding value of odds ratio are shown in Table 3.

Discussion

The results of this study revealed that older age is associated with increased risk of accidental falls, a fact that is generally known [15,16]. Falls are a major threat to the elderly, and the risk for such falls is greater among women [17]. Women are also more likely to develop osteoporosis, which results in more fall-related osteoporotic fractures [18]. In some studies, diabetes and previous falls with a fracture history were also reported to be associated with increased risk of falling [19,20]. In the present study, women with self-reported diabetes and a history of fracture tended to have greater risk of falling, although this did not reach statistical significance.

A self-reported history of hypertension disregarding the value of blood pressure is an independent risk factor for falling. Several studies have addressed the relationship between blood pressure and the risk of falling in the elderly. One has pointed out that aging could result in insufficient blood pressure homeostasis, such as orthostatic hypotension, which could be exacerbated by hypertension [21]. Gangavati et al. reported that orthostatic hypotension occurred mostly in the elderly with uncontrolled hypertension rather than among individuals with controlled hypertension or without hypertension. The elderly who have uncontrolled hypertension with systolic orthostatic hypotension are at greater risk of falling [22]. However, on the other hand, many other studies have reported that strict antihypertensive pharmacotherapy could also increase the risk of falling in the elderly [23,24], which might partially explain why the value of blood pressure did not show a significant association with the risk of fall in this study. Since preventing falls among the elderly is a nationally important health promotion issue [25], efforts should be made to pay even more attention to older people with chronic diseases such as hypertension and diabetes.

Table 1 — Characteristics of subjects with fall or not.

Variables	Subjects with fall		Subjects without fall		Univariate analysis	Binary logistic regression analysis	
	n	Mean ± SD, percentage	n	Mean ± SD, percentage	p	OR[e] (95% CI)	p[e]
Age (year-old)	183	68.8 ± 8.3	770	66.4 ± 8.4	<0.001[a]	1.02 (1.00—1.05)	0.027
Body height (cm)	182	151.7 ± 5.1	765	152.5 ± 5.6	0.064[a]	0.98 (0.95—1.02)	0.308
Body weight (kg)	182	58.1 ± 9.1	765	57.9 ± 9.3	0.760[a]		
BMI (kg/m^2)	182	25.3 ± 3.7	765	24.9 ± 3.6	0.196[a]		
Waist circumflex (cm)	182	83.2 ± 9.6	762	82.3 ± 9.4	0.283[a]		
Hip circumflex (cm)	175	96.6 ± 8.5	747	96.2 ± 7.9	0.552[a]		
Systolic blood pressure (mmHg)	182	140.7 ± 20.0	761	139.1 ± 19.6	0.331[a]		
Diastolic blood pressure (mmHg)	182	83.5 ± 11.4	761	82.6 ± 10.8	0.349[a]		
Hypertension	183	43.2 (79/183)	770	29.9 (230/770)	0.001[b]	1.54 (1.08—2.18)	0.016
Diabetes	183	17.5 (32/183)	770	10.9 (84/770)	0.014[b]	1.58 (1.00—2.50)	0.051
Fasting glucose	178	108.9 ± 38.4	759	105.3 ± 29.6	0.230[a]		
HbA1c	180	6.1 ± 1.2	760	6.0 ± 1.1	0.192[a]		
Fruit intake (frequency)	183	6.0 ± 4.1	770	6.5 ± 3.9	0.023[c]	0.97 (0.93—1.02)	0.192
Previous fracture history	183	23.0 (42/183)	770	17.1 (132/770)	0.068[b]	1.44 (0.97—2.15)	0.072
Blurred vision	183	2.2 (4/183)	770	2.1 (16/770)	>0.99[d]		
Stroke	183	0.5 (1/183)	770	0.5 (4/770)	>0.99[d]		
Exercise	183	22.0 (39/183)	770	25.9 (195/770)	0.283[b]		
Labor worker	183	15.4 (20/183)	770	17.9 (98/770)	0.499[b]		

Abbreviations: n: Case number; BMI: Body mass index; CI: Confidence interval; SD: Standard deviation; HbA1c: Glycohemoglobin.
[a] Determined by independent sample t-test.
[b] Determined by Pearson's Chi-square test.
[c] Determined by Mann—Whitney U-test.
[d] Determined by Fisher's exact test.
[e] Determined by binary logistic regression (dependent variable: Fall, covariates: age, body height, hypertension, diabetes, previous fracture history).

Subjects with fall-related fragility fractures were compared with those who had fallen but had not incurred fractures, and the results indicate that total vegetable intake is inversely associated with fall-related fragility fracture incidence in postmenopausal women. In contrast, other variables such as milk consumption, BMI, and exercise habit had no obvious association with fracture risk. Since the subjects without any fall accident in the observation period was already excluded in the analysis, the results here might be considered as that increased vegetable intake was associated with better bone strength rather than decreased the risk of falling. Although our study results show that other deep-colored vegetables and light-colored vegetables (but not dark-green vegetables) are associated with reduced risk of fragility fractures, one cannot interpret this as that other deep-colored vegetables and light-colored vegetables are superior to dark-green vegetables for bone health. In fact, our subjects consumed dark-green vegetables more frequently than the other two kinds of vegetables [Table 3], and the results should be interpreted in light of the overall relatively low intake of the two other kinds of vegetables. There is currently no specific evidence addressing which kinds of vegetables are more valuable for bone health. Besides, dark-green vegetables, especially green leafy vegetables are reported to be a very important source of dietary

Table 2 — Case number of each fragility fracture sites.

Fracture sites	n
Hand and wrist	5
Humerus	2
Rib	3
Spine	4
Femur (including hip)	5
Lower limbs other than femur	6
Total	25

Table 3 – Comparison between subjects with and without fragility fracture.

Variables	Subjects with fragility fracture		Subjects without fragility fracture		Univariate analysis	Multivariate analysis	
	n	Mean ± SD, percentage	n	Mean ± SD, percentage	p	OR[e] (95% CI)	p[e]
Age (year-old)	25	69.0 ± 8.8	158	68.7 ± 8.2	0.870[a]		
Body height (cm)	25	151.2 ± 6.7	157	151.7 ± 4.8	0.634[a]		
Body weight (kg)	25	56.7 ± 9.6	157	58.4 ± 9.0	0.384[a]		
BMI (kg/m^2)	25	24.7 ± 3.6	157	25.3 ± 3.7	0.440[a]		
Waist circumflex (cm)	25	83.1 ± 7.0	157	83.2 ± 10.0	0.990[a]		
Hip circumflex (cm)	25	97.5 ± 6.7	157	96.4 ± 8.8	0.570[a]		
Bun	24	17.5 ± 5.2	156	15.9 ± 4.5	0.108[a]		
Creatinine	24	0.8 ± 0.2	156	0.8 ± 0.2	0.419[a]		
Cholesterol	24	216.1 ± 41.1	157	208.0 ± 38.2	0.338[a]		
HDL	25	59.0 ± 11.9	158	57.0 ± 12.7	0.445[a]		
LDL	25	137.5 ± 32.9	157	131.9 ± 34.8	0.453[a]		
Triglyceride	24	131.5 ± 63.6	157	125.6 ± 67.6	0.687[a]		
Fasting glucose	24	114.3 ± 39.9	154	108.1 ± 38.2	0.468[a]		
HbA1c	24	6.2 ± 1.4	156	6.1 ± 1.2	0.618[a]		
Uric acid	24	5.5 ± 1.9	157	5.5 ± 1.3	0.983[a]		
Hypertension	25	36.0 (9/25)	158	44.3 (70/158)	0.436[b]		
Diabetes mellitus	25	20.0 (5/25)	158	17.1 (27/158)	0.777[c]		
Previous fracture history	25	20.0 (5/25)	158	23.4 (37/158)	0.706[b]		
Exercise habit	25	32.0 (8/25)	158	29.5 (47/158)	0.819[b]		
Labor worker	25	12.0 (3/25)	158	10.8 (17/158)	>0.99[c]		
Calcium tablet	25	32 (8/25)	158	23.4 (37/158)	0.354[b]		
Habitual milk intake	25	16.0 (4/25)	158	20.9 (33/158)	0.572[b]		
Habitual tea intake	25	8.0 (2/25)	158	10.8 (17/158)	>0.99[c]		
Various food intake frequency							
Egg	25	1.7 ± 1.3	158	2.0 ± 1.8	0.919[d]		
Fish	25	7.2 ± 4.3	158	7.0 ± 4.6	0.739[d]		
Meat	25	3.7 ± 2.8	158	4.5 ± 3.7	0.475[d]		
Offal food	25	0.1 ± 0.3	158	0.3 ± 0.8	0.230[d]		
Algae	25	1.2 ± 1.2	158	1.9 ± 2.2	0.120[d]		
Soy product	25	1.4 ± 1.7	158	1.7 ± 2.1	0.471[d]		
Fruit	25	6.1 ± 3.7	158	6.0 ± 4.2	0.570[d]		
Dark-green vegetable	25	7.9 ± 4.4	158	8.6 ± 4.4	0.431[d]		
Other deep-colored vegetable	25	5.1 ± 3.8	158	6.6 ± 4.2	0.024[d]	3.00[f] (1.06–8.53)	0.039
Light-colored vegetable	25	5.6 ± 3.3	158	7.7 ± 4.3	0.021[d]	2.70[f] (1.07–6.85)	0.029
Sum of vegetable	25	18.6 ± 9.9	158	22.8 ± 11.1	0.037[d]	2.88[g] (1.22–6.84)	0.016

Abbreviations: n: Case number; BMI: Body mass index; HDL-C: High-density lipoprotein cholesterol; LDL-C: Low-density lipoprotein cholesterol; HbA1c: Glycohemoglobin; CI: Confidence interval; OR: Odds ratio.

[a] Determined by independent sample t-test.
[b] Determined by Pearson's Chi-square test.
[c] Determined by Fisher's exact test.
[d] Determined by Mann–Whitney U-test.
[e] Determined by binary logistic regression. Dependent variable: Fragility fracture or not, covariates: Food item divided into two groups, age and body mass index. Each food item (including dark-green, other deep-colored, light-colored vegetable and sum of vegetable) was analyzed by each binary logistic regression model to avoid multicollinearity.
[f] OR for weekly intake frequency <6 versus ≥6.
[g] OR for weekly intake frequency <15 versus ≥15.

calcium and usually contribute more calcium than other vegetables [8,14].

Although there was increasing evidence of the benefits of vegetable intake on bone health, the exact mechanisms remain unclear. Vegetables contain many nutrients that might be beneficial to bone health including many minerals, flavonoids, carotenoids, omega-3-fatty acids, and Vitamins A, C, E, and K [26,27]. Vegetables are the second most important dietary source of calcium for the Taiwan's elder population

(149.0 mg/day), just after dairy products (257.5 mg/day), which comprises 24% of total daily calcium intake [14].

Another hypothesis centers on the effect of acid-base balance on bone. Adequate protein and energy intake are thought to be essential for bone health [28]; however, the dietary source of major energy and protein are all acid-forming, such as meat, fish, soybean, dairy products, and cereal. Thus, bone mineral dissolution to buffer these acid loads can develop if a diet lacks enough alkaline-forming foods such as fruits and

vegetables [29]. This is shown in research examining the relationship between urinary calcium excretion, markers of bone turnover, and dietary intake [30,31]. The mean daily protein intake for Taiwanese women is 59.5 g/day (16.8% of daily energy intake), which is higher than recommended levels (10—14% of daily energy intake) [14]. In this case, adequate vegetable intake might be crucial.

Some studies have reported that intake of calcium or dairy products is associated with increased BMD or reduced fracture risk; however, the results have not always been conclusive [32]. Dairy products are the most important dietary sources of calcium and Vitamin D and are thought to be important in osteoporosis prevention [14,26]. However, in several recent long-term prospective studies with fragility fracture as the observation end-point, no obvious association was found between the intake of dairy products and the occurrence of fracture [33—35]. It is worth mentioning that in Benetou et al.'s study, intake of dairy products showed no obvious association with hip fracture incidence. However, there is a weak and statistically nonsignificant evidence to suggest that vegetables are helpful in reducing fracture risk [33]. This puzzling result might be due to the fact that milk or dairy products contain some nutrients that are also detrimental to bone health and that may offset its benefit, for example, protein acid load or Vitamin A [36]. In addition, behavioral changes due to health problems may also confound the investigation of the causal relationship in longitudinal observational studies. Subjects who knew they were likely to have greater risk of osteoporosis would have higher motivation to increase their intake of milk or calcium supplements [34] which would interfere with analysis of the effect of these two variables.

BMI is well-known to be positively associated with BMD; however, its impact on fracture risk can be complicated and site-dependent. It has been reported that obesity is protective for hip fracture but associated with increased humerus, ankle, and leg fractures [37,38]. In this study, various fracture sites were included, and therefore, it was not expected that there would be a significant correlation between BMI and fragility fracture.

Similarly, exercise is known to be positively associated with BMD in pre- and post-menopausal women [39], but its impact on fall-related fragility fractures is still obscure. In Kemmler et al.'s systematic review and meta-analysis, the authors stated that although there is evidence to suggest exercise can reduce the overall incidence of fractures and to a lesser degree, vertebral fractures in the elderly, however, publication biases were obviously noted in the analysis [40]. This is a reflection of the fact that trials showing a positive connection between exercise and reduced fracture risk are published much more often than those showing negative or null findings. Furthermore, one recent Japanese study addressing lifestyle variables and osteoporosis in middle-aged and elderly women revealed that exercise is associated with increased incidence of fractures [41]. This might be partially explained by the fact that some types of exercise are associated with the increased risk of falls such as bicycling. It indicates that exercise should be carefully performed, especially for the elderly.

There were several limitations in the present study. First, the sample size and observation time were limited, which

could cause insufficient statistical power for analysis of some variables and limited reproducibility of the results. Second, the subjects were not randomly enrolled but were volunteers drawn from people attending the morning health examinations. These people might pay more attention to health than those in the general population and were not nationally representative. Therefore, such selection bias should be considered while interpreting the results of this study. For example, they might consume more dark-green vegetables than the general population and this might reduce the significance of the relationship between dark-green vegetables intake and fall-related fractures in the analysis. Third, possible recall bias and information bias should also be considered since the information about lifestyle variables and the occurrence of fracture were obtained through questionnaire and telephone interview, respectively. For example, use of medicine such as anti-osteoporotic drugs might be underreported as some subjects could not recognize or remember the drugs they used. On the other hand, lack of awareness of vertebral compression fractures in some subjects might result in underestimated fracture incidence. However, since most fractures, especially nonvertebral fracture would cause severe symptoms including intractable pain, swelling, and functional disability, leading individuals to seek medical assistance; we assume most participants could respond adequately about the occurrence of fractures during the telephone interviews within the 6—12-month interval. Nevertheless, on the other hand, the response rate of each telephone call interview to collect the information about falls and fracture was only 67.9—85.0%. Thus, among 183 subjects with accidental falls, those who responded more often or at the later times would have more chances to report a fracture. All of these factors would result in nondifferential misclassification and could thus dilute the association between variables. The fourth limitation was that the measurement of various kinds of food intake was done semi-quantitatively by total weekly frequency. Detailed information about the amount of intake of each nutrient component is not available. Therefore, the results were analyzed based merely on intake frequency rather than exact amount of food. Besides, BMD report of the subjects was not available in this study. Thus, lifestyle related BMD change could not be known. However, the results of the present study might be more directly related to fracture risk itself by using the incidence of fall-related fragility fracture as the outcome measure, since the bone strength is determined not only by BMD but also other factors such as bony microarchitecture.

Despite these limitations, to our knowledge, this is the first prospective study addressing the direct link between incidents of fall-related fractures and nutrition intake in Taiwan. The results revealed that subjects who consumed other deep-colored vegetables and light-colored vegetables fewer than 6 times a week or who consumed all types of vegetables fewer than 15 times/week were at greater risk for developing fragility fracture (odds ratio: 2.88). In light of these findings, it might be recommended that individuals consume vegetables at least 2 times a day for better bone health, and it is better also to include other deep-colored vegetable and light-colored vegetable in their regular diet. Further prospective cohort studies including larger sample sizes with longer

observation periods are warranted to provide more evidence of modifiable risk factors for fragility fracture prevention.

In summary, among postmenopausal women, older age and the presence of hypertension were associated with increased risks of falls. Increased vegetable intake might be helpful to reduce the incidence of fall-related fragility fractures.

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Conflicts of interest

There are no conflicts of interest.

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