Development of a Simple Food Frequency Questionnaire to Estimate Intakes of Calcium and Other Nutrients for the Prevention and Management of Osteoporosis

Kazuhiro UENISHI¹, Hiromi ISHIDA² and Kazutoshi NAKAMURA³

¹Laboratory of Physiological Nutrition, and ²Laboratory of Administrative Dietetics, Kagawa Nutrition University, Saitama 350-0288, Japan

³Department of Community Preventive Medicine, Niigata University Graduate School of Medical and Dental Sciences, Niigata 951-8510, Japan

(Received May 1, 2007)

Summary There have been no simple methods to estimate dietary nutrient intakes for the prevention and management of osteoporosis. The aim of this study was to develop and validate a new, simple food frequency questionnaire (FFQ) for dietary intake of calcium and other nutrients relevant to the bone health of adult Japanese women. We developed a 28-item FFQ. To validate this, 208 and 72 adult women aged between 18 and 69 y were recruited for testing reliability and reproducibility, respectively. In the 208 women, moderate-to-high Spearman's correlation coefficients between our FFQ and the conventional diet record method were found in intakes of calcium ($r=0.668$), sodium chloride (NaCl) ($r=0.475$), vitamin A ($r=0.501$), vitamin D ($r=0.413$), vitamin K ($r=0.649$), and energy ($r=0.471$). In the 72 women, coefficients of variance of the four repeated measurements of intakes throughout a year were 14.1% for calcium, 7.3% for NaCl, 21.2% for vitamin A, 13.6% for vitamin D, 36.8% for vitamin K, and 9.6% for energy. In conclusion, the FFQ we developed is a useful tool to evaluate the intake of dietary calcium of adult Japanese women. Although it can also measure intakes of dietary vitamin A, vitamin D, vitamin K, NaCl, and energy, further improvement is needed to measure intakes of these nutrients and energy.

Key Words dietary calcium, food frequency questionnaire, Japan, osteoporosis, validation studies

Osteoporosis is characterized by generalized skeletal fragility, and fractures due to osteoporosis have rapidly increased in Japan (1). In this situation, prevention and management of this disease is becoming more enhanced in clinical medicine and public health.

Calcium is an essential nutrient for bone health because its insufficient intake could adversely affect age-related bone loss and attainment of peak bone mass. Likewise, other dietary nutrients, such as vitamin D and vitamin K are known to have an important role for human bone metabolism. Therefore, assessment of intakes of these nutrients from diet is meaningful from the viewpoint of the prevention and management of osteoporosis.

There are several methods to estimate calcium intake. Among them, a food frequency questionnaire (FFQ) is simpler than other methods, such as a diet record or a duplicate portion sampling method, which is heavy a burden for a person to complete. Furthermore, the FFQ has another advantage, enhancing long-term intake of nutrients better than the 24-h recall method (2). For these reasons, the FFQ is considered to be one of the best tools to estimate calcium intake for the prevention and management of osteoporosis. Some

FFQs have been developed to estimate intakes of a wide range of nutrients, including calcium, for Japanese adults (3, 4). However, these FFQs currently used in Japan have many questions and they take a long time to finish, and thus an even shorter FFQ is needed for use in epidemiological and clinical settings. In European and North American countries, there are several simple FFQs specifically developed for estimating calcium intake (5–8); however, there have been few such FFQs validated for Japanese adults.

Recently, some other nutrients, such as iron, sodium chloride (NaCl), vitamin A, vitamin D, and vitamin K, have been suggested to be associated with bone mass (9), and therefore, monitoring intakes of these nutrients as well as calciums is becoming of importance. Nonetheless, there have been no simple methods to estimate dietary intakes of these nutrients. The aim of this study was to develop and validate a simple FFQ for the prevention and management of osteoporosis (FFQPOP) to estimate dietary intake of calcium and other relevant nutrients of adult Japanese women.

METHODS

Procedure for the development of an FFQ. The FFQPOP we developed was based on the semi-quantified food frequency questionnaire developed by the Drafting Com-

E-mail: uenishi@eiyo.ac.jp

Table 1. Mean values of nutrients and energy measured by the FFQPOP¹ and the diet record method in 208 subjects, and Pearson's product moment correlation coefficients of values between the two methods.

Nutrients or energy	Mean values (SD)		Relative difference to diet record (%)	Correlation coefficients ²	
	FFQPOP	Diet record		Pearson's	Spearman's
Calcium (mg/d)	476 (155)	522 (216)	-9	0.676	0.668
Iron (mg/d)	6.9 (2.0)	6.6 (3.7)	5	0.500	0.394
NaCl (g/d)	9.9 (1.9)	7.7 (2.2)	29	0.467	0.475
Vitamin A (μ g RE/d)	797 (421)	727 (641)	10	0.709	0.501
Vitamin D (μ g/d)	9.2 (2.3)	6.5 (4.7)	42	0.403	0.413
Vitamin K (μ g/d)	157 (108)	232 (161)	-32	0.669	0.649
Energy (kcal/d)	1,621 (294)	1,625 (309)	0	0.415	0.471
Protein (g/d)	70.1 (18.1)	58.9 (14.9)	19	0.319	0.339
Lipid (g/d)	62.2 (15.7)	52.0 (15.5)	20	0.307	0.345
Carbohydrate (g/d)	197 (38)	225 (46)	-12	0.394	0.299

¹ Food frequency questionnaire for the prevention and management of osteoporosis we developed.

² $p < 0.001$ for all.

mittee of the Ministry of Health and Welfare for Health Index (10). We selected 19 food items, which are major sources of calcium among Japanese foods, from the questionnaire. In addition, we adopted 9 items, such as nuts and liver, whose calcium content is low but which are major sources of other nutrients related to bone health, such as vitamin A, vitamin D, vitamin K, and energy. In total, the FFQPOP included 28 food items. The FFQPOP is shown in Appendix 1, in which each item includes 3 to 5 grades of frequency of food intake. Subjects were asked to select a grade of frequency in the last 1 mo. Intakes of the nutrients and energy were estimated by a grade of frequency multiplied by the relevant coefficients determined on the basis of the Standard Tables of Food Composition in Japan (11).

Subjects for testing reliability and reproducibility of the FFQPOP. The FFQPOP was validated by setting three populations: 1) 190 female college students aged between 18 and 22 y, and 18 adult females aged between 46 and 69 y to compare mean values of nutrients and energy between the FFQPOP and a conventional method of 3-d diet record with weighing used in the National Health and Nutrition Survey in Japan (12), 2) 30 female college students aged between 19 and 22 y, and 42 adult females aged between 46 and 61 y to evaluate reproducibility by measuring nutrients and energy with the FFQPOP four times a year (every 3 mo), and 3) 190 female college students aged between 18 and 22 y, and 234 adult females aged between 50 and 69 y to compare mean values of nutrients and energy of the FFQPOP with the results of the National Health and Nutrition Survey in Japan (2004) (12).

Statistical methods. Relative differences in values of nutritional intake obtained from the FFQPOP to the dietary record method were calculated. Spearman's correlation coefficients were mainly used to test a correlation between FFQPOP and the diet record method, although both Pearson's and Spearman's correlation coefficients are presented. Coefficients of variance (CVs)

were calculated to show a variation of repeated measurements for nutritional intakes.

RESULTS

Comparison with the diet record method

Average intakes of nutrients and energy measured by the FFQPOP and the diet record method, and correlation coefficients between the two methods are shown in Table 1. High correlation coefficients of near 0.7 were found in intakes of calcium and vitamin K. The relative difference between the FFQPOP and the diet record method was small in calcium (-9%), but the relative difference in vitamin K was larger (-32%) than that of calcium. Moderate correlation coefficients around 0.5 were found in intakes of NaCl, vitamin A, vitamin D and energy. Correlation coefficients for the other nutrients were low.

Reproducibility

Average intakes of nutrients and energy measured four times by the FFQPOP are shown in Table 2. CVs of the four repeated measurements were around 10% except for vitamin A (21.2%) and vitamin K (36.8%).

Comparison with results of the National Health and Nutrition Survey in Japan

Average intake of nutrients and energy measured by the FFQPOP and the results of the National Health and Nutrition Survey in Japan (2004) (12) in the 18-22-y age group and the 50s-and-60s group are shown in Table 3. Relative differences to the National Health and Nutrition Survey tended to be negative except in calcium and vitamin K in the 18-22-y age group, whereas they tended to be positive except in energy. A large difference was observed in vitamin D intake in the 50s-and-60s group.

DISCUSSION

This study demonstrated a high correlation ($r=0.67$) of calcium intakes between the FFQPOP and the diet record method, which implies that the FFQPOP is valid on the individual level. Furthermore, levels of calcium

Table 2. Mean values of nutrients and energy measured repeatedly by the FFQPOP¹ and their coefficients of variance (CVs) in 72 subjects.

Nutrients or energy	Mean value (SD)				Mean of the 4 measurements	CV (%)
	1st	2nd	3rd	4th		
Calcium (mg/d)	562 (159)	485 (157)	523 (148)	495 (151)	517	14.1
Iron (mg/d)	8.5 (2.0)	7.4 (1.9)	7.7 (1.9)	7.3 (2.2)	7.7	15.9
NaCl (g/d)	10.3 (1.9)	9.8 (1.4)	10.2 (1.9)	9.8 (1.6)	10.0	7.3
Vitamin A (μ g RE/d)	977 (430)	934 (388)	958 (552)	910 (478)	945	21.2
Vitamin D (μ g/d)	10.6 (2.5)	10.0 (2.3)	10.2 (2.2)	10.5 (2.4)	10.3	13.6
Vitamin K (μ g/d)	123 (32)	115 (35)	213 (112)	148 (81)	150	36.8
Energy (kcal/d)	1,642 (276)	1,594 (247)	1,623 (233)	1,602 (284)	1,615	9.6
Protein (g/d)	72.7 (15.5)	71.9 (12.6)	71.1 (11.6)	69.9 (14.3)	71.4	12.0
Lipid (g/d)	62.6 (14.5)	59.1 (11.1)	62.5 (11.9)	61.0 (12.0)	61.3	12.4
Carbohydrate (g/d)	202 (39)	198 (40)	199 (40)	198 (49)	199	11.0

¹ Food frequency questionnaire for the prevention and management of osteoporosis we developed.

Table 3. Mean values of major nutrients and energy measured by the FFQPOP¹ in 424 subjects and the results of the National Health and Nutrition Survey in Japan (2004) (12) by age groups in females.

Nutrients or energy	18–22-y-age group			50s-and-60s group		
	Mean (SD)		Relative difference to NHNS (%)	Mean (SD)		Relative difference to NHNS (%)
	FFQPOP	NHNS ²		FFQPOP	NHNS ²	
Calcium (mg/d)	503 (200)	429 (206)	17	585 (166)	568 (286)	3
Iron (mg/d)	6.2 (1.9)	6.8 (2.6)	–9	9.4 (2.5)	8.7 (3.7)	8
NaCl (g/d)	7.5 (2.0)	9.4 (3.5)	–20	10.9 (1.9)	11.2 (4.4)	–3
Vitamin A (μ g RE/d)	634 (301)	740 (650)	–13	1164 (701)	974 (778)	20
Vitamin D (μ g/d)	6.0 (4.5)	6.0 (8.4)	0	12.7 (2.5)	9.1 (9.5)	40
Vitamin K (μ g/d)	224 (155)	212 (179)	6	316 (149)	290 (237)	9
Energy (kcal/d)	1,602 (303)	1,670 (458)	–4	1,702 (292)	1,790 (469)	–5
Protein (g/d)	57.0 (13.3)	62.7 (19.0)	–9	76.4 (17.2)	70.5 (22.6)	8
Lipid (g/d)	51.4 (15.6)	54.0 (22.6)	–5	60.6 (13.1)	49.3 (21.0)	23
Carbohydrate (g/d)	223 (45)	225 (68)	–1	217 (42)	258 (73)	–16

¹ Food frequency questionnaire for the prevention and management of osteoporosis we developed.

² National Health and Nutrition Survey in Japan (2004) (12).

intake estimated by the FFQPOP in this study are comparable to the results of the National Health and Nutrition Survey, suggesting the FFQPOP is valid on the population level. Because of these reasons, the FFQPOP is primarily useful in the assessment of calcium intake for epidemiologic studies and health education in clinical settings.

In general, an acceptable correlation coefficient between an FFQ and the conventional diet record have been considered between 0.5 and 0.7 (2). The correlation coefficient of calcium intake between the FFQPOP and the diet record method was as high as 0.67. This value is better than those (0.52 and 0.53) of general FFQs for Japanese people previously reported (3, 4). Some FFQs have specifically been developed for assessing dietary calcium intake. There have been two FFQs assessing dietary calcium intake for Asians. Sato et al. (13) developed a simple FFQ for estimating calcium

intake for Japanese with a correlation coefficient of 0.51 (vs. 1-d food record), and Chee et al. (14) developed such an FFQ for Malaysian women with a correlation coefficient of 0.56 (vs. 3-d food record). Conversely, FFQs assessing calcium intake in the Western adult diet have yielded a correlation coefficient of 0.64–0.90 between the FFQ and gold standard methods (5–8). Their values are higher than those of calcium FFQs previously developed for Asians (13, 14). Calcium FFQs for North Americans and Europeans generally have good correlation coefficients probably because the amount of calcium intake is higher on average and ranges wider than those for Asians, and because their sources of calcium are simple, depending largely on milk and milk products. Sources of calcium for the Japanese diet are more varied than for the Western diet, and are from dried baby fish, colored vegetables, seaweed, and beans (and bean products) in addition to milk and milk prod-

ucts (12). Despite these facts, the FFQPOP had a similar correlation level to those for Western FFQs. The CV for calcium intake by the FFQPOP was 14%, and its relative difference to National Health and Nutrition Survey was 3–17%, which are acceptable levels. Therefore, the FFQPOP is satisfactorily valid and reproducible to estimate calcium intake.

There have been no simple FFQs to estimate nutrients other than calcium related to bone health. This study first demonstrated that intakes of vitamin K can be measured by the FFQPOP with high correlation to the diet record method. It should be cautioned, however, that the difference in vitamin K intake between the FFQPOP and the diet record method is relatively large, and that reproducibility for intakes of vitamin K is poorer than for other nutrients.

Moderate correlation coefficients between the FFQPOP and the diet record method were found for NaCl, vitamin A, vitamin D, and energy. Among them, the absolute vitamin D intake of the FFQPOP showed a relatively large difference from that of the diet record and National Health and Nutrition Survey (older women only). This should be taken into account, although the primary purpose of an FFQ is not necessarily to obtain the accurate absolute value of a nutritional intake, but to obtain its relative levels in a target population.

There are some limitations in this study. First, the 3-d diet record may not accurately estimate some nutrient intakes such as vitamins although it is often used as a gold standard in many validation studies. Basiotis et al. (15) suggested that a greater number of days of vitamin A intake is required than for energy and minerals. This may be the case for other vitamins, such as vitamin D and vitamin K. Ideally, vitamins in this FFQ should further be evaluated with a more reliable gold standard method. Second, some vitamins, such as vitamin K and vitamin A were relatively poorly reproducible. Their large CV values may probably be due to a seasonal variation in their intakes. Although the present reproducibility was potentially affected by the seasonal variations as a limitation, CVs of other nutrients and energy were relatively small. Finally, general nutrients, such as protein, could affect bone health, but their dietary intakes were not estimated with sufficient reliability. These limitations should be addressed by modifying this FFQPOP in future studies.

The FFQPOP we developed has several strengths. First, the FFQPOP is simple and convenient. It consists of only 28 questions, and it takes about 10 min to complete. Therefore, the FFQPOP can be used not only in an epidemiologic study, but also in clinical settings. Second, dietary calcium intake can be assessed with excellent validity and reproducibility. Third, multiple nutrients related to bone health and osteoporosis can be evaluated. In conclusion, the FFQPOP is a useful tool to evaluate the intake of dietary calcium in adult Japanese women for prevention and management of osteoporosis. Although it can also measure intakes of dietary vitamin A, vitamin D, vitamin K, NaCl, and energy, fur-

ther improvement is needed to measure intakes of these nutrients and energy.

Acknowledgments

The authors thank Dr. Masataka Shiraki (Research Institute and Practice for Involuntional Diseases, Nagano, Japan) and Megumi Kubota (Okayama Prefectural University, Okayama, Japan) for their help.

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Appendix 1. The food frequency questionnaire for the prevention and management of osteoporosis (FFQPOP).

Food items		Standard portion size	Frequency or amount
1	Milk	200 mL	none, sometimes, 1/d, ()mL/d
2	Milk products		
	Yogurt	100 g	rarely, 1–3/wk, 4–6/wk, 1/d, ()/d
	Cheese	20 g	rarely, 1–3/wk, 4–6/wk, 1/d, ()/d
	Skim milk	10 g	rarely, 1–3/wk, 4–6/wk, 1/d, ()/d
3	Egg	one	none, sometimes, 1/d, ()/d
4	Fish	80 g	none, sometimes, 1/d, ()/d
5	Shellfish	one dish	rarely, 1–2/mo, 1–3/wk, ≥ 4 /wk
6	Squid, octopus, prawn	one dish	rarely, 1–2/mo, 1–3/wk, ≥ 4 /wk
7	Dried baby fish (Shirasuboshi, Jako, etc.)	10 g	rarely, 1–2/mo, 1–3/wk, ≥ 4 /wk
8	Fish eggs (Ikura, Tarako, etc.)	one dish	rarely, 1–2/mo, 1–3/wk, ≥ 4 /wk
9	Meat or meat products	100 g	none, sometimes, 1/d, ()/d
10	Liver	50 g	rarely, 1–2/mo, 1–3/wk, ≥ 4 /wk
11	Beans or bean products	1/4 Tofu	rarely, small size/d, medium size/d, large size/d
12	Natto (fermented soy bean)	1 pack	rarely, 1–3/wk, 4–6/wk, 1/d, ()/d
13	Potatoes	50 g	rarely, small size/d, medium size/d, large size/d
14	Vegetables (green and yellow)	70 g	rarely, small size/d, medium size/d, large size/d
15	Vegetables (other)	70 g	rarely, small size/d, medium size/d, large size/d
16	Seaweed	one dish	rarely, 1–3/wk, 1/d, ≥ 2 /d
17	Nuts	20 g	rarely, 1–3/wk, 4–6/wk, 1/d
18	Fruit (apple, pear, orange, etc.)	one	rarely, a half/d, 1/d, ()/d
19	Staple food		
	Rice	one bowl	none, ()/d
	Bread	one slice	none, ()/d
	Noodles	one bowl	none, ()/d
20	Butter, margarine, jam with bread	10 g	none, spread thin, spread thick
21	Miso soup	one bowl	rarely, 1–3/wk, 4–6/wk, 1/d, ()/d
22	Coffee or tea	120 mL	none, sometimes, 1/d, ()/d
23	Sugar with coffee or tea	4 g	none, one portion, () portion
24	Sweet beverages	250 mL	none, sometimes, ()mL/d
25	Sweets	one	rarely, sometimes, 1/d
26	Greasy dish	—	rarely, sometimes, 1/d, ()/d
27	Pickles	one dish	rarely, sometimes, 1/d, ≥ 2 /d
28	Alcohol	one unit	rarely, 1–3/wk, 4–6/wk, 1/d, ()/d