Dietary patterns associated with bone mineral density in premenopausal Japanese farmwomen[1–3]

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ABSTRACT

Background: Because several nutrients are known to affect bone mineral density (BMD), the analysis of dietary patterns or combinations of foods may provide insights into the influence of diet on bone health.

Objective: We evaluated associations between dietary patterns and BMD in Japanese farmwomen.

Design: The study included 291 premenopausal farmwomen (aged 40–55 y) who participated in the Japanese Multi-centered Environmental Toxicant Study (JMETS; n = 1407). Forearm BMD was measured by using dual-energy X-ray absorptiometry. Diet was assessed by using a validated self-administered diet history questionnaire comprising 147 food items, from which 30 food groups were created and entered into a factor analysis.

Results: Four dietary patterns were identified. The "Healthy" pattern, characterized by high intakes of green and dark yellow vegetables, mushrooms, fish and shellfish, fruit, and processed fish, was positively correlated with BMD after adjustment for several confounding factors (P = 0.048). In contrast, the "Western" pattern, characterized by high intakes of fats and oils, meat, and processed meat, tended to be inversely associated with BMD; however, the association was not significant (P = 0.08).

Conclusion: A dietary pattern with high intakes of fish, fruit, and vegetables and low intakes of meat and processed meat may have a beneficial effect on BMD in premenopausal women. *Am J Clin Nutr* 2006;83:1185–92.

KEY WORDS Bone mineral density, dietary pattern, diets, fruit and vegetables, Japanese farmwomen

INTRODUCTION

Osteoporosis and related fractures among senior citizens are well recognized as a major public health problem in developed nations. They are the second-leading cause in Japan for patients to become bedridden, preceded only by cerebrovascular diseases in Japan. The prevalence of osteoporosis and related fractures appears to be increasing (1). In addition, osteoporosis and related fractures impose high health care costs in long-term nursing home care. The prevention of bone loss is thus desirable for both medical and economic reasons.

With regard to nutritional approaches to bone metabolism, a great deal of attention has been focused on the benefits of calcium and vitamin D. Other nutrients and dietary components, such as potassium, magnesium, vitamin K, and fruit and vegetables, have also shown beneficial effects (2–6), although a clear relation with bone metabolism has not been established. Moreover, beneficial effects have been hypothesized for protein, saturated fat, phosphorus, vitamin C, sodium, and dietary isoflavone (7–12). With regard to diet, however, the most common approach, that of examining single nutrients or foods, may not adequately account for complicated interactions and cumulative effects. Because people consume diets consisting of a variety of foods with complex combinations of nutrients, rather than isolated nutrients, the examination of only single nutrients or foods could result in the identification of erroneous associations between dietary factors and disease.

To overcome these limitations, the dietary pattern approach—namely, the measurement of overall diet—has been widely used to elucidate the relations between diet and disease (13, 14). This approach allows the development of appropriate recommendations for overall dietary habits to prevent undesirable conditions and diseases. Tucker et al (15) used the dietary pattern approach with cluster analysis to show that a diet rich in fruit and vegetables is associated with a greater bone mineral density (BMD) in elderly men. In Japan, only one study (16) examined the relation between diet and the results of an ultrasound bone density meter (USBDM) among elderly men and women. The results showed that the factor 2 score (ie, that for a diet with a high intake of breads instead of rice and a frequent intake of dairy products, called a bread-style diet) was significantly lower among elderly women in the USBDM-measured low bone density group (16). In the current study, we attempted to identify dietary patterns by using factor analysis. In addition, we examined the relations between dietary patterns and BMD in Japanese farmwomen aged

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40–55 y who live in rural communities and have maintained more traditional dietary habits than do typical residents of large cities.

SUBJECTS AND METHODS

Study population

The Japanese Multi-centered Environmental Toxicant Study (JMETS) was a nationwide, community-based study of farmwomen sampled between 2000 and 2003. The study was conducted in 5 districts—1 district is on the north end of Kyushu Island (the southernmost Japanese island), and the other 4 districts are located at the north end of Honshu Island (the largest Japanese island)—where the rice produced and consumed by the farmers has a low-to-moderate cadmium contamination. Study recruitment and enrollment were described in detail elsewhere (17, 18). Before the study, orientation sessions were held to explain the purposes and protocol of the study to the participants. At the same time, participants were instructed in completing 2 kinds of questionnaires and were asked to bring the questionnaires to the examination. A total of 1407 women aged 20–78 y who agreed to participate in the study completed the questionnaires, and their BMD was measured.

All subjects provided written informed consent. The study protocol was approved by the Committee on Medical Ethics of the Jichi Medical School.

Dietary assessment and food grouping

We used a previously validated 16-page self-administered diet history questionnaire (DHQ) to assess dietary habits in the previous month (19, 20). The DHQ consists of 7 sections: general dietary behaviors; most frequent cooking methods; frequency and amount of consumption of 6 alcoholic beverages; consumption frequency and semiquantitative portion size of 121 selected food and nonalcoholic beverages; dietary supplements; frequency and amount of consumption of 19 staple foods (ie, rice, bread, noodles, and other wheat foods) and miso soup (fermented soybean paste soup); and open-ended items for foods consumed regularly (≥1 time/wk) but not appearing in the DHQ. The food and beverage items and portion sizes in the DHQ were derived primarily from data in the National Nutrition Survey of Japan and several cookbooks for Japanese dishes (19). Measures of dietary intakes of 147 food and beverage items and energy were calculated by using an ad hoc computer algorithm for the DHQ, which was based on the Standard Tables of Food Composition in Japan (21). Information on dietary supplements and data from the open-ended questionnaire items were not used in the calculation of dietary intakes. More detailed descriptions of the questionnaire, the methods of calculating nutrients, and the validity of the questionnaire are given elsewhere (19, 20).

To reduce the complexity of the data, food items were categorized into groups (**Table 1**). In general, the food grouping was based on the principles of similarity of nutrient profiles or culinary usage of the foods, mainly according to the Standard Tables of Food Composition in Japan (21), and the classification of food groups used by the National Nutrition Survey of Japan (22). Finally, 30 separate food groups were established and used in our analyses to identify dietary patterns.

Measurement of bone mineral density

BMD (g/cm^2) and bone mineral mass [(BMM) g] were measured by using dual-energy X-ray absorptiometry (DXA) of each participant's nondominant forearm by using an osteometer (DTX-200; Osteometer MediTech Inc, Hawthorne, CA). DXA scanned at the distal sites of the radius and ulna. Subjects' BMD and bone mineral content [(BMC) g] were calculated in the area of the bones between the distal site of an 8-mm gap between the 2 bones and the proximal site 24 mm from the gap. The CVs of forearm BMD measurements were all within 1.0%.

Measurement of confounding factors

In addition to diet, we measured the following factors that may be related to BMD: body weight, body height, physical activity level, smoking habit, history of bone fracture, supplement use, menopausal status, current use of hormone replacement therapy, parity, and age at menarche. Body weight and height were measured to the nearest 0.1 kg and 0.1 cm, respectively, while subjects were wearing light clothing but no shoes. Body mass index (BMI) was calculated as body weight (kg) divided by body height squared (m^2). The maximum grasping power value of a participant's nondominant hand was measured 3 times by using a hand dynamometer. Grasping power was used in our analyses as an indicator of physical activity.

Age (in y, continuous), current smoking (yes or no), frequency of bone fracture (times, continuous), current use of hormone replacement therapy (yes or no), parity (times, continuous), and age at menarche (in y, continuous) were obtained from an 8-page questionnaire. Alcohol consumption (g/d) and use of calcium or multivitamin supplements (yes or no) were assessed from the DHQ.

Statistical analysis

In the statistical analysis, the dietary environmental cadmium exposure of the subjects did not show any significant effects on renal tubular functions (17) or BMD (18) after adjustment for possible confounders. However, to avoid unknown long-term effects of cadmium exposure, we restricted the cohort of the current study to the 339 women aged 40–55 y who were still menstruating at the time of entry. Of these 339 women, 48 were excluded for collagen disease (n = 1), hyperthyroidism (n = 1), a reported daily energy intake < 2.7 or > 14.4 MJ (650–3450 kcal) (n = 9; 23), and a reported change in dietary habits within the previous 3 y (n = 38). The remaining subjects had no history of taking medications that may affect bone or calcium metabolism and no history of any condition that affects bone metabolism. Thus, data from 291 women were included in the final analysis.

We calculated the ratio of energy intake (EI) to basal metabolic rate (BMR) to evaluate the relative accuracy of the reported energy intake. To compare the relative degree of underreporting and overreporting, we temporarily used EI:BMR as defined by FAO/WHO/UNU: ratios of 1.27 for the minimum survival level, 1.56 for the sedentary level for women and 2.0–2.4 for the maximum sustainable lifestyle level (24).

Analyses were conducted by using FACTOR PROCEDURE software (version 8.2; SAS Inc, Cary, NC; 25). Factor analysis was used to derive the dietary patterns on the basis of the 30 food groups from the DHQ. Intake of these food groups was adjusted for total energy intake by using the residual method (26). To

TABLE 1
The 30 food groupings used in the dietary pattern analysis[1]

Food group	Foods in the group
Rice	Well-milled rice, rice with barley (70% rice and 30% barley), rice with embryo, half-milled rice, 70%-milled rice, brown rice
Noodles	Japanese noodles (buckwheat or Japanese wheat noodles), instant noodles, Chinese noodles, pasta, spaghetti
Breads	White bread, butter roll, croissant, pizza, okonomiyaki (Japanese pancake fried with various ingredients), takoyaki (small ball of wheat flour with bits of octopus)
Miso soup	Miso (fermented soybean paste) soup
Dairy products	Whole milk, low-fat milk, skim milk, yogurt, cheese, cottage cheese, lactic acid bacteria beverages, ice cream, coffee cream
Meats	Beef, pork, ground beef or pork, chicken, liver (beef, pork, or chicken)
Processed meats	Ham, sausage, bacon, salami
Fish and shellfish	Eel, white-meat fish (sea bream, flatfish, codfish, and others), blue-back fish (mackerel, sardine, herring, and others), red-meat fish (tuna, salmon, and skipjack), shrimp, squid, octopus, oysters, other shellfish
Processed fish	Dried fish, small fish with bones, canned tuna, fish eggs, boiled fish in soy sauce, salted gut (fish, squid, or shellfish), surimi (ground fish meat) products
Eggs	Eggs
Nuts	Peanuts, other types of nuts
Soy products	Tofu (soybean curd), tofu products such as atsuage (deep-fried tofu cutlet), ganmodoki (deep-fried tofu burger), aburaage (deep-fried tofu pouch), natto (fermented soybeans), cooked beans, miso as seasoning
Green and dark yellow vegetables	Carrots, pumpkins, tomatoes, green pepper, broccoli, lettuce, green leafy vegetables such as spinach
White vegetables	Cabbage, cucumber, Chinese cabbage, bean sprouts, Japanese radish, onion, cauliflower, eggplant, burdock, lotus root
Pickled vegetables	Salted pickles, umeboshi (pickled and dried plum), kimchi (Korean pickles)
Fruit and vegetable juices	Vegetable juice, tomato juice, 100% fruit juice, sweetened fruit drinks (50% fruit)
Fruit	Oranges, grapefruits, bananas, apples, strawberries, grapes, peaches, pears, kiwi fruit, persimmons, melons, watermelon, raisins, canned fruit
Sugary foods	Sugar for coffee and tea, sugar for cooking, jam, marmalade
Mushrooms	Shiitake, shimeji, enoki
Seaweeds	Wakame seaweed, purple laver, brown algae
Potatoes	White potatoes, French fries, sweet potatoes, taros, konnyaku (devil's tongue jelly)
Sweets	Japanese sweetened bun, pancake, potato chips, senbei and arare (rice snacks), crackers, salted snacks, Japanese sweets with or without azuki beans, cakes, soft cookies, hard cookies, chocolates, candies, caramels, chewing gums, jellies, doughnut
Butter	Butter
Fats and oils	Margarine, vegetable oil, salad dressing with oil
Alcohol	Beer, sake (rice wine), shochu (distilled spirits), chuhai (shochu highball), whiskey, wine
Tea	Green tea, oolong tea, black tea
Coffee	Coffee, cocoa
Soft drinks	Cola, nonfruit juices, soft drinks without sugar, such as sports beverages
Seasonings	All condiments (eg, ketchup), mayonnaise, table salt, salt and salt-rich seasonings used during cooking, soy sauce, oil-free dressings, curry or stew roux, spices
Soup	Corn soup, Chinese soup

[1] Foods listed in the table were from the self-administered diet history questionnaire.

identify the number of factors to be retained, we used the criterion of eigenvalues > 1.0, the most widely used criterion in factor analysis, as a first step. However, this procedure created 12 independent factors, a number too large for further analyses. The screen plots dropped substantially (from 1.81 to 1.59) after the third factor and remained closer (1.54 for the fifth factor and 1.50 for the sixth factor) after the fifth factor, which suggested that the retention of 3 or 4 factors would be optimal. Finally, we decided to retain 4 factors for further analyses. The factors were rotated by orthogonal transformation (VARIMAX rotation function in SAS) to achieve a simpler structure with greater interpretability. After Varimax rotation, factor scores for each subject were saved from the principal component analysis. Factor loadings represent correlation coefficients between individual food groups and dietary patterns. The proportion of variance explained by each factor was calculated by dividing the sum of the squares of the respective factor loadings by the number of variables. The factor scores for each pattern and for each individual were determined by summing the intakes of each food group weighted by the factor loading (27). All data presented here are from the Varimax rotation. The scores were used for comparison with nutrient intake and other lifestyle factors and to estimate associations with BMD.

Factors were divided into quintiles, and sample means and frequencies were calculated. Partial correlation coefficients (adjusted for age) were calculated between each factor and forearm BMD and between each factor and energy-adjusted nutrient intake. We compared the adjusted mean (± SE) for each quintile of each dietary pattern using 3 models. In model 1, we adjusted for age and lifestyle variables, such as BMI, grasping power, and current smoking, as confounding factors. In model 2, we further adjusted for a history of bone fracture and female hormone-related factors, such as the use of hormone replacement therapy, age at menarche, and parity. In model 3, we also adjusted for

TABLE 2
Characteristics of study subjects[1]

	Premenopausal women
Age (y)	46.4 ± 3.7[2]
Body height (cm)	156.1 ± 5.2
Body weight (kg)	57.8 ± 8.4
BMI (kg/m^2)	23.7 ± 3.3
Grasping power (kg)	29.1 ± 4.5
Forearm bone mineral density (g/cm^2)	0.489 ± 0.053
Forearm bone mineral mass (g)	3.20 ± 0.45
Smoking status [*n* (%)]	
Current	11 (4)
Former	4 (1)
Never	276 (95)
History of fracture [*n* (%)]	26 (9)
Hormone replacement therapy [*n* (%)]	2 (1)
Age at menarche (y)	13.0 ± 1.2
Parity (*n*)	2.5 ± 0.9
Calcium supplement use [*n* (%)]	13 (4)
Multivitamin supplement use [*n* (%)]	14 (5)
EI:BMR[3]	1.41 ± 0.32
< 1.27	100 (34)
> 2.4	1 (1)
Nutrient intakes	
Total energy (MJ/d)	7.9 ± 1.7
Protein (% of energy)	13.6 ± 2.1
Fat (% of energy)	26.5 ± 5.6
Carbohydrate (% of energy)	57.8 ± 7.0
Potassium (mg/d)	2322 ± 713
Magnesium (mg/d)	251 ± 73
Calcium (mg/d)	498 ± 185
Phosphorus (mg/d)	969 ± 282
Vitamin C (mg/d)	109 ± 55
Vitamin D (μg/d)	7.8 ± 4.4
Vitamin K (μg/d)	322 ± 181
Isoflavon (mg/d)	36.4 ± 21.8
Alcohol (g/d)	2.6 ± 6.1

[1] *n* = 291. EI:BMR, the ratio of energy intake to basal metabolic rate.
[2] $\bar{x}$ ± SD (all such values).
[3] Subjects who had an EI:BMR < 1.27 were defined as severe underreporters and those with an EI:BMR > 2.4 were defined as overreporters according to the FAO/WHO/UNU (24).

dietary variables, such as the use of calcium or multivitamin supplements. *P* values to test for linear trends were calculated by using dietary pattern scores as a continuous variable after control for possible confounding factors.

All statistical analyses were performed by using SAS software (version 8.2). A *P* value of < 0.05 was considered significant, except during the analysis of correlations between dietary patterns and nutrient intake, because those correlations were not necessarily independent of each other. In those instances, a partial correlation coefficient of > 0.2 or < −0.2 was considered significant.

RESULTS

Mean (±SD) values for forearm BMD, nutrient intake, and continuous potential confounders used in the present analysis are shown in **Table 2**. Proportional distributions are presented for categorical variables. The following activities were rare among participants in the current study: current smoking (4%) and the use of calcium supplement (4%), multivitamin supplement (5%), and hormone replacement therapy (1%). The mean value of EI:BMR as an indicator of reporting accuracy was 1.41 ± 0.32. Thirty-four percent of the subjects had an EI:BMR below the minimum survival value of 1.27, and 1% had an EI:BMR higher than the maximum value of 2.4 for a sustainable lifestyle.

The factor-loading matrices are shown in **Table 3**. The high positive loadings indicate strong associations between given food groups and patterns, whereas negative loadings indicate negative associations with the patterns. The patterns were labeled according to the food groups with high loadings. Factor 1, which loaded heavily on green and white vegetables, mushrooms, fish and shellfish, fruit, processed fish, seaweed, and soy products, was labeled the "Healthy" pattern. Factor 2, with high loadings for rice, miso soup and soy products, was labeled the "Japanese traditional" pattern. Factor 3 with high loadings for fats and oils, meat, processed meats, and seasoning was labeled the "Western" pattern. Factor 4, with high loadings for coffee, soft drinks, dairy products, sugary foods, and meats, was labeled the "beverage and meats" pattern. Overall, the 4 dietary patterns accounted for 29.7% of the variance in food intakes.

The subjects were divided into quintiles by the factor score of each dietary pattern. Samples means and frequencies were calculated across quintiles. Sample characteristics of premenopausal women in the lowest and highest quintiles of each food pattern (Q1 and Q5, respectively) are shown in **Table 4**. Participants in the highest quintile of the Healthy pattern were older (47.3 ± 3.7 y), whereas those in the highest quintile of the Western pattern were younger (45.6 ± 3.3 y). The greatest incidence of calcium supplement use (10.3%) was observed in the highest quintile of the Western pattern, whereas the smallest incidence of multivitamin supplement use (3.5%) was observed in the highest quintile of the Japanese traditional pattern.

Partial correlation coefficients between each of the 4 dietary patterns and forearm BMD and energy-adjusted nutrient intakes are shown in **Table 5**. BMD was not correlated with any dietary pattern after adjustment for age only. For energy-adjusted nutrient intakes, the Healthy pattern was correlated with protein (r = 0.65), potassium (r = 0.82), magnesium (r = 0.69), calcium (r = 0.51), phosphorus (r = 0.70), vitamin C (r = 0.51), vitamin D (r = 0.53), vitamin K (r = 0.48), and alcohol (r = 0.22). The Western pattern was positively correlated with fat (r = 0.54) and negatively correlated with carbohydrate (r = −0.55). In contrast, the Japanese traditional pattern showed a strong positive correlation with isoflavone (r = 0.49) and a negative correlation with fat (r = −0.22).

The multivariate-adjusted mean BMD across quintiles of all 4 dietary patterns is shown in **Table 6**. The highest quintile of the Healthy pattern had a significantly higher BMD than did the lowest quintile after adjustment for nondietary factors and dietary supplements (0.498 ± 0.006 and 0.476 ± 0.006 g/cm^2 for Q5 and Q1, respectively; P = 0.014). The highest quintile of the Western pattern had a significantly lower BMD than did the lowest quintile (0.480 ± 0.006 and 0.500 ± 0.006 g/cm^2 for Q5 and 1, respectively; P = 0.043). To test for linear trend, modeling of factor scores as continuous variables showed a positive and significant association in the Healthy pattern (P = 0.048), whereas a negative, but nonsignificant, association was observed in the Western pattern for premenopausal women (P = 0.08). No association with BMD was seen for any other dietary pattern.

TABLE 3
Factor-loading matrix for the 4 dietary patterns identified among 291 premenopausal Japanese farmwomen who participated in the Japanese Multicentered Environmental Toxicant Study[1]

	Factor 1: Healthy	Factor 2: Japanese traditional	Factor 3: Western	Factor 4: Beverage and meats
Green and dark yellow vegetables	0.61	—	—	—
Mushrooms	0.57	—	—	—
Fish and shellfish	0.57	—	—	—
Fruit	0.49	—	—	—
Processed fish	0.44	—	—	−0.35
White vegetables	0.40	0.35	0.33	—
Eggs	—	—	—	—
Alcohol	—	—	—	—
Rice	−0.50	0.64	−0.28	—
Miso soup	—	0.61	—	—
Soy products	0.26	0.54	—	—
Seaweeds	0.36	0.39	—	—
Nuts	—	—	—	—
Noodles	—	−0.33	—	−0.25
Sweets	—	−0.53	−0.42	—
Breads	—	−0.63	—	—
Fats and oils	—	—	0.62	—
Meats	—	—	0.59	0.30
Processed meats	—	—	0.54	—
Butter	—	—	0.41	—
Seasonings	—	—	0.37	—
Soup	—	—	0.30	—
Salted vegetables	0.30	—	−0.37	—
Coffee	—	—	—	0.65
Sugary foods	—	—	—	0.50
Soft drinks	—	—	—	0.35
Dairy products	—	—	—	0.35
Fruit and vegetable juices	—	—	—	—
Potatoes	—	0.30	—	−0.37
Tea	—	—	—	−0.45
Percentage of variance (%)	8.3	8.1	7.0	6.3

[1] Data for 291 subjects from the self-administered diet history questionnaire. Absolute values < 0.25 were excluded from the table for simplicity.

DISCUSSION

Using factor analysis, an approach that considers overall eating patterns, we identified 4 dietary patterns in premenopausal women aged 40–55 y and found associations between dietary patterns and BMD. The Healthy pattern showed a positive correlation with BMD, whereas the Western pattern showed a negative association.

To our knowledge, no previous study examined the relation between dietary patterns by using factor analysis and BMD as measured by DXA. Although only one cross-sectional study has examined the relation between dietary patterns and BMD in Japanese elderly men and women, BMD in that study was measured by using USBDM (16). Uchida et al (16) reported that the factor 2 score (ie, a bread-style diet) was significantly lower in the low USBDM-measured group than in the mean and high USBDM-measured groups of elderly women. A second study, by Tucker et al (15), examined the association between BMD and dietary patterns derived from cluster analysis. That study, a case-control study from the Framingham Osteoporosis Study, found that the cluster for a diet high in fruit, vegetables, and cereals had significantly greater BMD at all 3 hip sites and in the radius in elderly men but not in elderly women, whereas a cluster high in candy had significantly lower BMD in both men and women. Direct comparison between the results of our study and these other studies is difficult because they are derived by using different analytic methods (ie, factor or cluster analysis) and in populations with different age ranges and genetic and cultural make-ups, who may have the specific (customary) dietary and lifestyle patterns of Western and Asian countries. Therefore, the results should be interpreted with caution.

Diets high in animal meat intakes and low in fruit and vegetable intakes—typical diets in industrialized countries—have a negative effect on bone health by increasing calcium excretion and bone resorption (28). In addition, acidosis may inhibit osteoblast function and increase osteoclast activity, which limits bone formation and increasing bone loss (29). However, high intakes of dietary potassium and magnesium, along with other nutrients associated with intakes of fruit and vegetables, have been suggested to promote an alkaline environment by reducing the potential renal acid load and net endogenous acid production (30, 31). In a previous study, New et al (4) and Macdonald et al (7) found that the intakes of several nutrients related to fruit and vegetables were positively correlated with BMD and negatively correlated with bone loss in premenopausal women (4, 7). In addition, a previous cross-sectional study showed a correlation between high intakes of magnesium, potassium, and fruit and vegetables (per serving) and BMD in both elderly men and

TABLE 4
Sample characteristics for the lowest and highest quintiles (Q) of 4 dietary patterns identified for 219 premenopausal women participating in the Japanese Multi-centered Environmental Toxicant Study[1]

	Healthy		Japanese traditional		Western		Beverage and meats	
	Q1	Q5	Q1	Q5	Q1	Q5	Q1	Q5
Age (y)	45.3 ± 3.7[2]	47.3 ± 3.7[3]	45.8 ± 4.2	46.2 ± 3.6	47.2 ± 4.0	45.6 ± 3.3[4]	47.2 ± 3.8	45.8 ± 3.7
Grasping power (kg)	29.5 ± 4.0	27.5 ± 4.0[4]	30.0 ± 5.0	28.8 ± 5.0	28.5 ± 4.4	28.9 ± 4.1	29.4 ± 5.0	28.8 ± 4.5
Forearm bone mineral density (g/cm^2)	0.482 ± 0.054	0.495 ± 0.052	0.496 ± 0.058	0.495 ± 0.048	0.499 ± 0.055	0.482 ± 0.059	0.479 ± 0.061	0.496 ± 0.051
Forearm bone mineral mass (g)	3.19 ± 0.51	3.28 ± 0.44	3.29 ± 0.48	3.18 ± 0.50	3.34 ± 0.48	3.17 ± 0.46	3.13 ± 0.48	3.29 ± 0.45
Age at menarche (y)	12.9 ± 1.3	13.1 ± 1.2	13.0 ± 1.2	13.2 ± 1.3	12.8 ± 1.1	13.0 ± 1.2	13.2 ± 1.3	12.9 ± 1.2
Parity (n)	2.5 ± 1.0	2.4 ± 0.8	2.4 ± 0.7	2.7 ± 0.9	2.4 ± 0.9	2.5 ± 0.8	2.5 ± 1.1	2.5 ± 0.9
BMI (kg/m^2)	24.6 ± 3.6	24.0 ± 3.3	24.3 ± 3.4	23.7 ± 3.1	23.8 ± 4.1	24.0 ± 3.5	23.9 ± 3.6	24.5 ± 3.0
< 18.5 [n (%)]	2 (3.5)	2 (3.5)	1 (1.7)	2 (3.5)	1 (1.7)	2 (3.5)	3 (5.2)	0 (0)
18.5–24.9 [n (%)]	33 (56.9)	34 (58.6)	37 (63.8)	39 (67.2)	37 (63.8)	36 (62.1)	36 (62.1)	33 (56.9)
≥ 25.0 [n (%)]	23 (39.7)	22 (37.9)	20 (34.5)	17 (29.3)	20 (34.5)	20 (34.5)	19 (32.8)	25 (43.1)
Smoking status [n (%)]								
Current	1 (1.7)	3 (5.2)	2 (3.5)	2 (3.5)	3 (5.2)	2 (3.5)	1 (1.7)	4 (6.9)
Former	2 (3.5)	0 (0)	1 (1.7)	0 (0)	1 (1.7)	1 (1.7)	1 (1.7)	2 (3.5)
Never	55 (94.8)	55 (94.8)	55 (94.8)	56 (96.7)	54 (93.1)	55 (94.8)	56 (96.6)	52 (89.7)
Calcium supplement use [n (%)]	2 (3.5)	4 (6.9)	2 (3.5)	4 (6.9)	1 (1.7)	6 (10.3)[5]	3 (5.2)	3 (5.2)
Multivitamin supplement use [n (%)]	3 (5.2)	4 (6.9)	5 (8.6)	2 (3.5)[5]	3 (5.2)	4 (6.9)	2 (3.5)	2 (3.5)
History of fracture [n (%)]	8 (13.8)	3 (5.3)	8 (14.0)	4 (6.9)	3 (5.2)	7 (12.3)	7 (12.1)	4 (6.9)
Hormone replacement therapy [n (%)]	0 (0)	1 (1.7)	0 (0)	0 (0)	1 (1.7)	0 (0)	1 (1.7)	0 (0)

[1] The factors were standardized continuous variables, and each subject had a score for each factor. n = 58 in Q1, Q2, Q4, and Q5 and 59 in Q3.
[2] $\bar{x}$ ± SD (all such values).
[3,4] Test for linearity across quintiles of factors: [3]$P < 0.001$, [4]$P < 0.05$.
[5] Significant difference between quintiles in all categories. $P < 0.01$ (chi-square test).

women (3). In accordance with these previous findings, the Western pattern identified in the current study is negatively associated with BMD; however, the association was not significant ($\beta = -0.005$, $P = 0.08$). In contrast, the Healthy pattern, which was highly and positively correlated with potassium, magnesium, calcium, vitamin C, vitamin D, and vitamin K, also was positively correlated with BMD ($\beta = 0.006$, $P = 0.048$).

The current study has several limitations. First, the DHQ assessed dietary habits only in the previous month, which was too short a time for the examination of a nutrient–bone mass association. Therefore, as in our previous report, we included only those subjects who had maintained stable dietary habits for ≥3 y (6). Second, the classification of menopausal status was self-reported according to 3 categories (regular, irregular, or no menstrual cycle). We did not ask the irregularly menstruating or nonmenstruating women about the length of time since their last menses. Therefore, given its clear effect on bone metabolism, we also considered age in the definition of menstrual status. Moreover, because the BMD of the perimenopausal women showed no decrease and did not differ significantly from that of the premenopausal women (0.492 and 0.486 g/cm^2, respectively; $P = 0.14$), we evaluated women with regular and irregular cycles together as premenopausal women. Third, 4 of the 5 selected districts were cadmium-polluted areas, in which low-to-moderate cadmium contamination of rice has been detected.

TABLE 5
Partial Pearson correlation coefficients between each of 4 dietary patterns and bone mineral density and daily nutrient intakes for 291 premenopausal Japanese farmwomen who participated in the Japanese Multi-centered Environmental Toxicant Study[1]

	Factor 1: Healthy	Factor 2: Japanese traditional	Factor 3: Western	Factor 4: Beverage and meats
Forearm bone mineral density (g/cm^2)	0.05	0.01	−0.08	0.08
Nutrient intakes				
Carbohydrate (% of energy)	−0.39	0.20	−0.55	0.06
Protein (% of energy)	0.65	−0.01	0.18	−0.10
Fat (% of energy)	0.25	−0.22	0.54	−0.03
Potassium (mg/d)	0.82	0.14	0.05	0.19
Magnesium (mg/d)	0.69	0.22	0.00	0.02
Calcium (mg/d)	0.51	0.07	−0.07	0.12
Phosphorus (mg/d)	0.70	0.09	0.10	0.06
Vitamin C (mg/d)	0.51	0.11	−0.07	−0.03
Vitamin D (μg/d)	0.53	−0.01	−0.02	−0.26
Vitamin K (μg/d)	0.48	0.31	−0.03	−0.04
Isoflavone (mg/d)	0.28	0.49	−0.08	−0.21
Alcohol (g/d)	0.22	−0.15	0.19	−0.01

[1] All nutrients were energy-adjusted by using the residual method. All partial correlation coefficients were adjusted for age. A partial correlation coefficient of >0.2 or <−0.2 was considered significant.

TABLE 6
Multivariate-adjusted bone mineral density by quintile (Q) of 4 dietary patterns among 291 premenopausal women participating in the Japanese Multicentered Environmental Toxicant Study[1]

Dietary pattern	Q1 (n = 58)	Q2 (n = 58)	Q3 (n = 59)	Q4 (n = 58)	Q5 (n = 58)	P for trend
Factor 1: Healthy						
Model 1	0.476 ± 0.006[2]	0.480 ± 0.006	0.504 ± 0.006	0.491 ± 0.006	0.497 ± 0.006	0.11
Model 2	0.476 ± 0.006	0.479 ± 0.006	0.503 ± 0.006[3]	0.492 ± 0.006	0.498 ± 0.006[4]	<0.05
Model 3	0.476 ± 0.006	0.479 ± 0.006	0.504 ± 0.006[3]	0.492 ± 0.006	0.498 ± 0.006[4]	<0.05
Factor 2: Japanese traditional						
Model 1	0.491 ± 0.006	0.490 ± 0.006	0.483 ± 0.006	0.488 ± 0.006	0.495 ± 0.006	0.58
Model 2	0.493 ± 0.007	0.490 ± 0.006	0.485 ± 0.006	0.486 ± 0.006	0.495 ± 0.006	0.95
Model 3	0.493 ± 0.007	0.490 ± 0.006	0.485 ± 0.006	0.486 ± 0.007	0.495 ± 0.007	0.92
Factor 3: Western						
Model 1	0.500 ± 0.006	0.484 ± 0.006	0.492 ± 0.006	0.490 ± 0.006	0.480 ± 0.006	0.06
Model 2	0.501 ± 0.006	0.484 ± 0.006	0.492 ± 0.006	0.491 ± 0.006	0.482 ± 0.006	0.08
Model 3	0.501 ± 0.006	0.484 ± 0.006	0.492 ± 0.006	0.491 ± 0.006	0.482 ± 0.007	0.08
Factor 4: Beverage and meats						
Model 1	0.477 ± 0.006	0.494 ± 0.006	0.483 ± 0.006	0.501 ± 0.006	0.492 ± 0.006	0.31
Model 2	0.478 ± 0.006	0.495 ± 0.006	0.484 ± 0.006	0.501 ± 0.006	0.492 ± 0.006	0.35
Model 3	0.478 ± 0.006	0.495 ± 0.006	0.484 ± 0.006	0.501 ± 0.006	0.492 ± 0.006	0.34

[1] Model 1: multivariate models were adjusted for age, BMI (kg/m^2), grasping power, and current smoking. Model 2: further adjusted for fracture history, the use of hormone replacement therapy, age at menarche, and parity. Model 3: further adjusted for the use of calcium and multivitamin supplements.
[2] $\bar{x}$ ± SE (all such values).
[3,4] Significantly different from Q1: [3]$P < 0.01$, [4]$P < 0.05$.

However, BMD was not related to urinary cadmium excretion in these subjects ($r = 0.02$, $P = 0.72$), and we previously reported that dietary cadmium exposure did not affect BMD in the premenopausal (41–48 y), perimenopausal (49–55 y), and even postmenopausal (56–75 y) women after adjustment for possible confounders (18). Fourth, the validity and reproducibility of the dietary patterns identified in the current study are unknown. Methodologic studies that examine the validity and reproducibility of the dietary factor analysis used in the current study and that establish the appropriate statistical procedures may have improved the current results. Undoubtedly, such studies may be conducted in the future to find more appropriate dietary factors to represent the current diversity of Japanese diets. In fact, the identified dietary factors in the current study accounted for only 29.7% of the variance in food intake in Japan. Finally, our sample size was comparatively small, which may have attenuated our ability to detect significant differences in BMD.

The principal components method itself also has limitations that stem from several subjective or arbitrary decisions that investigators must make. These decisions may have some effect on both the results and their interpretation (32). Therefore, the current study attempted to replicate dietary patterns reported in other epidemiologic studies by using similar steps in the subjective decision-making process. Moreover, we repeated the same analyses with varied numbers of factors and randomly divided the sample into 2 groups to examine whether these subjective choices affected the reproducibility of our findings. The results showed closely similar dietary patterns (data not shown). Our decision to retain 4 factors was based on eigenvalues, scree plots, and interpretability; however, it should be noted that >2 meaningful dietary patterns must exist in nature, as proposed by Newby (33). In addition, the dietary patterns defined in the current study were not established a priori but were based on actual data. The Western pattern in our study was similar to patterns labeled "Western" among Japanese (34), US (11, 35) and Swedish (36) populations. The Healthy pattern was also somewhat similar to the Healthy and Prudent (13, 35) patterns observed across different populations. Even though we observed similar patterns, it should be noted that the results of dietary pattern analysis depend on the population and may differ according to the geographic area, race, and culture of the population. In the current study, we identified a Japanese traditional pattern, characterized by high consumption of rice, miso soup, and soy products, that was quite different from the Western pattern. This pattern was comparable to the rice/snack and traditional pattern seen in a previous Japanese study (34, 37).

In conclusion, among Japanese premenopausal women, dietary patterns were associated with BMD. A diet with high intakes of green vegetables, fruits, fish and shellfish and low intakes of meat and processed meat may contribute to the maintenance of BMD. Our data suggest dietary recommendations for preventing bone loss in premenopausal women; however, further studies in various populations following different dietary patterns are required to confirm these results.

HO carried out the data analysis and wrote the manuscript. SS was involved in the design of the dietary study and assisted in manuscript preparation. HH and EO were responsible for the study design, data collection, and data management. KM and YH were involved in data collection. KMK provided statistical programming support. FK was responsible for the study design, data collection, and the overall management. All the authors provided suggestions during the preparation of the manuscript and approved the final version submitted for publication. None of the authors had any personal or financial conflict of interest.

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Dietary glycemic index and load in relation to metabolic risk factors in Japanese female farmers with traditional dietary habits[1–3]

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ABSTRACT

Background: Little is known about the relation of dietary glycemic index (GI) and glycemic load (GL) to metabolic risk factors, particularly in non-Western populations.

Objective: We examined the cross-sectional associations between dietary GI and GL and several metabolic risk factors in healthy Japanese women with traditional dietary habits.

Design: The subjects were 1354 Japanese female farmers aged 20–78 y from 5 regions of Japan. Dietary GI and GL were assessed with a self-administered diet-history questionnaire. Body mass index (BMI) was calculated as weight (kg) divided by the square of height (m). Fasting blood samples were collected for biochemical measurements.

Results: The mean dietary GI was 67, and the mean dietary GL (/1000 kcal) was 88 (GI for glucose = 100). White rice (GI = 77) was the major contributor to dietary GI and GL (58.5%). After adjustment for potential dietary and nondietary confounding factors, dietary GI was positively correlated with BMI (n = 1354; P for trend = 0.017), fasting triacylglycerol (n = 1349; P for trend = 0.001), fasting glucose (n = 764; P for trend = 0.022), and glycated hemoglobin (n = 845; P for trend = 0.038). Dietary GL was independently negatively correlated with HDL cholesterol (n = 1354; P for trend = 0.004) and positively correlated with fasting triacylglycerol (P for trend = 0.047) and fasting glucose (P for trend = 0.012).

Conclusions: Both dietary GI and GL are independently correlated with several metabolic risk factors in subjects whose dietary GI and GL were primarily determined on the basis of the GI of white rice. *Am J Clin Nutr* 2006;83:1161–9.

KEY WORDS Glycemic index, glycemic load, white rice, body mass index, triacylglycerol, glucose, glycated hemoglobin, HDL cholesterol, Japanese women, epidemiology, Japanese Multicentered Environmental Toxicants Study, JMETS

INTRODUCTION

Dietary carbohydrates are typically categorized into simple sugars and complex carbohydrates on the basis of their degree of polymerization. Their effects on health, however, may be better categorized according to their physiologic effects, specifically their ability to raise blood glucose (1), because the blood glucose response varies substantially among different carbohydrate-containing foods and cannot be predicted by their chemical composition (2). This varied glycemic response is quantified according to the glycemic index (GI), which is a measure of how much each carbohydrate-containing food raises blood glucose compared with a standard food of either glucose or white bread (per 50 g available carbohydrate) (3). In consideration of the amounts of carbohydrate-containing foods and total dietary carbohydrate, the concept of glycemic load (GL: GI × available carbohydrate content) has also been proposed (4, 5).

Recent results from a limited number of observational studies have suggested that diets with a low GI, a low GL, or both have a beneficial effect on several metabolic risk factors for cardiovascular disease and type 2 diabetes, such as body mass index (BMI; in kg/m^2) (6), HDL cholesterol (7–11), triacylglycerol (9, 10, 12), and glycated hemoglobin (Hb A_{1c}) (12, 13). However, almost all studies of dietary GI or dietary GL and metabolic risk factors have been conducted in Western countries, whereas, to our knowledge, only one small study (10) was carried out in Asian countries, including Japan.

For Japanese people, rice is the food that contributes most to total carbohydrate and energy intake (43% and 29%, respectively), which is a characteristic seldom observed in Western people (14). Therefore, a different correlation of dietary GI or dietary GL and metabolic risk factors may exist between Western and Japanese populations. Additionally, whereas cardiovascular disease is the second leading cause of all death in Japan (15), the number of Japanese people with type 2 diabetes is estimated to be no fewer than 6.8 million (16); thus, as is the case in Western people, these are serious health problems in Japan. Consequently, we examined the cross-sectional associations between dietary GI and GL and several metabolic risk factors for cardiovascular disease and type 2 diabetes, including BMI, fasting

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serum triacylglycerol, fasting plasma glucose, Hb A_{1c}, and serum total, HDL, and LDL cholesterol in a group of apparently healthy Japanese women.

SUBJECTS AND METHODS

Subjects

The subjects in the present study were participants in the Japanese Multi-centered Environmental Toxicants Study (JMETS), the main purpose of which was to identify the threshold concentration in the dose-response relation of cadmium renal dysfunction (17, 18). For this purpose, the JMETS was conducted in female farmers in 4 moderately cadmium-polluted areas and 1 non-cadmium-polluted area in Japan; however, no difference in the effects of environmental exposure to cadmium was observed between the 4 polluted areas and 1 nonpolluted area, at least regarding renal function and bone density (17, 18). Thus, the study did not identify evidence that environmental exposure to cadmium, at the level found in the 4 polluted areas, has an adverse affect on health. The 5 areas surveyed consist of rural agricultural communities with inhabitants who remain in the community even after marriage. Thus, most of the farmers in these areas are assumed to have maintained traditional Japanese dietary patterns, consuming their own crops, including rice, for decades. During the winters of 2000 and 2001, female farmers in each area were recruited through the local Agricultural Cooperative to participate in a medical examination organized for the JMETS. One week before the examination, group orientations were held for the study participants, at which the study purpose and protocol were explained and written informed consent was obtained from each participant. In addition, participants were instructed on how to complete questionnaires regarding diet and other lifestyle factors and were asked to bring them to the examination. The protocol of the JMETS was approved by the ethical committee of Jichi Medical University. Additional details about the JMETS were reported elsewhere (17, 18).

A total of 1407 women aged 20–78 y completed both a medical examination and the lifestyle-related questionnaires. Subjects excluded from the present study were those with previously diagnosed diabetes ($n = 15$) or cardiovascular disease ($n = 18$), those with extremely low or high energy intakes (<600 or >4000 kcal/d; $n = 10$), and those with missing covariate information ($n = 4$). Furthermore, subjects with missing information regarding dependent variables, were excluded from the analysis of LDL cholesterol ($n = 6$), glucose ($n = 609$), and Hb A_{1c} ($n = 527$), and subjects who ate breakfast before blood was drawn were excluded from the analysis of fasting triacylglycerol and glucose ($n = 5$). Thus, the final sample was 1354 for BMI and serum total and HDL cholesterol, 1348 for serum LDL cholesterol, 1349 for fasting serum triacylglycerol, 764 for fasting plasma glucose, and 845 for Hb A_{1c}; however, some subjects were included in more than one exclusion category. Further exclusion of subjects with a diagnosis of hyperglycemia, dyslipidemia, hypercholesterolemia, or a combination thereof ($n = 24$ for BMI, cholesterol, and triacylglycerol and $n = 17$ for glucose and Hb A_{1c}) did not alter the findings of the present study; therefore, these subjects were included in the analyses.

Metabolic risk factors

At the medical examination site, each subject's weight (measured while wearing light clothes and no shoes) was measured with a set of balance scales calibrated to 0.01 kg. Body height was also measured at the site. The BMI of each subject was calculated as weight (kg) divided by the square of height (m). Peripheral blood samples were obtained from subjects after an overnight fast. Blood was collected in evacuated tubes containing no additives, allowed to clot, and centrifuged at 3000 × *g* for 10 min at room temperature to separate the serum. Blood samples for blood sugar measurement were collected in hydrogen fluoride–containing tubes. All of the following biochemical variables of the samples were assayed at Mitsubishi Kagaku Bio-Clinical Laboratories Inc (Itabashi, Tokyo, Japan) within 3 d of collection to avoid significant degradation. Total cholesterol, HDL cholesterol, and triacylglycerol were measured by enzymatic assay methods. Serum LDL-cholesterol concentrations were calculated by using the Friedewald equation (19) for subjects with fasting serum triacylglycerol concentrations <400 mg/dL. Hb A_{1c} was measured by latex agglutination–turbidimetric immunoassay. In-house quality-control procedures for all of the abovementioned assays were fulfilled at Mitsubishi Kagaku Bio-Clinical Laboratories Inc.

Dietary assessment

Dietary habits during the past month were assessed with a self-administered diet-history questionnaire (DHQ) (20–22), which was completed by each subject at home and was checked by ≥2 dietitians during the medical examination. The DHQ is a 16-page structured questionnaire that consists of the following 7 sections: general dietary behaviors, major cooking methods, consumption frequency and portion size of 6 alcoholic beverages, semiquantitative frequency of intake of 121 selected food and nonalcoholic beverage items, dietary supplements, consumption frequency and amount of 19 staple foods (rice, bread, noodles, and other wheat foods) and *miso* (fermented soybean paste) soup, and open-ended items for foods consumed regularly (≥1 time/wk) but not appearing in the DHQ. The food and beverage items and portion sizes in the DHQ were derived primarily from data in the National Nutrition Survey of Japan and several recipe books for Japanese dishes (20). Measures of dietary intake for 147 food and beverage items, energy, fat, total carbohydrate, alcohol, and dietary fiber were calculated by using an ad hoc computer algorithm developed for the DHQ, which was based on the Standard Tables of Food Composition in Japan (23). Information on dietary supplements and data from the open-ended questionnaire items were not used in the calculation of dietary intake. Detailed descriptions of the methods used for calculating dietary intake and the validity of the DHQ were published elsewhere (20–22). Pearson's correlation coefficients between the DHQ and 3-d dietary records were 0.48 for energy, 0.55 for fat, and 0.48 for total carbohydrate in 47 women (20). In addition, Pearson's correlation coefficients between the DHQ and 16-d dietary records were 0.79 for alcohol and 0.69 for dietary fiber in 92 women (S Sasaki, unpublished observations, 2004).

Calculation of dietary GI and GL

The GI of a food is defined as the 2-h incremental area under the blood glucose response curve after consumption of a food portion containing a specific amount (usually 50 g) of available carbohydrate, divided by the corresponding area after consumption of a portion of a reference food (usually glucose or white

bread) containing the same amount of available carbohydrate, and multiplied by 100 to be expressed as a percentage (24). We calculated dietary GI by multiplying the percentage contribution of each individual food to daily available carbohydrate intake by the food's GI value and summed these products. Available carbohydrate was calculated as total carbohydrate minus dietary fiber (24). We also calculated dietary GL by multiplying the dietary GI by the total amount of daily available carbohydrate intake (divided by 100).

To determine the GI value of each food for these calculations, each food item on the DHQ was directly matched to foods in the international table of GI (24), in several publications about the GI of Japanese foods (25–27), and in a recent article about the GI of potatoes (28). Glucose was used as the reference (GI for glucose = 100). The white bread–based GI values were transformed into glucose-based GI values by multiplying the white bread–based GI by 0.7, as in Western studies (24, 28), or by 0.73 [= 100/137 (white bread–based GI value of white bread/white bread–based GI value of glucose)] as in Japanese studies (27). The white rice–based GI values were transformed into glucose-based GI values by multiplying white rice–based GI by 0.82 [= 100/122 (white rice-based GI of white rice/white rice-based GI of glucose)] (25, 26). When more than one GI value was available, the mean GI values was used. Ten foods for which a GI value had not been determined were assigned a value according to the nearest comparable food, as follows: Chinese noodles were assigned the GI of instant noodles, Japanese-style pancakes were assigned the GI of pizza, jellies were assigned the GI of pudding, lotus roots were assigned the GI of carrots, vegetable juice was assigned the GI of tomato juice, curry and roux in stew were assigned the GI of white rice with curry, nutritional-supplement drinks were assigned the GI of sports drinks, nutritional supplement bars were assigned the GI of a sports bar, and ground fish-meat products and boiled-fish, shellfish, and seaweed in soy sauce were assigned the GI of fish fingers. Although alcoholic beverages contain little carbohydrate, large quantities of several alcoholic beverages, such as beer and sake, may raise glucose concentrations slightly; however, by definition, the GI is based on 50 g available carbohydrate. Thus, we ignored alcoholic beverages during the calculation of dietary GI and GL. Furthermore, foods with a very low available carbohydrate content were excluded because their GI values cannot be tested. The cutoff for exclusion of foods was set at 3.5 g available carbohydrate per serving (6). Of the total 147 food and beverage items included in the DHQ, 6 (4.1%) are alcoholic beverages, 8 (5.4%) contain no available carbohydrate, and 63 (42.9%) contain <3.5 g available carbohydrate per serving. The calculation of dietary GI and GL was thus based on the remaining 70 items with GI values ranging from 16 to 91. The GI value of each item is presented in **Table 1**. In the present study, the available carbohydrate content of these 70 items contributed to 94.0 ± 2.5% ($\bar{x}$ ± SD) of total available carbohydrate intake, which is comparable with previous studies (6, 10).

Other variables

Smoking status, menopausal status, dietary supplement use during the previous month, and rate of eating were self-reported in questionnaires. Body weight at age 20 y was also self-reported, and BMI at age 20 y was computed by dividing self-reported weight (kg) at age 20 y by the square of current measured height (m). In addition, the subjects reported the average times per week spent on 13 activities such as sleeping, household-related activities, leisure-time sporting activities, and leisure-time sedentary activities. The reported number of hours spent on each activity (per week) was divided by 7 to obtain the mean number of hours per day. For subjects whose recorded total hours per day were < or >24 h, the total number of hours spent daily were proportionately increased or decreased to equal 24. Each activity was assigned a metabolic equivalent (MET) value from a previously published table (29, 30). The mean number of hours spent per day on each activity was multiplied by the MET value of that activity, and all MET-hour products were summed to give a total MET-hour score for the day. Total energy expenditure was calculated by multiplying the total MET-hour score by body weight. Physical activity level was calculated by dividing total energy expenditure by basal metabolic rate, which was estimated as standard values of basal metabolic rate for Japanese women multiplied by body weight (31).

Statistical analysis

Dietary GI and GL were examined in relation to the 7 metabolic risk factors: BMI; serum total, HDL, and LDL cholesterol; fasting serum triacylglycerol; fasting plasma glucose; and Hb A_{1c}. We used crude values for dietary GI and energy-adjusted values for dietary GL (/1000 kcal) because, by definition, dietary GI is a measure of carbohydrate quality, not quantity, whereas dietary GL is a measure of the combination of carbohydrate quality and quantity. The mean (±SE) values for these metabolic factors were calculated according to quintiles of dietary GI and GL after multivariate adjustment for potential confounding variables. Confounding variables included residential area (5 categories), age (≤39, 40–49, 50–59, 60–69, and ≥ 70 y), menopausal status (premenopausal or postmenopausal), current smoking (no or yes), dietary supplement use (no or yes), rate of eating (fast, medium, or slow), physical activity level (quintiles), energy intake (quintiles), percentage of energy as fat (quintiles), alcohol intake (nondrinkers, >0 to <1% of energy, or ≥1% of energy), and energy-adjusted intake (g/1000 kcal) of dietary fiber (quintiles). In the analyses, except for the analysis of BMI, current BMI (quintiles) and BMI at age 20 y (quintiles) were also included as confounding variables. Linear trends with increasing levels of dietary GI and GL were tested by assigning each participant the median value for the category and modeling this value as a continuous variable. All statistical analyses were carried out by using SAS statistical software (version 8.2; SAS Institute Inc, Cary, NC). All reported P values are 2-tailed, and a P value <0.05 was considered statistically significant.

RESULTS

Basic characteristics of the 1354 subjects are shown in **Table 2**. The mean intakes of protein, fat, and carbohydrate were 14.0%, 25.3%, and 59.0% of energy, respectively. The mean dietary GI was 66.7 and the mean dietary GL was 88.0 (/1000 kcal; crude mean = 167.7). White rice was the major contributor to dietary GI and GL (58.5%), followed by confectioneries (10.6%), fruit (6.7%), sugars (5.5%), bread (4.3%), noodles (3.4%), other rice (3.2%), and potatoes (2.6%). Potential confounding variables of the 1354 subjects are shown in **Table 3** according to quintiles of dietary GI and GL. Fewer women in the higher quintiles of dietary GI used dietary supplements and more were nondrinkers of alcohol. Women in the higher quintiles of

TABLE 1
Glycemic index (GI) value of each food and beverage item used in the present study[1]

Food and beverage item	GI
White rice	77
White rice with barley	67
White rice with germs	66
50% Polished rice	66
70% Polished rice	70
Brown rice	55
Soba (buckwheat noodles) and udon (Japanese wheat noodles)	47
Instant noodles	47
Chinese noodles	47
Spaghetti	46
White bread	74
Cake bread	62
Butter roll	59
Croissant	67
Pizza	51
Japanese-style pancake	51
Pancake	67
Cornflakes	81
Potato chips	54
French fries	70
Other potatoes	78
Sweet potatoes, yams, and taros	51
Jam and marmalade	51
Sugar for coffee and tea	68
Sugar used during cooking	68
Rice crackers	91
Snacks made from wheat flour	63
Japanese sweets with azuki beans	49
Japanese sweets without azuki beans	68
Cakes	46
Cookies and biscuits	59
Chocolates	43
Candies, caramels, and chewing gum	74
Jellies	44
Doughnuts	76
Boiled beans	16
Raisins	64
Canned fruits	49
Fruit juice (100%)	47
Other fruit juice	47
Tomato juice	38
Oranges	39
Bananas	51
Apples	37
Strawberries	40
Grapes	50
Peaches	42
Pears	38
Persimmons	50
Kiwi fruit	53
Melons	42
Watermelons	58
Pumpkins	75
Lotus roots	47
Vegetable juice	38
Curry and roux in stew	67
Cocoa	51
Lactic acid bacteria beverages	42
Soft drinks	61
Nutritional supplement drinks	66
Ground fish meat products	38
Boiled fish, shellfish, and seaweed in soy sauce	38
Full-fat milk	27
Low-fat milk	30
Skim milk	32
Yogurt (sweetened)	24
Yogurt (nonsweetened)	36
Yogurt (moderately sweetened)	30
Ice cream	61
Nutritional supplement bars	48

[1] GI of glucose = 100. These 70 food and beverage items from the 147 items in the diet-history questionnaire were used for the calculation of GI. The remaining 77 items not used consisted of 6 alcoholic beverages (beer, sake, shochu, schochu highball, whiskey, and wine), 8 items containing no available carbohydrate (oils used during cooking, table salt, salt used during cooking, sugarless soft drinks, chicken, Chinese soup, noodle soup, and water), and 63 items containing <3.5 g available carbohydrate per serving [peanuts, other nuts, konnyaku, butter, margarine, mayonnaise, salad dressing, tofu, tofu products, natto, miso as seasoning, miso in miso soup, carrots, tomatoes, green peppers, broccoli, green leafy vegetables, salted pickled plums (umeboshi), other salted pickles, cabbage, cucumbers, lettuce, Chinese cabbage, bean sprouts, radishes, onions, cauliflower, eggplants, burdocks, mushrooms, wakame seaweed, laver, ketchup, nonoil salad dressing, soy sauce, green tea and oolong tea, tea, coffee, dried fish, small fish with bones, canned tuna, eel, white meat fish, blue-back fish, red meat fish, shrimp, squid and octopus, oysters, other shellfish, fish eggs, salted fish intestines, ground beef and pork, pork, beef, liver, ham and sausages, bacon, eggs (heno and quailo), cheese, cottage cheese, coffee cream, corn soup, and artificial sweeteners].

dietary GI had lower mean energy, fat, and dietary fiber intakes. In addition, women in the higher quintiles of dietary GL had higher mean values for age and physical activity level and lower mean energy, fat, and dietary fiber intakes. Fewer women in the higher quintiles of dietary GL were premenopausal, current smokers, and dietary supplement users and more were nondrinkers of alcohol. Similar patterns were observed for potential confounding variables according to quintiles of dietary GI and GL among the subjects included in the analyses of serum LDL cholesterol (n = 1348), fasting serum triacylglycerol (n = 1349), fasting plasma glucose (n = 764), and Hb A_{1c} (n = 845) (data not shown).

Multivariate-adjusted mean values for metabolic risk factors across quintile categories of dietary GI and GL are shown in **Table 4**. After adjustment for potential confounding variables, dietary GI was significantly positively correlated with BMI (mean difference between the lowest and highest quintiles = 0.7; P for trend = 0.017), fasting serum triacylglycerol (mean difference = 16.0 mg/dL; P for trend = 0.001), fasting plasma glucose (mean difference = 6.4 mg/dL; P for trend = 0.022), and Hb A_{1c} (mean difference = 0.2%; P for trend = 0.038). No correlation was observed between dietary GI and serum concentrations of total, HDL, and LDL cholesterol.

In contrast, after control for potential confounding variables, dietary GL was significantly negatively correlated with serum HDL cholesterol (mean difference = −6.4 mg/dL; P for trend = 0.004) and positively correlated with fasting serum triacylglycerol (mean difference = 14.4 mg/dL; P for trend = 0.047) and fasting plasma glucose (mean difference = 12.5 mg/dL; P for trend = 0.012). Other metabolic risk factors examined, including

TABLE 2
Basic characteristics of the 1354 Japanese women

	Value
Age (y)	55.3 ± 10.3[1]
≤39 y	69 (5.1)[2]
40–49 y	319 (23.6)
50–59 y	446 (32.9)
60–69 y	440 (32.5)
≥70 y	80 (5.9)
Body height (cm)	152.9 ± 5.9
Body weight (kg)	56.1 ± 8.3
Current BMI (kg/m^2)	24.0 ± 3.3
BMI at age 20 y (kg/m^2)	21.7 ± 2.6
Menopausal status	
Premenopausal	427 (31.5)
Postmenopausal	927 (68.5)
Current smoking	
No	1309 (96.7)
Yes	45 (3.3)
Dietary supplement use	
No	954 (70.5)
Yes	400 (29.5)
Rate of eating	
Fast	480 (35.5)
Medium	644 (47.6)
Slow	230 (17.0)
Physical activity level	1.84 ± 0.28
Energy intake (kcal/d)	1944 ± 497
Protein intake (% of energy)	14.0 ± 2.2
Fat intake (% of energy)	25.3 ± 5.8
Carbohydrate intake (% of energy)	59.0 ± 7.1
Alcohol intake (% of energy)	0.8 ± 2.3
Nondrinkers	836 (61.7)
>0% to < 1% of energy	271 (20.0)
≥1% of energy	247 (18.2)
Dietary fiber intake (g/1000 kcal)	7.6 ± 2.1
Dietary glycemic index[4]	66.7 ± 4.0
Dietary glycemic load (/1000 kcal)[4]	88.0 ± 15.1

[1] $\bar{x}$ ± SD (all such values).
[2] *n*; percentage in parentheses (all such values).
[3] Glycemic index for glucose = 100.

BMI, serum concentrations of total and LDL cholesterol, and Hb A_{1c} were not significantly correlated with dietary GL. Adjustment for the percentage of energy from carbohydrate instead of the percentage of energy from fat did not change the results materially, which suggests that the observed correlations between dietary GI and GL and metabolic risk factors are independent of carbohydrate intake (data not shown).

DISCUSSION

Because only limited evidence is available regarding associations between dietary GI and GL and metabolic risk factors, particularly in Asian populations, we investigated these associations in the present cross-sectional study of healthy Japanese female farmers with traditional dietary habits. We found that dietary GI was positively associated with BMI, fasting serum triacylglycerol, fasting plasma glucose, and Hb A_{1c} after control for potentially confounding lifestyle and dietary factors. We also found that dietary GL was independently negatively associated with serum HDL cholesterol and positively associated with serum triacylglycerol and fasting plasma glucose.

Concerns have been expressed regarding the utility of the GI for mixed meals (32, 33). However, many researchers have shown that the GI of a mixed meal can be predicted consistently as the mean of the GI values of each of the component foods, weighted according to their relative contribution to carbohydrate intake (34–36). In reality, studies using standardized techniques have observed high correlation coefficients between observed and calculated GI values, ranging from 0.84 to 0.99 (34–36). Dietary GI and GL values in the present study were similar when compared with those in a previous Japanese study (67 compared with 64 for GI and 168 compared with 150 for GL) (10). However, the dietary GI and GL values observed in the present and previous (10) Japanese studies were considerably higher than the corresponding values in Western countries (48–60 for GI and 84–120 for GL) (4–6, 7–9, 37–40). This may have resulted from the differences in the major food contributors. Dietary GIs and GLs in Western populations are determined by a variety of food items, including potatoes (7–8%), breakfast cereals (4–7%), bread (5%), and rice (5%) (41–43). However, white rice (GI = 77) was the major contributor in the present and previous (10) Japanese studies, accounting for 59% of dietary GI and GL in the present study.

All self-reported dietary assessment methods are subject to measurement error and selective underestimation or overestimation of dietary intake (44). In the present study, however, we used a previously validated DHQ (20–22) to minimize data inaccuracy. Additionally, dietary GI and GL values calculated in the present study are believed to be relatively accurate because the major determinant of dietary GI and GL in the present study, rice (62%), is more accurately reported than are other foods on the DHQ because it is consumed regularly in relatively fixed amounts. Moreover, the same tendency was observed in a repeated analysis of subjects with a physiologically plausible energy intake, ie, subjects with a ratio of energy intake to basal metabolic rate of 1.2–2.5 (45)—≈78% of the subjects included in the main analysis (data not shown). Thus, we considered that the correlations observed in the present study reflect true associations, not spurious associations resulting from inaccurate dietary data.

In the present study, dietary GI was positively correlated with BMI. A 5-wk crossover, randomized, controlled trial conducted in overweight nondiabetic men with ad libitum dietary intakes also showed a significantly lower fat mass and a tendency for a higher fat-free mass, but not a lower body weight, after a low-GI diet than after a high-GI diet (46). In contrast, other ad libitum trials conducted in subjects with type 2 diabetes showed no significant differences in body weight change between high-GI and low-GI diets (47–49). However, in a 10-wk ad libitum, randomized, controlled trial conducted in healthy overweight women, decreases in body weight and fat mass were larger in a low-GI diet group than in a high-GI diet group, although these differences were not statistically significant (50). Moreover, as was shown in this study, a recent observational study also showed a positive association between dietary GI and BMI and no association between dietary GL and BMI (6).

Dietary GL has consistently been shown to be inversely correlated with HDL cholesterol in cross-sectional studies (8–11). In contrast, the correlation between dietary GI and HDL cholesterol is not consistent. An inverse correlation has been reported

TABLE 3
Selected characteristics of the 1354 Japanese women according to quintiles of dietary glycemic index and load

	Quintiles of dietary glycemic index or load					
	1 (n = 270)	2 (n = 271)	3 (n = 271)	4 (n = 271)	5 (n = 271)	P^1
Dietary glycemic index[2]	60.8 ± 2.6[3]	64.8 ± 0.7	67.0 ± 0.6	68.9 ± 0.6	71.8 ± 1.4	
Age (y)	55.8 ± 11.3	54.7 ± 10.4	55.1 ± 10.4	55.4 ± 9.7	55.7 ± 9.4	0.89
Current BMI (kg/m^2)	23.9 ± 3.3	23.9 ± 3.1	23.8 ± 3.1	24.2 ± 3.3	24.2 ± 3.5	0.23
BMI at age 20 y (kg/m^2)	21.7 ± 2.8	21.5 ± 2.2	21.6 ± 2.4	21.8 ± 2.5	21.9 ± 2.8	0.22
Premenopausal women (%)	27	31	35	30	34	0.21
Current smokers (%)	6	3	3	1	4	0.13
Dietary supplement users (%)	37	30	31	26	24	0.0005
Rate of eating (%)						0.45
Fast	37	36	33	39	33	
Medium	46	51	47	47	47	
Slow	17	13	20	14	20	
Physical activity level	1.82 ± 0.29	1.84 ± 0.28	1.83 ± 0.28	1.85 ± 0.28	1.84 ± 0.29	0.45
Energy intake (kcal/d)	2171 ± 559	2067 ± 453	1979 ± 467	1809 ± 404	1695 ± 440	<0.0001
Fat intake (% of energy)	27.7 ± 5.5	27.0 ± 5.4	25.6 ± 5.2	24.3 ± 5.4	22.2 ± 5.5	<0.0001
Alcohol intake (%)						0.0007
Nondrinkers	57	57	62	67	66	
>0% to < 1% of energy	20	21	21	19	20	
≥1% of energy	23	22	17	14	15	
Dietary fiber intake (g/1000 kcal)	9.1 ± 2.3	7.9 ± 2.0	7.6 ± 1.7	7.2 ± 1.7	6.4 ± 1.6	<0.0001
Dietary glycemic load (/1000 kcal)[2]	67.6 ± 6.7	79.9 ± 2.4	87.4 ± 2.3	95.4 ± 2.5	109.7 ± 8.4	
Age (y)	53.5 ± 12.1	54.4 ± 10.6	54.5 ± 10.1	56.9 ± 8.9	56.9 ± 9	<0.0001
Current BMI (kg/m^2)	24.1 ± 3.3	23.8 ± 3.0	24.0 ± 3.4	24.1 ± 3.2	24.0 ± 3.4	0.70
BMI at age 20 y (kg/m^2)	21.6 ± 2.6	21.7 ± 2.4	21.6 ± 2.6	21.7 ± 2.5	21.9 ± 2.6	0.21
Premenopausal women (%)	38	34	32	28	27	0.002
Current smokers (%)	6	3	3	3	2	0.024
Dietary supplement users (%)	34	32	32	27	22	0.0007
Rate of eating (%)						0.58
Fast	39	32	36	34	37	
Medium	47	48	50	45	47	
Slow	14	20	14	21	16	
Physical activity level	1.79 ± 0.27	1.84 ± 0.29	1.84 ± 0.27	1.86 ± 0.29	1.85 ± 0.30	0.010
Energy intake (kcal/d)	2285 ± 549	2106 ± 438	1926 ± 404	1808 ± 396	1595 ± 378	<0.0001
Fat intake (% of energy)	31.8 ± 4.7	28.4 ± 3.0	25.6 ± 3.1	22.4 ± 2.8	18.5 ± 3.5	<0.0001
Alcohol intake (%)						<0.0001
Nondrinkers	49	54	63	67	75	
>0% to <1% of energy	17	23	22	21	18	
≥1% of energy	34	23	15	12	7	
Dietary fiber intake (g/1000 kcal)	8.1 ± 2.3	7.9 ± 2.0	7.6 ± 1.8	7.7 ± 2.1	6.9 ± 1.9	<0.0001

[1] For continuous variables, tests for linear trend used the median value in each quintile as a continuous variable in linear regression; a Mantel-Haenszel chi-square test was used for categorical variables.
[2] Glycemic index for glucose = 100.
[3] $\bar{x}$ ± SD (all such values).

in 3 (7, 8, 10), but not in another 2 (9, 37), cross-sectional studies. Furthermore, recent randomized controlled trials have not supported the beneficial effect of a low-GI diet on HDL cholesterol in contrast with a high-GI diet (46–50). In the present study, we also found an inverse correlation between dietary GL and HDL cholesterol, but no correlation between dietary GI and HDL cholesterol.

Both dietary GI and GL were positively correlated with fasting triacylglycerol in 2 cross-sectional studies (9, 10); however, no association between dietary GI and fasting triacylglycerol was observed in a study of elderly men (37). In the present study, both dietary GI and GL were positively associated with fasting triacylglycerol. Several randomized controlled trials have also shown the beneficial effect of a low-GI diet on triacylglycerol (51), although the lack of an effect of GI has been observed in subjects with low triacylglycerol concentrations (52).

We identified a positive correlation between dietary GI and GL and fasting glucose, whereas no correlation was observed in a cross-sectional study of elderly men (37). Several prospective cohort studies (4, 5, 38), but not others (39, 40, 53), in the United States have shown a positive association between dietary GI, GL, or both and the incidence of type 2 diabetes, which is not in conflict with our finding. Recently, several (48, 49), but not all (46, 47, 50), randomized controlled trials have also shown lower fasting glucose concentrations after consumption of a low-GI diet than after a high-GI diet.

TABLE 4
Metabolic risk factors according to quintiles of dietary glycemic index and load in Japanese women

	Total *n*	Quintiles of dietary glycemic index or load					*P* for trend[1]
		1	2	3	4	5	
Dietary glycemic index[2,3]	1354	61 (46.1–63.4)	65 (63.5–65.9)	67 (66.0–67.9)	69 (68.0–70.0)	72 (70.1–76.5)	
BMI (kg/m^2)[4]	1354	23.7 ± 0.2 (270)[5]	23.9 ± 0.2 (271)	23.8 ± 0.2 (271)	24.2 ± 0.2 (271)	24.4 ± 0.2 (271)	0.017
Serum total cholesterol (mg/dL)[4,6]	1354	212.1 ± 2.2 (270)	211.8 ± 2.0 (271)	211.6 ± 2.0 (271)	216.5 ± 2.0 (271)	211.5 ± 2.2 (271)	0.74
Serum HDL cholesterol (mg/dL)[4,6]	1354	64.7 ± 0.9 (270)	62.5 ± 0.9 (271)	63.0 ± 0.9 (271)	63.8 ± 0.9 (271)	63.6 ± 1.0 (271)	0.58
Serum LDL cholesterol (mg/dL)[4,6]	1348	130.0 ± 2.1 (269)	129.4 ± 1.9 (269)	128.2 ± 1.9 (269)	133.2 ± 1.9 (271)	127.3 ± 2.1 (270)	0.73
Fasting serum triacylglycerol (mg/dL)[4,6]	1349	87.1 ± 3.0 (269)	99.1 ± 2.8 (270)	101.7 ± 2.7 (270)	98.0 ± 2.8 (270)	103.1 ± 3.0 (270)	0.001
Fasting plasma glucose (mg/dL)[4,6]	764	92.9 ± 2.0 (152)	97.0 ± 1.8 (153)	97.0 ± 1.8 (153)	99.8 ± 1.8 (153)	99.3 ± 1.9 (153)	0.022
Glycated hemoglobin (%)[4,6]	845	5.0 ± 0.1 (169)	5.1 ± 0.1 (169)	5.1 ± 0.1 (169)	5.2 ± 0.1 (169)	5.2 ± 0.1 (169)	0.038
Dietary glycemic load (/1000 kcal)[2,7]	1354	69 (31.1–75.7)	80 (75.8–83.7)	87 (83.8–91.2)	95 (91.3–100.2)	107 (100.3–148.5)	
BMI (kg/m^2)[4]	1354	24.2 ± 0.3 (270)	23.8 ± 0.2 (271)	24.0 ± 0.2 (271)	24.2 ± 0.2 (271)	23.8 ± 0.3 (271)	0.48
Serum total cholesterol (mg/dL)[4,6]	1354	212.6 ± 3.0 (270)	215.1 ± 2.4 (271)	212.1 ± 2.1 (271)	212.2 ± 2.4 (271)	211.6 ± 3.2 (271)	0.87
Serum HDL cholesterol (mg/dL)[4,6]	1354	67.2 ± 1.3 (270)	65.5 ± 1.0 (271)	62.1 ± 0.9 (271)	61.9 ± 1.0 (271)	60.8 ± 1.4 (271)	0.004
Serum LDL cholesterol (mg/dL)[4,6]	1348	127.2 ± 2.8 (267)	130.4 ± 2.3 (271)	130.7 ± 2.0 (270)	130.0 ± 2.2 (270)	129.9 ± 3.0 (270)	0.56
Fasting serum triacylglycerol (mg/dL)[4,6]	1349	91.0 ± 4.1 (269)	96.8 ± 3.3 (270)	95.6 ± 2.9 (270)	100.1 ± 3.2 (270)	105.4 ± 4.4 (270)	0.047
Fasting plasma glucose (mg/dL)[4,6]	764	90.9 ± 2.7 (152)	97.0 ± 2.1 (153)	97.5 ± 1.9 (153)	97.2 ± 2.1 (153)	103.4 ± 2.9 (153)	0.012
Glycated hemoglobin (%)[4,6]	845	5.0 ± 0.1 (169)	5.1 ± 0.1 (169)	5.1 ± 0.1 (169)	5.1 ± 0.1 (169)	5.2 ± 0.1 (169)	0.10

[1] Linear trends were tested with increasing dietary glycemic indexes and loads by assigning each participant the median value for the category and modeling this value as a continuous variable.

[2] Glycemic index for glucose = 100. Values are medians; ranges in parentheses.

[3] The median values shown are the same for BMI, triacylglycerol, and total, HDL, and LDL cholesterol but are different for glucose and glycated hemoglobin: 61, 64, 67, 69, and 71, respectively.

[4] Adjusted for residential area (5 categories), age (≤39, 40–49, 50–59, 60–69, and ≥70 y), menopausal status (premenopausal or postmenopausal), current smoking (no or yes), dietary supplement use (no or yes), rate of eating (fast, medium, or slow), physical activity level (quintiles), energy intake (quintiles), percentage of energy as fat (quintiles), alcohol intake (nondrinker, >0% to <1% of energy or ≥1% of energy), and energy-adjusted dietary fiber intake (quintiles).

[5] $\bar{x}$ ± SE; *n* in parentheses (all such values).

[6] Additionally adjusted for current BMI (quintiles) and BMI at age 20 y (quintiles).

[7] The median values shown are the same for BMI, triacylglycerol, glycated hemoglobin, and total, HDL, and LDL cholesterol but are different for glucose: 68, 79, 87, 95, and 107/1000 kcal, respectively.

We found a positive correlation between dietary GI and Hb A_{1c}. A positive association was also reported in cross-sectional studies conducted in patients with type 2 diabetes treated by dietary restriction alone (12) and in patients with type 1 diabetes (13). Additionally, a low-GI diet reduced Hb A_{1c} more than did a high-GI diet in several randomized controlled trials (48, 49). Furthermore, a recent meta-analysis of 14 randomized controlled trials has shown the amelioration of Hb A_{1c} through a low-GI diet (54).

Both total and LDL cholesterol were not correlated with dietary GI or GL in the present study, although randomized controlled trials have generally shown that low-GI diets result in lower total and LDL cholesterol concentrations (54). However, similar to our findings, no correlation between dietary GI or GL and total or LDL cholesterol was observed in several cross-sectional studies (7, 10, 37).

Our results may not be extrapolated into general Japanese populations because the subjects in the present study were selected female farmers. Additionally, our DHQ, although similar to most previous epidemiologic studies, was not designed specifically to measure dietary GI and GL; however, the satisfactory validity of this DHQ for total carbohydrate (20) provides some reassurance. Moreover, although we attempted to adjust for a wide range of potential confounding variables, we could not rule out residual confounding because of these or other unknown variables. Furthermore, because the study population consisted of generally healthy persons, the clinical relevance of our findings remains to be elucidated. However, our results should provide valuable insight from a prevention perspective.

In summary, after adjustment for a variety of confounding factors, we observed positive correlations between dietary GI and BMI, fasting serum triacylglycerol, fasting plasma glucose, and Hb A_{1c} and between dietary GL and fasting serum triacylglycerol and fasting plasma glucose and negative correlations between dietary GL and serum HDL cholesterol in healthy Japanese female farmers whose dietary GI and GL were primarily determined by white rice. Because the cross-sectional nature of the present study precludes any causal inferences, more observational and experimental studies are needed before any firm conclusions can be drawn with regard to the effect of dietary GI and GL on metabolic risk factors.

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KM created a table of glycemic index, conducted the statistical analyses, and wrote the manuscript. SS was involved in the design of the dietary study and assisted in the creation of the table and the manuscript. YT assisted in the creation of the table. HO was involved in the management of the dietary dataset and data collection during the dietary study. YH was involved in the data collection for the dietary study. HH and EO were responsible for the research design, data collection, and data management. FK was responsible for the research design, data collection, and overall management. All authors provided suggestions during the preparation of the manuscript and approved

the final version submitted for publication. None of the authors had any conflict of interest to declare.

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Applied nutritional investigation

No relation between intakes of calcium and dairy products and body mass index in Japanese women aged 18 to 20 y

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Abstract

Objective: This cross-sectional study examined possible associations of intakes of calcium and dairy products to body mass index (BMI; kilograms per square meter) in young Japanese women.
Methods: Subjects were 1905 female Japanese dietetic students who were 18 to 20 y of age. Dietary intake was assessed over a 1-mo period with a validated, self-administered diet history questionnaire. BMI was computed by using self-reported weight and height. BMI among quartiles of energy-adjusted intakes (per 1000 kcal) of calcium and dairy products was compared while controlling for intakes of protein, fat, and dietary fiber, self-reported rate of eating, and other non-dietary variables.
Results: Mean BMI ± standard deviation was 20.8 ± 2.6 kg/m^2. Mean estimated intakes were 268 ± 93 mg/1000 kcal for calcium and 80 ± 63 g/1000 kcal for dairy products. Intakes of calcium and dairy products were not significantly associated with BMI (adjusted means in the lowest and highest quartiles were 20.7 and 20.8 for calcium, P for trend = 0.48, and 20.6 and 20.6 for dairy products, P for trend = 0.81). These results were also observed after excluding 481 energy under- and over-reporters for calcium (20.4 and 20.5, respectively, P for trend = 0.73) and dairy products (20.3 and 20.4, respectively, P for trend = 0.73).
Conclusions: Intakes of calcium and dairy products may not necessarily be associated with BMI among young Japanese women who not only are relatively lean but also have a relatively low intake of calcium and dairy products.

Keywords: Calcium intake; Dairy product intake; Body mass index; Japanese women; Epidemiology

Introduction

A recently emerging body of literature suggests that the intake of calcium and/or dairy products may protect humans against the development of obesity [1–15]. A possible theory is that a low calcium intake causes high intracellular calcium concentrations, which in turn promote lipogenesis, inhibit lipolysis, and decrease thermogenesis, whereas a high calcium intake reverses these trends [3]. It seems that the effect of calcium in the form of dairy products may be greater than that of elemental calcium [16]. However, several published reports have not supported the potentially favorable effects of calcium and/or dairy products on measurements of obesity [17–22]. Thus, the relation of calcium and/or dairy product intake to obesity remains unclear. In addition, research on this issue has been conducted mainly in Western countries, whereas information is quite limited in non-Western countries including Japan, where the prevalence of obesity and dietary intakes of calcium and dairy products are relatively low [23]. Therefore, we investigated possible associations of intakes of calcium and dairy products with body mass index (BMI) in young Japanese women.

Materials and methods

Subjects were students who entered dietetic courses at 22 colleges and technical schools in three of the four main islands of Japan in April 1997 (n = 2069) [24–26].

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A total of 2063 students (2017 women and 46 men) participated in the survey (response rate 99.7%). For statistical analysis, we selected female subjects who were 18 to 20 y of age (n = 1960). We excluded from the 1960 women those who were currently receiving dietary counseling (n = 33), those with an extremely low or high reported energy intake (<775 or >3950 kcal/d, n = 18), and those with missing information on variables used in the present study (n = 6). Because some subjects were in more than one exclusion category, the final analytic sample contained 1905 subjects.

Dietary habits during the previous month were assessed by using a previously validated, self-administered diet history questionnaire (DHQ) [27–29]. Measurements of dietary intake for 147 food and beverage items, energy, protein, fat, carbohydrate, alcohol, dietary fiber, and calcium were calculated by using an ad hoc computer algorithm developed for the DHQ, which was based on the *Standard Tables of Food Composition in Japan* [30]. Although dietary supplement usage was queried in the DHQ, intake from dietary supplements was not included in this study due to the lack of a reliable composition table of dietary supplements in Japan. Dairy products consisted of full-fat, low-fat, and skimmed milk, sweetened and non-sweetened yogurt, cheese, cottage cheese, ice cream, and coffee cream [31]. Pearson's correlation coefficient between DHQ and 3-d diet records was 0.49 for calcium intake that was adjusted for energy intake by using a residual model among 47 women [27]. For dairy products (grams per 1000 kcal), Spearman's correlation coefficient between DHQ and 16-d diet records was 0.52 among 92 women (unpublished observations, S. Sasaki, 2004).

Body weight and height were self-reported as part of the DHQ. BMI was computed as weight (kilograms) divided by the square of height (meters). In the DHQ, subjects also reported their rate of eating (very slow, relatively slow, medium, relatively fast, or very fast) and intentional dietary change (no, changed within 1 y, changed within 3 y, or changed >3 y ago). In addition, a self-administered questionnaire on general lifestyle during the previous month asked about the following four variables: current smoking (yes or no), experience of dieting (≥2 kg intentional decrease in body weight within 1 mo, yes or no), residential area, and participation in sports club activities (times per month) without inquiring into the types of sports, intensity, or duration. Residential areas were categorized into 12 regional blocks according to the *National Nutrition Survey in Japan* [23]. Because relatively few subjects were categorized into three of these blocks (Hokkaido, Tohoku, and Hokuriku), they were included in their adjacent blocks, resulting in nine categories (Kanto II, Hokkaido, and Tohoku; Kanto I; Tokai and Hokuriku; Kinki I; Kinki II; Chugoku; Shikoku; Kita-kyushu; and Minami-kyushu). The residential areas were also divided into three categories according to population (city with population ≥1 million, city with population <1 million, or town and village). Subjects who participated in sports club activities at least once per week were regarded as "active" and all others as "sedentary" without consideration of other kinds of activities.

All statistical analyses were performed with SAS 8.2 (SAS Institute, Cary, NC, USA). For analyses, subjects were categorized into quartiles according to the energy-adjusted intakes (per 1000 kcal) of calcium and dairy products. Mean BMI ± standard error (SE) was calculated by quartiles of these variables while controlling for a series of covariates that could affect body weight (residential block [nine categories], size of residential area [three categories], current smoking [two categories], alcohol drinking [yes or no because of extremely low alcohol intake, mean 0.8 g/d], physical activity [two categories], experience of dieting [two categories], intentional dietary change [four categories], rate of eating [five categories], protein intake [percentage of energy intake, continuous], fat intake [percentage of energy intake, continuous], and dietary fiber intake [grams per 1000 kcal, continuous]). We did not include percentage of energy intake from carbohydrate as a covariate because of its very high correlation with percentage of energy intake from fat (Pearson's correlation coefficient −0.94). We tested for linear trends with increasing levels of intakes of calcium and dairy products by assigning each participant the median value for the category and modeling this value as a continuous variable. We also calculated the partial regression coefficient (β) and SE for intakes of calcium and dairy products by multiple regression analysis with BMI as the dependent variable, with adjustment for the potential confounding variables indicated above. All reported P values are two-tailed, and $P < 0.05$ was considered statistically significant.

In a previous study [7], the size of the effect of calcium intake on BMI was −0.26 kg/m^2 per 100 mg per 1000-kcal increase in calcium intake. In our population [24], mean calcium intake ± standard deviation was 306 ± 148 mg/1000 kcal, and the standard deviation of BMI was 2.6 kg/m^2. Using these values, power calculations revealed that a sample of 532 women (133 women in each quartile category) was sufficient to demonstrate the expected difference (−0.89 kg/m^2) between the highest and lowest quartile categories (excepted medians 477 and 136 mg/1000 kcal, respectively), with 80% power at the $\alpha = 0.05$ significance level. Because these calculations for t test (not for analysis of variance or test for linear trend) did not take into consideration the adjustment for potential confounding variables, a larger number of subjects was needed in practice. However, our sample (n = 1905) was much larger than the calculated sample size, indicating that its size was sufficient for detecting the difference in BMI between extreme quartiles, if the size of the effect of calcium on BMI similar to that observed in the previous study [7] was really present in our population.

Results

Basic characteristics of the subjects are presented in Table 1. Mean BMI ± standard deviation of subjects was 20.8 ± 2.6 kg/m^2, and mean intakes were 268 ± 93 mg/1000 kcal for calcium and 80 ± 63 g/1000 kcal for dairy products. Potential confounding variables of the subjects are listed in Table 2 according to quartiles of intakes of calcium and dairy products. Among women in the higher quartiles of those intakes, more were defined as physically active and reported recent intentional dietary changes. Women in the higher quartiles of those intakes also had higher means of protein, fat, and dietary fiber intake. There were more subjects with dieting experience and more slower eaters in the higher quartiles of calcium intake.

As presented in Table 3, after adjustment for potential confounding variables, calcium and dairy product intakes were not significantly associated with BMI (adjusted means in the lowest and highest quartiles were 20.7 and 20.8 kg/m^2 for calcium, P for trend = 0.48, and 20.6 and 20.6 kg/m^2 for dairy products, P for trend = 0.81). Similar insignificant associations were observed when calcium and dairy products were treated as continuous variables in multiple regression analyses (β ± SE −0.0002 ± 0.0008 kg/m^2 for calcium, P = 0.77, and −0.0004 ± 0.0001 kg/m^2 for dairy products, P = 0.71). A repeated analysis of 1424 women with plausible reported energy intakes (ratio of energy intake to basal metabolic rate of 1.2 to 2.5) [32], conducted because of possible selective misreporting of dietary intake [33], also showed no relation between intakes of calcium and dairy products and BMI (adjusted means in the lowest and highest quartiles were 20.4 and 20.5 kg/m^2 for calcium, P for trend = 0.73, and 20.3 and 20.4 kg/m^2 for dairy products, P for trend = 0.73; β ± SE 0.0001 ± 0.0008 kg/m^2 for calcium, P = 0.90, and 0.0006 ± 0.0010 kg/m^2 for dairy products, P = 0.54).

Discussion

Using cross-sectional data of relatively lean young Japanese women with relatively low intakes of calcium and dairy products, we found no clear association of intakes of calcium and dairy products with BMI. This finding was consistent regardless of exclusion of implausible energy reporters.

An inverse relation of intakes of calcium and/or dairy products to measurements of obesity has been indicated in a considerable number of case-control [2], cross-sectional [3,5,7–10,12], and longitudinal [1,4,6] studies and intervention trials [13–15] conducted in Western countries. In addition, the frequency of dairy consumption has been inversely associated with BMI in Iranian adults [11]. In contrast, no significant relation has been shown in two longitudinal studies [18,21] or in several intervention trials [17,19,20] in Western countries. A recent longitudinal study

Table 1
Basic characteristics of subjects (n = 1905)*

Variable	
Age (y)	18.1 ± 0.4
Body height (cm)	157.9 ± 5.2
Body weight (kg)	51.8 ± 7.3
Body mass index (kg/m^2)	20.8 ± 2.6
Residential block†	
Kanto II, Hokkaido, and Tohoku	84 (4)
Kanto I	434 (23)
Tokai and Hokuriku	278 (15)
Kinki I	152 (8)
Kinki II	118 (6)
Chugoku	294 (15)
Shikoku	156 (8)
Kita-kyushu	214 (11)
Minami-kyushu	175 (9)
Size of residential area	
City with population ≥1 million	318 (17)
City with population <1 million	1106 (58)
Town and village	481 (25)
Current smoking	
No	1849 (97)
Yes	56 (3)
Current alcohol drinking	
No	1514 (79)
Yes	391 (21)
Physical activity‡	
Sedentary	1647 (86)
Active	258 (14)
Experience of dieting§	
No	1160 (61)
Yes	745 (39)
Intentional dietary change	
No	1481 (78)
Changed within 1 y	213 (11)
Changed within 3 y	127 (7)
Changed >3 y ago	84 (4)
Rate of eating	
Very slow	92 (5)
Relatively slow	431 (23)
Medium	683 (36)
Relatively fast	610 (32)
Very fast	89 (5)
Use of calcium supplement	
No	1868 (98)
Yes	37 (2)
Energy intake (kcal/d)	1911 ± 517
Protein intake (% energy)	13.7 ± 2.2
Fat intake (% energy)	30.5 ± 6.1
Carbohydrate intake (% energy)	54.4 ± 6.8
Dietary fiber intake (g/1000 kcal)	6.3 ± 1.7
Calcium intake (mg/1000 kcal)	268 ± 93
Dairy product intake (g/1000 kcal)	80 ± 63

* Values are means ± standard deviations or numbers of subjects (%).

† Residential blocks were categorized into 12 blocks according to the National Nutrition Survey of Japan [23]. Because relatively few subjects were categorized into three of these blocks (Hokkaido, Tohoku, and Hokuriku), they were included in their adjacent blocks.

‡ Subjects who took part in sports club activities at least once per week were defined as "active" and others as "sedentary."

§ "Dieting" was defined as at least 2 kg of intentional decrease of body weight within 1 mo.