tors, including residential block, size of residential area, current smoking, rate of eating, alcohol drinking, physical activity (total metabolic equivalent-hours/day, continuous), and energy intake (kilocalories/day, continuous; model 1). We also included BMI (kilograms per square meter, continuous) as a confounding factor (model 2). For nutrients, we further adjusted for intake (continuous) of other nutrients (total fat as percentage of energy and dietary fiber as grams per 1000 kcal for protein; protein as percentage of energy and dietary fiber for total fat, saturated, monounsaturated, polyunsaturated fatty acids, and carbohydrate; and protein and total fat for dietary fiber; model 3). For fatty acids, we further adjusted for other fatty acids (model 4). Because the distribution of serum leptin concentrations was highly skewed, the analyses were done using natural log-transformed values. We tested for linear trends with increasing levels of dietary intake by assigning each participant the median value for the category and modeling this value as a continuous variable. All statistical analyses were performed using SAS 8.2 (SAS Institute, Cary, NC, USA). All reported P values are two-tailed, and $P < 0.05$ was considered statistically significant.

Results

Subject characteristics are listed in Table 1. Mean serum leptin concentration was 7.7 ng/mL. Mean intakes of protein, fat, and carbohydrate were 13.9%, 29.6%, and 55.1% energy, respectively, whereas mean intakes of dietary fiber, vegetables, and pulses were 7.1, 129.4, and 25.3 g/1000 kcal, respectively. Subject characteristics according to quintile of serum leptin concentration are also presented in Table 1. Women in the higher quintiles of serum leptin weighed more, consumed less alcohol, and had lower intake of protein, dietary fiber, vegetables, and pulses.

Independent associations between nutrient intake and serum leptin concentration are presented in Table 2. Intakes of protein and polyunsaturated fatty acids were significantly inversely associated with serum leptin concentration, independent of not only potential confounding factors (model 1: P for trend = 0.004 and 0.008, respectively) but also of BMI (model 2: P for trend = 0.007 and 0.035, respectively). This association disappeared after further adjustment for intake of other nutrients (model 3: P for trend = 0.21 and 0.23, respectively; model 4 for polyunsaturated fatty acids: P for trend = 0.86). Although total fat intake was significantly inversely associated with serum leptin concentration, independent of potential confounding factors (model 1: P for trend = 0.033), this was not independent of BMI (model 2: P for trend = 0.23) or other nutrients (model 3: P for trend = 0.31). Intakes of saturated and monounsaturated fatty acids and carbohydrate were not significantly associated with serum leptin concentration regardless of adjustment for other factors. Conversely, dietary fiber intake was a significant determinant of serum leptin concentration, independent of not only potential confounding factors (model 1: P for trend = 0.0003) including BMI (model 2: P for trend = 0.003) but also of other nutrient intakes (model 3: P for trend = 0.026). Higher dietary fiber intake was independently associated with lower serum leptin concentration (mean difference in serum leptin concentration between the lowest and highest quintiles of dietary fiber intake = −1.1 ng/mL, model 3).

Table 3 presents independent associations between food intake and serum leptin concentration. Cereals were significantly positively associated with serum leptin concentration, independent of potential confounding factors (model 1: P for trend = 0.013), but this was not independent of BMI (model 2: P for trend = 0.22). Vegetables and pulses were significantly associated with serum leptin concentration independently of not only potential confounding factors (model 1: P for trend = 0.001 and 0.027, respectively) but also of BMI (model 2: P for trend = 0.007 and 0.019, respectively). Increasing intake of these foods was independently associated with a lower serum leptin concentration (mean difference in serum leptin concentration between the lowest and highest quintiles of intake = −1.1 ng/mL for vegetables and −1.2 ng/mL for pulses, model 2). However, after further adjustment for intake of dietary fiber, a single nutrient independently associated with serum leptin concentration in the present study, the significant associations of intake of vegetables and pulses with serum leptin concentration disappeared (P for trend = 0.50 and 0.25, respectively). Intakes of other foods were not significantly associated with serum leptin concentration regardless of adjustment for other factors.

Discussion

In this study of young Japanese women, we found that higher intakes of dietary fiber, vegetables, and pulses were associated with lower serum leptin concentrations, independently of potential confounding factors including BMI. Given that our subjects were selected female dietetic students rather than a random sample of Japanese women, these results might not be extrapolated to the general Japanese population. However, the biological relation between diet and leptin levels in this population is likely similar to that among women in general. In addition, because the study population consisted of generally healthy participants, the clinical relevance of our findings remains to be elucidated. Nevertheless, our results should provide valuable insight from a prevention perspective. The relatively healthy dietary habits and the narrower range of leptin levels in this population of young healthy and lean women would mean that greater differences might be seen in other populations.

On average, serum leptin concentration in this study of 18- to 22-y-old Japanese women with a mean BMI of 21.4 kg/m^2 (arithmetic mean = 8.8 ng/mL) was relatively com-

Table 1
Subject characteristics according to quintile of serum leptin concentration*

Variable	All (n = 424)	Quintile of serum leptin concentration					P[†]
		1 (n = 89)	2 (n = 80)	3 (n = 86)	4 (n = 83)	5 (n = 86)	
Serum leptin concentration (ng/mL)	7.7 (7.3–8.1)	4.2	5.9	7.8	10.4	14.5	
Age (y)	19.5 ± 1.0	19.9 ± 1.2	19.5 ± 0.8	19.3 ± 0.9	19.3 ± 1.0	19.4 ± 0.9	0.002
Body height (cm)	157.9 ± 5.6	158.4 ± 5.3	157.8 ± 5.1	156.7 ± 6.0	158.7 ± 6.0	157.8 ± 5.3	0.91
Body weight (kg)	53.3 ± 8.1	48.1 ± 4.4	50.2 ± 4.8	51.8 ± 5.4	55.2 ± 5.1	61.4 ± 10.9	<0.0001
Body mass index (kg/m^2)	21.4 ± 2.9	19.2 ± 1.6	20.1 ± 1.6	21.1 ± 1.8	21.9 ± 1.7	24.6 ± 3.8	<0.0001
Residential block							0.038
North (Kanto and Tohoku)	263 (62)	47 (53)	43 (54)	61 (71)	57 (69)	55 (64)	
Central (Tokai and Hokuriku)	68 (16)	17 (19)	17 (21)	10 (12)	11 (13)	13 (15)	
South (Kyushu and Chugoku)	93 (22)	25 (28)	20 (25)	15 (17)	15 (18)	18 (21)	
Size of residential area							0.23
City with population ≥1 million	75 (18)	15 (17)	15 (19)	21 (24)	12 (15)	12 (14)	
City with population <1 million	314 (74)	66 (74)	61 (76)	60 (70)	64 (77)	63 (73)	
Town and village	35 (8)	8 (9)	4 (5)	5 (6)	7 (8)	11 (13)	
Current smoking							0.55
No	412 (97)	86 (97)	76 (95)	86 (100)	80 (96)	84 (98)	
Yes	12 (3)	3 (3)	4 (5)	0 (0)	3 (4)	2 (2)	
Rate of eating							0.013
Slow	134 (32)	32 (36)	28 (35)	29 (34)	19 (23)	26 (30)	
Medium	134 (32)	30 (34)	26 (33)	29 (34)	33 (40)	16 (19)	
Fast	156 (37)	27 (30)	26 (33)	28 (33)	31 (37)	44 (51)	
Alcohol drinking							0.033
Non-drinker	253 (60)	47 (53)	39 (49)	58 (67)	53 (64)	56 (65)	
>0% to <1% energy	103 (24)	25 (28)	22 (28)	22 (26)	17 (20)	17 (20)	
≥1% energy	68 (16)	17 (19)	19 (24)	6 (7)	13 (16)	13 (15)	
Physical activity (total metabolic equivalents-h/d)	34.1 ± 3.5	34.1 ± 3.3	34.0 ± 3.0	34.5 ± 4.8	34.5 ± 3.9	33.4 ± 2.1	0.27
Energy intake (kcal/d)	1764 ± 408	1715 ± 417	1831 ± 420	1775 ± 373	1723 ± 397	1782 ± 429	0.83
Nutrient intake							
Protein (% energy)	13.9 ± 1.9	14.3 ± 2.0	13.8 ± 1.9	14.1 ± 1.8	13.8 ± 1.7	13.4 ± 1.8	0.003
Total fat (% energy)	29.6 ± 5.0	30.0 ± 5.0	30.1 ± 5.1	29.7 ± 4.2	28.6 ± 4.9	29.4 ± 5.5	0.18
Saturated fatty acids (% energy)	8.6 ± 2.0	8.6 ± 1.8	8.9 ± 2.2	8.6 ± 1.8	8.4 ± 2.1	8.5 ± 2.1	0.29
Monounsaturated fatty acids (% energy)	10.2 ± 2.1	10.4 ± 2.1	10.4 ± 2.0	10.2 ± 1.9	9.9 ± 2.0	10.1 ± 2.4	0.13
Polyunsaturated fatty acids (% energy)	6.5 ± 1.3	6.6 ± 1.2	6.5 ± 1.2	6.5 ± 1.3	6.4 ± 1.4	6.3 ± 1.6	0.071
Carbohydrate (% energy)	55.1 ± 5.7	54.3 ± 5.7	54.6 ± 5.8	55.0 ± 4.9	55.8 ± 5.7	55.5 ± 6.4	0.089
Dietary fiber (g/1000 kcal)	7.1 ± 2.1	7.6 ± 2.5	7.3 ± 2.2	7.1 ± 1.8	7.0 ± 2.1	6.6 ± 1.8	0.0009
Food intake (g/1000 kcal)							
Cereals	215.7 ± 55.5	206.9 ± 52.3	210.5 ± 51.5	214.1 ± 49.9	229.1 ± 61.7	218.4 ± 59.8	0.052
Potatoes	18.2 ± 12.9	19.7 ± 12.2	16.4 ± 11.9	19.1 ± 13.6	19.0 ± 12.8	16.6 ± 13.6	0.32
Confectioneries	50.4 ± 21.2	50.2 ± 20.9	50.0 ± 20.3	49.4 ± 21.8	45.1 ± 16.7	57.0 ± 24.2	0.079
Fats and oils	11.8 ± 5.0	12.3 ± 5.2	11.8 ± 4.4	11.9 ± 4.8	11.5 ± 5.0	11.4 ± 5.3	0.22
Fruits	35.7 ± 33.9	36.9 ± 33.1	35.3 ± 30.4	38.4 ± 38.1	32.3 ± 30.7	35.2 ± 36.6	0.61
Vegetables[‡]	121.8 ± 72.4	138.7 ± 87.1	126.5 ± 80.3	121.7 ± 58.8	119.8 ± 59.7	101.8 ± 68.1	0.0008
Pulses[§]	25.3 ± 16.4	26.7 ± 17.9	26.1 ± 16.7	25.9 ± 14.4	26.5 ± 16.7	21.5 ± 15.6	0.040
Meats	33.2 ± 16.2	35.6 ± 17.9	34.2 ± 18.7	31.1 ± 13.6	33.8 ± 13.3	31.5 ± 16.9	0.15
Eggs	20.9 ± 12.8	21.9 ± 12.3	18.3 ± 10.7	24.5 ± 14.5	18.7 ± 11.2	20.9 ± 14.1	0.69
Fish and shellfish	29.7 ± 15.5	32.6 ± 17.2	29.4 ± 15.4	29.5 ± 16.6	29.6 ± 13.6	27.4 ± 14.3	0.052
Dairy products	89.2 ± 75.8	84.5 ± 62.4	86.0 ± 70.7	99.8 ± 74.1	99.7 ± 94.0	76.4 ± 73.9	0.58
Beverages	411.8 ± 254.8	448.4 ± 272.1	409.4 ± 230.0	392.1 ± 253.8	410.8 ± 253.6	397.0 ± 262.4	0.29

* Values are means ± standard deviations for continuous variables and number of subjects (%) for categorical variables except for serum leptin concentration (geometric mean [95% confidence interval] for total sample and median for each quintile).

† 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.

‡ Including mushrooms and sea vegetables.

§ Including nuts.

Table 2
Serum leptin concentration (mg/ml) according to quintile of nutrient intake (n = 424)*

Variable	Quintile of nutrient intake					P for trend†
	1 (n = 84)	2 (n = 85)	3 (n = 85)	4 (n = 85)	5 (n = 85)	
Protein (% energy)	11.7	12.8	13.8	14.6	16.3	
Model 1‡	8.8 (7.8–9.8)	8.1 (7.2–9.1)	7.4 (6.6–8.3)	7.2 (6.4–8.1)	7.1 (6.3–7.9)	0.004
Model 2§	8.5 (7.8–9.3)	7.8 (7.1–8.5)	7.5 (6.9–8.1)	7.6 (7.0–8.3)	7.1 (6.5–7.8)	0.007
Model 3‖	8.2 (7.5–9.0)	7.6 (7.0–8.3)	7.4 (6.8–8.1)	7.7 (7.1–8.4)	7.4 (6.8–8.1)	0.21
Total fat (% energy)	23.5	27.1	29.6	31.9	36.0	
Model 1‡	8.6 (7.6–9.7)	7.5 (6.7–8.5)	7.6 (6.7–8.5)	7.9 (7.0–8.9)	6.9 (6.1–7.8)	0.033
Model 2§	8.0 (7.3–8.7)	7.6 (7.0–8.3)	7.7 (7.1–8.4)	7.9 (7.3–8.6)	7.2 (6.6–7.9)	0.23
Model 3¶	7.9 (7.2–8.6)	7.6 (7.0–8.3)	7.8 (7.2–8.5)	7.9 (7.2–8.6)	7.2 (6.6–7.9)	0.31
Saturated fatty acids (% energy)	6.3	7.5	8.3	9.4	11.4	
Model 1‡	8.5 (7.5–9.5)	7.4 (6.6–8.4)	7.4 (6.6–8.3)	7.7 (6.8–8.6)	7.5 (6.6–8.4)	0.29
Model 2§	8.1 (7.4–8.8)	7.3 (6.7–7.9)	7.6 (7.0–8.3)	8.0 (7.4–8.7)	7.4 (6.8–8.1)	0.55
Model 3¶	8.1 (7.4–8.8)	7.4 (6.8–8.0)	7.7 (7.0–8.3)	8.0 (7.4–8.7)	7.3 (6.7–8.0)	0.37
Model 4**	7.8 (7.0–8.7)	7.3 (6.6–7.9)	7.6 (7.0–8.3)	8.1 (7.5–8.9)	7.6 (6.8–8.5)	0.88
Monounsaturated fatty acids (% energy)	7.6	9.0	10.1	11.2	13.0	
Model 1‡	8.4 (7.5–9.4)	7.7 (6.9–8.7)	7.8 (6.9–8.7)	7.3 (6.5–8.2)	7.3 (6.5–8.2)	0.08
Model 2§	8.1 (7.4–8.8)	7.7 (7.1–8.4)	7.6 (7.0–8.3)	7.5 (6.9–8.1)	7.5 (6.9–8.2)	0.26
Model 3¶	8.0 (7.3–8.8)	7.7 (7.1–8.4)	7.7 (7.1–8.4)	7.5 (6.9–8.1)	7.5 (6.9–8.2)	0.26
Model 4††	7.7 (6.7–8.8)	7.6 (6.9–8.3)	7.7 (7.1–8.4)	7.6 (6.9–8.3)	7.9 (6.8–9.0)	0.85
Polyunsaturated fatty acids (% energy)	4.9	5.7	6.4	7.1	8.1	
Model 1‡	9.0 (8.0–10.1)	7.9 (7.1–8.9)	7.4 (6.6–8.3)	6.7 (6.0–7.5)	7.5 (6.7–8.4)	0.01
Model 2§	8.5 (7.8–9.2)	7.8 (7.1–8.5)	7.5 (6.9–8.2)	7.2 (6.6–7.8)	7.5 (6.9–8.2)	0.035
Model 3¶	8.3 (7.5–9.0)	7.7 (7.1–8.4)	7.5 (6.9–8.2)	7.2 (6.6–7.9)	7.7 (7.1–8.4)	0.23
Model 4‡‡	8.0 (7.0–9.2)	7.6 (6.9–8.4)	7.5 (6.9–8.2)	7.3 (6.7–8.0)	8.0 (6.9–9.1)	0.86
Carbohydrate (% energy)	47.8	52.4	55.0	57.8	62.4	
Model 1‡	7.5 (6.7–8.5)	7.5 (6.6–8.4)	7.2 (6.4–8.0)	7.8 (6.9–8.7)	8.5 (7.6–9.6)	0.14
Model 2§	7.5 (6.9–8.2)	7.6 (7.0–8.3)	7.6 (6.9–8.2)	7.7 (7.1–8.4)	7.9 (7.3–8.7)	0.38
Model 3¶	7.7 (6.9–8.4)	7.7 (7.0–8.4)	7.6 (7.0–8.3)	7.7 (7.1–8.4)	7.8 (7.0–8.6)	0.84
Dietary fiber (g/1000 kcal)	5.0	6.0	6.8	7.8	9.7	
Model 1‡	9.1 (8.1–10.2)	8.4 (7.5–9.4)	7.1 (6.4–8.0)	6.9 (6.2–7.8)	7.0 (6.3–7.9)	0.0003
Model 2§	8.7 (8.0–9.4)	8.0 (7.3–8.7)	7.5 (6.9–8.2)	7.0 (6.4–7.6)	7.4 (6.8–8.0)	0.003
Model 3§§	8.6 (7.9–9.4)	7.9 (7.3–8.6)	7.5 (6.9–8.1)	7.0 (6.5–7.7)	7.5 (6.8–8.2)	0.026

* Values are medians for nutrient intake and geometric means (95% confidence intervals) for serum leptin concentration.
† Tests for linear trend used the median value in each quintile as a continuous variable in linear regression.
‡ Adjusted for residential block (north: Kanto and Tohoku, central: Tokai and Hokuriku, and south: Kyushu and Chugoku), size of residential area (city with population ≥1 million, city with population with <1 million, or town and village), current smoking (yes or no), rate of eating (slow, medium, or fast), alcohol drinking (non-drinker, >0% to <1% energy, or ≥1% energy), physical activity (total metabolic equivalents-hours/day, continuous), and energy intake (kcal/d, continuous).
§ Adjusted for variables used in model 1 and body mass index (kg/m^2, continuous).
‖ Adjusted for variables used in model 2 and intakes (continuous) of total fat (% energy) and dietary fiber (g/1000 kcal).
¶ Adjusted for variables used in model 2 and intakes (continuous) of protein (% energy) and dietary fiber (g/1000 kcal).
** Adjusted for variables used in model 3 and intakes (continuous) of monounsaturated fatty acids (% energy) and polyunsaturated fatty acids (% energy).
†† Adjusted for variables used in model 3 and intakes (continuous) of saturated fatty acids (% energy) and polyunsaturated fatty acids (% energy).
‡‡ Adjusted for variables used in model 3 and intakes (continuous) of saturated fatty acids (% energy) and monounsaturated fatty acids (% energy).
§§ Adjusted for variables used in model 2 and intakes (continuous) of protein (% energy) and total fat (% energy).

parable to those in a limited number of studies of lean young women. Arithmetic mean values of circulating leptin level were 8.2 ng/mL in 63 Canadian women aged 18–35 y (mean BMI = 21.9 kg/m^2) [18], 9.1 ng/mL in 18 American women aged 20–31 y (mean BMI = 21.9 kg/m^2) [7], and 9.9 ng/mL in 61 Greek women aged 14–26 y (mean BMI = 21.2 kg/m^2) [8]. Our mean estimate of dietary fiber intake was 12.6 g/d, which was comparable to that in a representative sample of Japanese women aged 18–29 y (12.0 g/d) [19].

Intakes of protein, fat (including fatty acids), and carbohydrate were not independently associated with serum leptin concentration in the present study. Although protein and polyunsaturated fatty acid intake was inversely associated with serum leptin concentration independent of potential confounding factors including BMI, this association was not independent of other nutrient intake. This may be due to relatively strong positive correlations of intakes of protein and polyunsaturated fatty acids with dietary fiber intake, a single nutrient independently associated with serum leptin concentration in the present study (Pearson's correlation coefficient, r = 0.42 and 0.20, respectively) compared with those of other nutrients (r = −0.15 to −0.01). No association between macronutrient intake and circulating leptin

Table 3
Serum leptin concentration (mg/ml) according to quintile of food intake (n = 424)*

Variable	Quintile of nutrient intake					P for trend†
	1 (n = 84)	2 (n = 85)	3 (n = 85)	4 (n = 85)	5 (n = 85)	
Cereals (g/1000 kcal)	144.8	187.4	214.2	240.8	285.3	
Model 1‡	7.3 (6.5–8.2)	7.1 (6.3–8.0)	7.4 (6.6–8.3)	7.7 (6.8–8.6)	9.0 (8.0–10.2)	0.013
Model 2‡§	7.8 (7.1–8.5)	7.3 (6.7–8.0)	7.1 (6.6–7.8)	7.9 (7.3–8.6)	8.3 (7.6–9.0)	0.22
Potatoes (g/1000 kcal)	6.2	10.8	15.1	20.9	33.7	
Model 1‡	8 (7.1–8.9)	7.8 (6.9–8.7)	8.5 (7.6–9.6)	6.9 (6.2–7.8)	7.3 (6.5–8.1)	0.12
Model 2‡§	8.0 (7.3–8.7)	7.6 (7.0–8.3)	7.8 (7.1–8.5)	7.3 (6.7–7.9)	7.8 (7.2–8.5)	0.70
Confectioneries (g/1000 kcal)	26.9	39.1	46.8	57.0	77.8	
Model 1‡	7.3 (6.5–8.2)	7.6 (6.8–8.5)	8.3 (7.5–9.3)	6.8 (6.1–7.6)	8.4 (7.5–9.4)	0.25
Model 2‡§	7.6 (7.0–8.3)	7.2 (6.6–7.8)	8.0 (7.4–8.7)	7.3 (6.7–7.9)	8.3 (7.6–9.0)	0.15
Fats and oils (g/1000 kcal)	6.0	8.8	11.1	14.1	17.8	
Model 1‡	7.9 (7.1–8.9)	8.2 (7.3–9.1)	7.9 (7.1–8.9)	7.2 (6.4–8.0)	7.2 (6.4–8.1)	0.07
Model 2‡§	7.9 (7.3–8.6)	7.9 (7.3–8.6)	7.7 (7.1–8.4)	7.5 (6.9–8.2)	7.3 (6.7–8.0)	0.14
Fruits (g/1000 kcal)	7.8	16.0	25.1	40.6	75.2	
Model 1‡	8.7 (7.8–9.8)	7.4 (6.6–8.3)	8.1 (7.2–9.1)	6.8 (6.1–7.7)	7.4 (6.6–8.3)	0.09
Model 2‡§	8.5 (7.8–9.3)	7.4 (6.8–8.1)	7.9 (7.3–8.6)	7.0 (6.5–7.6)	7.6 (7.0–8.3)	0.13
Vegetables (g/1000 kcal)‖	47.5	79.3	105.6	139.0	211.0	
Model 1‡	8.5 (7.6–9.5)	8.5 (7.6–9.5)	7.3 (6.6–8.2)	7.6 (6.8–8.5)	6.6 (5.9–7.4)	0.001
Model 2‡§	8.1 (7.5–8.9)	8.1 (7.5–8.8)	7.6 (6.9–8.2)	7.7 (7.1–8.4)	7.0 (6.4–7.6)	0.007
Pulses (g/1000 kcal)¶	8.5	15.2	21.2	30.5	46.9	
Model 1‡	9.0 (8.0–10.0)	8.1 (7.3–9.1)	6.9 (6.2–7.7)	7.2 (6.4–8.0)	7.4 (6.6–8.3)	0.027
Model 2‡§	8.8 (8.1–9.6)	7.9 (7.3–8.6)	7.1 (6.6–7.8)	7.1 (6.5–7.7)	7.6 (7.0–8.2)	0.019
Meats (g/1000 kcal)	15.8	23.7	30.0	39.9	52.4	
Model 1‡	8.1 (7.2–9.0)	7.4 (6.7–8.3)	7.8 (7.0–8.7)	7.9 (7.1–8.9)	7.2 (6.4–8.0)	0.32
Model 2‡§	8.1 (7.4–8.8)	7.4 (6.8–8.0)	7.6 (7.0–8.3)	7.8 (7.2–8.5)	7.5 (6.9–8.2)	0.53
Eggs (g/1000 kcal)	4.7	13.1	21.3	27.5	35.5	
Model 1‡	8.4 (7.5–9.4)	7.5 (6.7–8.4)	7.4 (6.6–8.3)	7.4 (6.6–8.3)	7.8 (7.0–8.7)	0.33
Model 2‡§	8.2 (7.5–8.9)	7.2 (6.6–7.8)	7.5 (6.9–8.2)	7.6 (7.0–8.3)	7.9 (7.2–8.6)	0.83
Fish and shellfish (g/1000 kcal)	12.3	21.0	27.2	35.2	50.6	
Model 1‡	8.3 (7.4–9.3)	7.5 (6.7–8.4)	7.8 (7.0–8.8)	7.6 (6.8–8.5)	7.2 (6.4–8.1)	0.14
Model 2‡§	8.1 (7.4–8.8)	7.7 (7.1–8.4)	7.8 (7.2–8.5)	7.5 (6.9–8.2)	7.3 (6.7–7.9)	0.08
Dairy products (g/1000 kcal)	13.9	37.7	69.1	110.0	210.8	
Model 1‡	8.2 (7.3–9.2)	8.0 (7.1–8.9)	7.3 (6.5–8.2)	7.3 (6.5–8.2)	7.7 (6.8–8.6)	0.46
Model 2‡§	8.5 (7.8–9.2)	7.7 (7.1–8.4)	7.1 (6.6–7.7)	7.3 (6.7–7.9)	7.9 (7.2–8.6)	0.52
Beverages (g/1000 kcal)	119.8	267.4	355.7	505.8	767.8	
Model 1‡	8.2 (7.4–9.2)	7.1 (6.3–8.0)	8.1 (7.3–9.1)	7.4 (6.6–8.3)	7.6 (6.8–8.5)	0.46
Model 2‡§	8.2 (7.6–9.0)	7.5 (6.9–8.1)	7.9 (7.2–8.5)	7.3 (6.7–7.9)	7.6 (7.0–8.3)	0.22

* Values are medians for food intake and geometric means (95% confidence intervals) for serum leptin concentration.
† Tests for linear trend used the median value in each quintile as a continuous variable in linear regression.
‡ Adjusted for residential block (north: Kanto and Tohoku, central: Tokai and Hokuriku, and south: Kyushu and Chugoku), size of residential area (city with population ≥1 million, city with population with <1 million, or town and village), current smoking (yes or no), rate of eating (slow, medium, or fast), alcohol drinking (non-drinker, >0% to <1% energy, or ≥1% energy), physical activity (total metabolic equivalents-hours/day, continuous), and energy intake (kcal/d, continuous).
§ Further adjusted for body mass index (kg/m^2, continuous).
‖ Including mushrooms and sea vegetables.
¶ Including nuts.

level was obtained in 32 American men and women aged 20–31 y [7] and 114 Greek men and women aged 14–26 y [8]. In contrast, although macronutrient composition was not independently associated with plasma leptin concentrations in 268 American men aged 47–83 y, the percentage of energy from total fat and monounsaturated fat showed an independent positive association in a subanalysis of 121 men with a BMI <25 kg/m^2 [9]. These discrepancies might be explained at least in part by the different populations investigated, different dietary assessment methods used, differences in the number and type of variables used as confounding factors, whether or not other nutrients in multivariate analysis were taken into account. Further studies are needed in this poorly investigated field.

Dietary fiber intake showed an independent inverse association with serum leptin concentration. At the food level, an independent negative association was seen between the intake of vegetables and pulses and serum leptin concentration. The finding on vegetables and pulses is very consistent with the finding on dietary fiber, because vegetables and pulses were the top and second contributors to dietary fiber in the present study (39.1% and 11.4%), respectively, and the significant associations of vegetables and pulses with serum leptin disappeared after further adjustment for dietary fiber. To our knowledge, no previous study has investigated an association between circulating leptin level and dietary fiber and its main sources such as vegetables and pulses. However, a study in 938 middle-aged American men and women found that the intake of whole grains, which are high in dietary fiber, showed an independent inverse association with plasma leptin levels [10]. We were unable to investigate this association because only 7% of our subjects reported the consumption of whole grains. In addition, a Polish study found that vegetarian prepubertal children (n = 22) had a significantly higher dietary fiber intake and significantly lower serum leptin concentrations than did control omnivores (n = 13) [11]. These findings do not conflict with our results. An African population consuming fish as the main component of their diet (n = 279) had significantly lower plasma leptin levels than a population that consumed no fish at all but rather mainly maize and rice (n = 329) [12]. In the present study, fish and shellfish intake showed an inverse association with serum leptin concentration, although without statistical significance (P for trend = 0.08). Further research in a range of populations is required to elucidate the apparent influence of diet on circulating leptin levels.

It remains unknown whether dietary factors influence circulating leptin levels directly or indirectly. One possibility is that dietary factors (such as dietary fiber, vegetables, and pulses) are associated with a decrease in serum concentrations through decreased leptin production. Alternatively, they may increase leptin sensitivity, leading in turn to a subsequent decline in leptin production through unknown feedback mechanisms, a possibility suggested by interventional [20] and observational [9] studies of circulating leptin levels and physical activity.

Several limitations of our study warrant mention. First, the cross-sectional nature of the study does not permit the assessment of causality owing to the uncertain temporality of the association. Second, we used a self-administered semiquantitative dietary assessment questionnaire for dietary data collection [13–15]. Although the questionnaire had been previously validated, actual dietary habits were not observed, so the results should be interpreted cautiously. A population of young female dietetic students in particular would be expected to report the assumed "correct" and balanced dietary intake. However, mean reported intakes of energy, protein, total fat, and carbohydrate (1764 kcal/d, 61.4 g/d, 58.8 g/d, and 240.9 g/d, respectively) and mean percentages of energy from total fat and carbohydrate (29.6% and 55.1% energy, respectively) were relatively comparable to those in a representative sample of Japanese women aged 18–29 y (1701 kcal/d, 64.0 g/d, 56.0 g/d, 226.4 g/d, 29.1% energy, and 55.7% energy, respectively; not available for percentage of energy from protein) [19]. To minimize the influence of dietary under-reporting, an ongoing controversy in studies that collect dietary information using self-report instruments [21], we used energy-adjusted values of dietary intake. Third, single measurement of serum leptin concentration may represent short-term status only and introduce random errors. Nonetheless, this kind of error would tend to bias toward attenuating rather than enhancing the relation, and multiple or serial leptin measurements would have only increased the precision of the results. Fourth, although we attempted to adjust for a wide range of potential confounding variables, we could not rule out residual confounding. In particular, physical activity was assessed relatively roughly from only five activities, which might not have been sufficient. Furthermore, we could not adjust for body fat mass, which is strongly associated with circulating leptin levels [1], because of a lack of information on this variable in the present study, although we did adjust for BMI. Moreover, although leptin levels change during the menstrual cycle [22], we unfortunately did not assess menstrual cycle. Further research examining association of lifestyle factors with circulating leptin in reproductive-age women should take into account menstrual cycle.

Conclusion

Increasing intakes of dietary fiber, vegetables, and pulses were independently associated with lower serum leptin concentrations in young Japanese women. Because the cross-sectional nature of our study precludes causal inferences, any firm conclusions regarding the effect of diet on circulating leptin levels will require additional observational and experimental studies.

References

[1] Considine RV, Sinha MK, Heiman ML, Kriauciunas A, Stephens TW, Nyce MR, et al. Serum immunoreactive-leptin concentrations in normal-weight and obese humans. N Engl J Med 1996;334:292–5.

[2] Chu NF, Spiegelman D, Yu J, Rifai N, Hotamisligil GS, Rimm EB. Plasma leptin concentrations and four-year weight gain among US men. Int J Obes Relat Metab Disord 2001;25:346–53.

[3] Soderberg S, Ahren B, Jansson JH, Johnson O, Hallmans G, Asplund K, et al. Leptin is associated with increased risk of myocardial infarction. J Intern Med 1999;246:409–18.

[4] Wallace AM, McMahon AD, Packard CJ, Kelly A, Shepherd J, Gaw A, et al. Plasma leptin and the risk of cardiovascular disease in the west of Scotland coronary prevention study (WOSCOPS). Circulation 2001;104:3052–6.

[5] Reseland JE, Anderssen SA, Solvoll K, Hjermann I, Urdal P, Holme I, et al. Effect of long-term changes in diet and exercise on plasma leptin concentrations. Am J Clin Nutr 2001;73:240–5.

[6] Coleman RA, Herrmann TS. Nutritional regulation of leptin in humans. Diabetologia 1999;42:639–46.

[7] Miller GD, Frost R, Olive J. Relation of plasma leptin concentrations to sex, body fat, dietary intake, and peak oxygen uptake in young adult women and men. Nutrition 2001;17:105–11.

[8] Yannakoulia M, Yiannakouris N, Bluher S, Matalas AL, Klimis-Zacas D, Mantzoros CS. Body fat mass and macronutrient intake in relation to circulating soluble leptin receptor, free leptin index, adiponectin, and resistin concentrations in healthy humans. J Clin Endocrinol Metab 2003;88:1730–6.

[9] Chu NF, Stampfer MJ, Spiegelman D, Rifai N, Hotamisligil GS, Rimm EB. Dietary and lifestyle factors in relation to plasma leptin concentrations among normal weight and overweight men. Int J Obes Relat Metab Disord 2001;25:106–14.
[10] Jensen MK, Koh-Banerjee P, Franz M, Sampson L, Gronbaek M, Rimm EB. Whole grains, bran, and germ in relation to homocysteine and markers of glycemic control, lipids, and inflammation. Am J Clin Nutr 2006;83:275–83.
[11] Ambroszkiewicz J, Laskowska-Klita T, Klemarczyk W. Low serum leptin concentration in vegetarian prepubertal children. Rocz Akad Med Bialymst 2004;49:103–5.
[12] Winnicki M, Somers VK, Accurso V, Phillips BG, Puato M, Palatini P, et al. Fish-rich diet, leptin, and body mass. Circulation 2002;106: 289–91.
[13] Sasaki S, Yanagibori R, Amano K. Self-administered diet history questionnaire developed for health education: a relative validation of the test-version by comparison with 3-day diet record in women. J Epidemiol 1998;8:203–15.
[14] Sasaki S, Yanagibori R, Amano K. Validity of a self-administered diet history questionnaire for assessment of sodium and potassium: comparison with single 24-hour urinary excretion. Jpn Circ J 1998; 62:431–5.
[15] Sasaki S, Ushio F, Amano K, Morihara M, Todoriki T, Uehara Y, et al. Serum biomarker-based validation of a self-administered diet history questionnaire for Japanese subjects. J Nutr Sci Vitaminol 2000;46:285–96.
[16] Science and Technology Agency. Standard tables of food composition in Japan (in Japanese). 5th rev ed. Tokyo: Printing Bureau of the Ministry of Finance; 2005.
[17] Ainsworth BE, Haskell WL, Leon AS, Jacobs DR Jr, Montoye HJ, Sallis JF, et al. Compendium of physical activities: classification of energy costs of human physical activities. Med Sci Sports Exerc 1993;25:71–80.
[18] St-Pierre DH, Faraj M, Karelis AD, Conus F, Henry JF, St-Onge M, et al. Lifestyle behaviours and components of energy balance as independent predictors of ghrelin and adiponectin in young non-obese women. Diabetes Metab 2006;32:131–9.
[19] Ministry of Health, Labour and Welfare of Japan. The national heath and nutrition survey in Japan, 2003. Tokyo: Daiichi Shuppan Publishing; 2006. (in Japanese)
[20] Pasman WJ, Westerterp-Plantenga MS, Saris WH. The effect of exercise training on leptin levels in obese males. Am J Physiol 1998;274:E280–6.
[21] Livingstone MBE, Black AE. Markers of the validity of reported energy intake. J Nutr 2003;133:895S–920.
[22] Wunder DM, Yared M, Bersinger NA, Widmer D, Kretschmer R, Birkhauser MH. Serum leptin and C-reactive protein levels in the physiological spontaneous menstrual cycle in reproductive age women. Eur J Endocrinol 2006;155:137–42.

European Journal of Clinical Nutrition (2007) 61, 616–622

0954-3007/07 $30.00
www.nature.com/ejcn

ORIGINAL ARTICLE

Association between dietary fiber, water and magnesium intake and functional constipation among young Japanese women

K Murakami[1], S Sasaki[1], H Okubo[2], Y Takahashi[1], Y Hosoi[1], M Itabashi[1] and the Freshmen in Dietetic Courses Study II Group

[1]*Nutritional Epidemiology Program, National Institute of Health and Nutrition, Shinjuku-ku, Tokyo, Japan and* [2]*Department of Nutrition Sciences, Kagawa Nutrition University, Saitama, Japan*

Objective: Most research on constipation has focused on dietary fiber intake. Here, we examined the intake of water and magnesium, nutrients possibly associated with constipation, as well as that of dietary fiber in relation to constipation.
Design: Cross-sectional study.
Subjects: A total of 3835 female Japanese dietetic students aged 18–20 years from 53 institutions in Japan.
Methods: Dietary intake was estimated with a validated, self-administered diet history questionnaire. Functional constipation was defined using the Rome I criteria.
Results: The prevalence of functional constipation was 26.2%. Neither dietary fiber intake (mean = 6.4 g/4186 kJ) nor intakes of total water and water from fluids were associated with constipation. Conversely, low intake of water from foods was associated with an increasing prevalence of constipation. In comparison with women in the first (lowest) quintile, the multivariate adjusted odds ratio (OR) (95% confidence interval (CI)) for women in the second, third, fourth, and fifth quintiles were 0.72 (0.57, 0.90), 0.78 (0.62, 0.98), 0.71 (0.56, 0.89), and 0.77 (0.61, 0.97), respectively (*P* for trend = 0.04). Additionally, low magnesium intake was associated with increasing prevalence of constipation. Compared with women in the first quintile, the multivariate adjusted OR (95% CI) for women in the second, third, fourth and fifth quintiles were 0.70 (0.56, 0.88), 0.75 (0.60, 0.95), 0.73 (0.58, 0.92) and 0.79 (0.63, 0.996), respectively (*P* for trend = 0.09).
Conclusions: Low intakes of water from foods and magnesium are independently associated with an increasing prevalence of functional constipation among a population whose dietary fiber intake is relatively low.
European Journal of Clinical Nutrition (2007) **61**, 616–622. doi:10.1038/sj.ejcn.1602573; published online 6 December 2006

Keywords: dietary fiber intake; water intake; magnesium intake; functional constipation; Japanese women; epidemiology

Correspondence: Dr S Sasaki, Nutritional Epidemiology Program, National Institute of Health and Nutrition, Toyama 1-23-1, Shinjuku-ku, Tokyo 162-8636, Japan.
E-mail: stssasak@nih.go.jp
Guarantor: S Sasaki.
Contributors: KM was involved in the study designing, data collection and data management; created a constipation questionnaire, conducted the statistical analyses and wrote the manuscript. SS was responsible for the study designing, data collection, data management, and the overall management, and assisted in the manuscript preparation. HO was involved in the study designing. YT assisted in the manuscript preparation. YH was involved in the study designing, data collection and data management. MI was involved in data collection and data management. All the authors provided suggestions during the preparation of the manuscript and approved the final version submitted for publication.
Received 28 April 2006; accepted 17 October 2006; published online 6 December 2006

Introduction

Constipation is a common health problem (Wong *et al.*, 1999; Pare *et al.*, 2001; Garrigues *et al.*, 2004; Higgins and Johanson, 2004), and diet is considered a major modifiable lifestyle factor associated with this condition (Locke *et al.*, 2000; Talley, 2004). The favorable effect of dietary fiber on constipation is widely accepted and several (Dukas *et al.*, 2003; Sanjoaquin *et al.*, 2004), although not all (Campbell *et al.*, 1993; Towers *et al.*, 1994; Murakami *et al.*, 2006), observational studies have indicated an inverse relation between dietary fiber intake and constipation. However, while most previous studies have defined constipation according to the infrequency of bowel movement (Campbell *et al.*, 1993; Towers *et al.*, 1994; Dukas *et al.*, 2003; Sanjoaquin et al., 2004) or the subjective perception of patients (Murakami et al., 2006), a consensus definition of constipation consists of straining, hard stools and incomplete evacuation in addition to infrequency (Rome criteria) (Whitehead et al., 1991).

Other nutrients that might be associated with constipation include water and magnesium. Low intake of water can reduce the water content of stools and hence lead to constipation (Arnaud, 2003), although the potential benefit of an increase in intake is unknown (Klauser et al., 1990; Anti et al., 1998; Young et al., 1998; Chung et al., 1999). Magnesium might form sulfate or citrate salts that would promote fluid retention in the digestive tract and indirectly alter motility, and thereby act as a light laxative (Saez, 1991). To our knowledge, however, no observational studies have investigated the intake of water and magnesium in relation to constipation.

The aim of this cross-sectional study of young Japanese women was to examine associations between dietary fiber, water and magnesium intake, as assessed with a previously validated, self-administered diet history questionnaire (DHQ) (Sasaki et al., 1998a, b, 2000), and functional constipation as defined according to the Rome criteria (Whitehead et al., 1991).

Subjects and methods

Subjects and survey procedure

The study was based on a self-administered questionnaire survey of a wide range of dietary and non-dietary behaviors among dietetic students ($n = 4679$) from 54 universities, colleges and technical schools in 33 of 47 prefectures in Japan. Staff at each institution distributed two questionnaires on dietary habits (DHQ) and other lifestyle items during the previous month to students during an orientation session or a first lecture designed for freshman students entering dietetic courses in April 2005; in most institutions, this was carried out within 2 weeks after the course began. Students filled out the questionnaires during the session, lecture, or at home and then submitted the completed forms to staff at each institution as soon as possible. A third questionnaire on lifestyle during the previous 6 years (i.e. junior high school and high school) was also distributed and answered in similar fashion; in most institutions, this was carried out within 4 weeks after the course began.

The staff at each institution checked the responses as soon as possible according to the survey protocol. When missing answers or logical errors were identified, the student was asked to complete the questionnaire again. The staff at each institution mailed the questionnaires to the survey center. Staff at the survey center checked the answers again and, when necessary, returned problematic questionnaires to staff at the respective institution, and the student was asked to complete the questionnaires again. All questionnaires were thus checked at least once by staff at the respective institution and by staff at the survey center. Most surveys were completed by May 2005. The protocol of the study was approved by the Ethics Committee of the National Institute of Health and Nutrition.

A total of 4286 students (4066 women and 220 men) answered all three questionnaires (response rate = 91.6%). For the purposes of the current analysis, we selected female subjects aged 18–20 years ($n = 3967$). We then excluded from these 3967 women those who were in an institution where the survey had been conducted at the end of May ($n = 97$), those with extremely low or high energy intake (<2093 or >16744 kJ/day) ($n = 23$), and those with missing information on the variables studied ($n = 24$). As some subjects were in more than one exclusion category, the final analysis sample comprised 3825 women. Further exclusion of subjects with intentional dietary change within the preceding year ($n = 649$), those habitually using oral laxatives ($n = 231$), or both did not materially alter the findings, and these were therefore included in the analyses.

Dietary intake

Dietary habits during the previous month were assessed using a previously validated, self-administered DHQ (Sasaki et al., 1998a, b, 2000). This is a 16-page structured questionnaire that consists of the following seven sections: general dietary behavior; major cooking methods; consumption frequency and amount of six alcoholic beverages; consumption frequency and semi-quantitative portion size of 121 selected food and non-alcoholic beverage items; dietary supplements; consumption frequency and semi-quantitative portion size of 19 staple foods (rice, bread and noodles) and miso soup (fermented soybean paste soup); and open-ended items for foods consumed regularly (⩾once/week) 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 (Sasaki et al., 1998a).

Estimates of dietary intake for 147 food and beverage items, energy, total, soluble and insoluble dietary fiber, total water, water from fluids, water from foods, and magnesium, were calculated using an *ad hoc* computer algorithm for the DHQ, which was based on the *Standard Tables of Food Composition in Japan* (Science and Technology Agency, 2000). Information on dietary supplements and data from the open-ended questionnaire items were not used in the calculation of dietary intake. Dietary fiber was determined by an enzymatic-gravimetric procedure (modified Prosky method) (Science and Technology Agency, 2000) from the intake of 86 fiber-containing foods in the DHQ. Total water was defined as the sum of water from all 147 food and beverage items. Water from fluids was defined as the sum of water from all beverages, milks, juices, and soups and water, whereas water from foods was defined as the sum of water from all other food items. Although we calculated magnesium intake from foods and drinks only, and not from dietary supplements, no subjects used magnesium supplements and only 14 (0.4%) used multimineral supplements, rendering it unlikely that dietary supplementation had a major impact on the findings. Detailed descriptions of the methods used for calculating dietary intake and the validity of the DHQ have been published elsewhere (Sasaki et al., 1998a, b, 2000). The Pearson correlation coefficient between DHQ and 3-day estimated dietary records was 0.48 for energy among 47 women (Sasaki et al., 1998a). In addition, the Pearson correlation coefficients between DHQ and 16-day weighed dietary records were 0.69 for total dietary fiber, 0.62 for soluble dietary fiber, 0.70 for insoluble dietary fiber, 0.25 for total water, 0.25 for water from fluids, 0.64 for water from foods and 0.57 for magnesium in 92 women (S Sasaki, unpublished observations, 2006).

Constipation

A constipation questionnaire was developed based on a previous study (Garrigues et al., 2004) and incorporated into the 20-page questionnaire for lifestyle during the previous 6 years. We used the definition of functional constipation recommended by an international workshop on the management of constipation (Rome I criteria) (Whitehead et al., 1991). Although the Rome I criteria were modified in 1999 to the Rome II criteria (Thompson et al., 1999), epidemiologic studies have consistently shown that the latter may be too restrictive for the diagnosis of constipation (Pare et al., 2001; Garrigues et al., 2004), and we therefore used the former. The following four questions were used to assess Rome I-defined functional constipation: (1) Do you strain during a bowel movement? (2) Do you feel an incomplete emptying sensation after a bowel movement? (3) How often are your stools hard? and (4) How many bowel movements do you usually have each week? These questions referred to the last 12 months. For questions 1–3, four answers were offered: never, sometimes (<25% of the time), often (⩾25% of the time) and always. Functional constipation was defined as meeting two or more of the four criteria (an answer of *often* or *always* to questions 1–3 and <3 bowel movements per week (question 4)).

Other variables

In the questionnaires, subjects reported body weight and height, residential area, current smoking (yes or no) and oral medication usage (yes or no). Body mass index (BMI) was calculated as weight (kg) divided by the square of height (m). We classified BMI into three categories (<18.5, 18.5–24.9 and ⩾25 kg/m^2) according to the *Japan Society for the Study of Obesity* (Matsuzawa et al., 2000). The reported residential areas were grouped into six categories (Hokkaido and Tohoku; Kanto; Hokuriku and Tokai; Kinki; Chugoku and Shikoku; and Kyushu) based on the regional blocks used in the National Nutrition Survey in Japan (Ministry of Health, Labour, and Welfare, 2004) (hereafter referred to as 'residential block'). The residential areas were also grouped into three categories according to population size (city with a population ⩾1 million; city with a population <1 million; and town and village) (hereafter referred to as 'size of residential area').

Additionally, subjects reported the time when they usually went to bed and arose in the morning, which was used to calculate sleeping hours, and the frequency and duration of high- and moderate-intensity activities, walking, and sedentary activities. For subjects whose recorded total hours were <24 h, unrecorded hours were assumed to be spent on sedentary activities. For subjects whose recorded total hours were >24 h, the total number of hours spent daily were proportionately decreased to equal 24. Each activities was assigned a metabolic equivalent (MET) value from a previously published table; 0.9 for sleeping, 1.5 for sedentary activity, 3.3 for walking, 5.0 for moderate-intensity activity and 7.0 for high-intensity activity (Ainsworth et al., 1993, 2000). The 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. This score essentially corresponds to the number of kilojoules per kilogram of body weight expended by an individual during the day. The standard value of basal metabolic rate for Japanese people is also expressed as the number of kilojoules per kilogram of body weight expended by an individual during the day. Physical activity level was then calculated by dividing total MET-hour score (kJ/kg of body weight/day) by the standard value of basal metabolic rate for Japanese women aged 18–29 years (99 kJ/kg of body weight/day) (Ministry of Health, Labour, and Welfare, 2005).

Statistical analysis

Associations between functional constipation (the dependent variable) and energy-adjusted (/4186 kJ) intakes of total, soluble and insoluble dietary fiber, total water, water from fluids, and water from foods and magnesium were examined. We calculated both crude and multivariate adjusted odds ratios (ORs) and 95% confidence intervals (CIs) for functional constipation for each quintile category of dietary variable using logistic regression analysis. Multivariate adjusted ORs were calculated by adjusting for BMI (three categories), residential block (six categories), size of residential area (three categories), current smoking (two categories), current alcohol drinking (two categories (yes or no) because of extremely low alcohol intake: mean = 0.8 g/day), oral medication usage (two categories), physical activity level (quintiles) and energy intake (quintiles). We further conducted multivariate analyses including dietary fiber, water and magnesium simultaneously in order to investigate the independent associations with constipation. As results for the crude and multivariate analyses were similar for all variables analyzed, we present here only those derived from the multivariate models. Trend of association was assessed by a logistic regression model assigning scores to the levels of the independent variable. All statistical analyses were performed using SAS statistical software, version 8.2 (SAS Institute Inc., Cary, NC, USA). All reported P-values are two-tailed, and a P-value of <0.05 was considered statistically significant.

Results

Basic characteristics of the subjects are shown in Table 1. Mean total dietary fiber intake was 6.4 g/4186 kJ, mean total water intake was 1025 g/4186 kJ and mean magnesium intake was 119 mg/4186 kJ. A total of 1002 women (26.2%) were classified as having constipation. Table 2 shows the multivariate adjusted ORs for constipation by quintiles of dietary variables. Dietary fiber intake was not associated with constipation. Further, no association was seen for total water intake or intake of water from fluids. However, low intake of water from foods was associated with increasing prevalence of constipation. In comparison with women in the first (lowest) quintile of intake of water from foods, the multivariate adjusted OR (95% CI) for women in the second, third, fourth and fifth quintiles were 0.72 (0.57, 0.90), 0.78 (0.62, 0.98), 0.71 (0.56, 0.89) and 0.77 (0.61, 0.97), respectively (P for trend = 0.04). Low magnesium intake was also associated with increasing prevalence of constipation. Compared with women in the first quintile of magnesium intake, the multivariate adjusted OR (95% CI) for women in the second, third, fourth and fifth quintiles were 0.70 (0.56, 0.88), 0.75 (0.60, 0.95), 0.73 (0.58, 0.92) and 0.79 (0.63, 0.996), respectively (P for trend = 0.09). Including dietary fiber, water and magnesium intake simultaneously in the models generally attenuated the association between dietary intake and constipation (see multivariate and nutrient-adjusted ORs in Table 2). However, these analyses did not materially change the relations of intake of water from foods and intake of magnesium to constipation, suggesting that both are independently associated with an increasing prevalence of constipation.

Table 1 Characteristics of 3825 Japanese women aged 18–20 years

	Mean ± s.d. or %
Age (years)	18.1 ± 0.3
Body height (cm)	157.9 ± 5.3
Body weight (kg)	52.3 ± 7.7
Body mass index (kg/m^2)	21.0 ± 2.8
<18.5	14.6
18.5–24.9	77.8
⩾25	7.6
Residential block	
Hokkaido and Tohoku	9.8
Kanto	34.3
Hokuriku and Tokai	14.0
Kinki	20.0
Chugoku and Shikoku	11.0
Kyushu	10.9
Size of residential area	
City with a population ⩾1 million	19.5
City with a population <1 million	65.2
Town and village	15.3
Current smoker	1.5
Current alcohol drinker	19.0
Oral medication user	9.9
Physical activity level	1.45 ± 0.15
Dietary intake	
Total energy (kJ/day)	7615 ± 2101
Total dietary fiber (g/4186 kJ)	6.4 ± 2.0
Soluble dietary fiber (g/4186 kJ)	1.7 ± 0.6
Insoluble dietary fiber (g/4186 kJ)	4.7 ± 1.5
Total water (g/4186 kJ)	1028 ± 360
Water from fluids (g/4186 kJ)	654 ± 337
Water from foods (g/4186 kJ)	374 ± 65
Magnesium (mg/4186 kJ)	118 ± 29
Functional constipation[a]	
No	73.8
Yes	26.2

[a]Defined according to the Rome I criteria (Whitehead *et al.*, 1991).

Discussion

To our knowledge, this study is the first to examine dietary fiber, water and magnesium intake in relation to Rome I-defined functional constipation. After controlling for a series of potential confounding factors, we found that a low intake of water from foods and magnesium was associated with an increasing prevalence of functional constipation. In contrast, no association was seen for dietary fiber, total water and water from fluids.

The prevalence of Rome I-defined functional constipation in the present group was 26.2%. A similar prevalence by these criteria has been reported in Canadian (21.0%) (Pare *et al.*, 2001) and Spanish (28.6%) (Garrigues *et al.*, 2004) women, whereas a somewhat smaller ratio was seen in elderly Singaporean women (10.5%) (Wong *et al.*, 1999).

Increased intake of dietary fiber is widely considered to protect against constipation, and several studies have indeed found an inverse relation between dietary fiber intake and constipation (Dukas *et al.*, 2003; Sanjoaquin *et al.*, 2004). Here, however, in common with several other studies (Campbell *et al.*, 1993; Towers *et al.*, 1994; Murakami *et al.*, 2006), we failed to find such an association. A possible explanation for this is that the dietary fiber intake of most subjects was too low to have a protective effect. Estimated intake in the present study (mean = 11.8 g/day) was, however, comparable to that observed in women aged 18–29 years in the Japanese National Nutrition Survey (mean-12.0 g/day) (Ministry of Health, Labour, and Welfare, 2004).

Although we saw no relation between the intake of total water and water from fluids, and constipation, a low intake of water from foods was associated with an increasing prevalence of constipation. To our knowledge, no previous observational study has investigated the relationship

Table 2 Multivariate adjusted odds ratios (ORs) and 95% confidence intervals (CIs) for functional constipation by quintiles of dietary fiber, water, and magnesium intake in 3825 Japanese women aged 18–20 years[a]

	Quintiles of dietary intake					
	1 (n = 765)	*2 (n = 765)*	*3 (n = 765)*	*4 (n = 765)*	*5 (n = 765)*	*P for trend*
Total dietary fiber (g/4186 kJ)[b]	4.3 [1.9–4.9]	5.3 [4.9–5.7]	6.1 [5.7–6.6]	7.1 [6.6–7.7]	8.9 [7.7–28.5]	
n with/without functional constipation	203/562	199/566	197/568	203/562	200/565	
Multivariate adjusted OR (95% CI)[c]	1.0	0.94 (0.75, 1.19)	0.96 (0.76, 1.21)	0.97 (0.77, 1.22)	0.93 (0.74, 1.18)	0.66
Multivariate and nutrient adjusted OR (95% CI)[c,d]	1.0	1.07 (0.84, 1.37)	1.17 (0.90, 1.52)	1.21 (0.91, 1.61)	1.15 (0.83, 1.59)	0.28
Soluble dietary fiber (g/4186 kJ)[b]	1.1 [0.3–1.2]	1.4 [1.2–1.5]	1.6 [1.5–1.7]	1.9 [1.7–2.1]	2.4 [2.1–6.4]	
n with/without functional constipation	195/570	188/577	211/554	202/563	206/559	
Multivariate adjusted OR (95% CI)[c]	1.0	0.92 (0.72, 1.16)	1.08 (0.86, 1.37)	1.02 (0.80, 1.28)	1.01 (0.80, 1.28)	0.63
Multivariate and nutrient adjusted OR (95% CI)[c,d]	1.0	1.02 (0.80, 1.31)	1.26 (0.98, 1.62)	1.23 (0.94, 1.60)	1.23 (0.91, 1.65)	0.08
Insoluble dietary fiber (g/4186 kJ)[b]	3.2 [1.7–3.6]	3.9 [3.6–4.2]	4.4 [4.2–4.8]	5.1 [4.8–5.6]	6.5 [5.6–22.0]	
n with/without functional constipation	208/557	205/560	193/572	192/573	204/561	
Multivariate adjusted OR (95% CI)[c]	1.0	0.96 (0.76, 1.21)	0.92 (0.73, 1.16)	0.87 (0.69, 1.10)	0.94 (0.74, 1.18)	0.38
Multivariate and nutrient adjusted OR (95% CI)[c,d]	1.0	1.07 (0.84, 1.37)	1.09 (0.84, 1.42)	1.05 (0.78, 1.40)	1.11 (0.80, 1.55)	0.63
Total water (g/4186 kJ)[b]	656 [311–747]	823 [747–891]	959 [891–1037]	1125 [1037–1259]	1485 [1259–4340]	
n with/without functional constipation	218/547	197/568	179/586	193/572	215/550	
Multivariate adjusted OR (95% CI)[c]	1.0	0.89 (0.70, 1.11)	0.76 (0.60, 0.96)	0.81 (0.64, 1.02)	0.92 (0.73, 1.16)	0.33
Multivariate and nutrient adjusted OR (95% CI)[c,e]	1.0	0.94 (0.74, 1.19)	0.82 (0.64, 1.04)	0.88 (0.69, 1.13)	1.01 (0.78, 1.31)	0.89
Water from fluids (g/4186 kJ)[b]	316 [62–397]	461 [397–518]	580 [518–654]	746 [654–862]	1085 [862–4145]	
n with/without functional constipation	209/556	190/575	188/577	199/566	216/549	
Multivariate adjusted OR (95% CI)[c]	1.0	0.87 (0.69, 1.10)	0.84 (0.66, 1.06)	0.89 (0.71, 1.13)	0.97 (0.77, 1.22)	0.86
Multivariate and nutrient adjusted OR (95% CI)[c,e]	1.0	0.91 (0.72, 1.15)	0.89 (0.70, 1.12)	0.95 (0.75, 1.21)	1.05 (0.82, 1.34)	0.60
Water from foods (g/4186 kJ)[b]	279 [106–307]	327 [307–347]	364 [347–385]	406 [385–434]	478 [434–1282]	
n with/without functional constipation	240/525	184/581	196/569	184/581	198/567	
Multivariate adjusted OR (95% CI)[c]	1.0	0.72 (0.57, 0.90)	0.78 (0.62, 0.98)	0.71 (0.56, 0.89)	0.77 (0.61, 0.97)	0.04
Multivariate and nutrient adjusted OR (95% CI)[c,e]	1.0	0.74 (0.59, 0.94)	0.82 (0.64, 1.05)	0.74 (0.57, 0.96)	0.79 (0.58, 1.07)	0.12
Magnesium (mg/4186 kJ)[b]	87 [60–95]	102 [95–108]	114 [108–120]	127 [120–138]	155 [138–350]	
n with/without functional constipation	231/534	182/583	197/568	188/577	204/561	
Multivariate adjusted OR (95% CI)[c]	1.0	0.70 (0.56, 0.88)	0.75 (0.60, 0.95)	0.73 (0.58, 0.92)	0.79 (0.63, 0.996)	0.09
Multivariate and nutrient adjusted OR (95% CI)[c,f]	1.0	0.68 (0.53, 0.87)	0.71 (0.54, 0.93)	0.67 (0.50, 0.91)	0.73 (0.51, 1.02)	0.09

[a]Functional constipation was defined according to the Rome I criteria (Whitehead *et al.*, 1991).
[b]Values are median [range].
[c]Adjusted for body mass index (<18.5, 18.5–24.9, and ⩾25 kg/m^2), residential block (Hokkaido and Tohoku; Kanto; Hokuriku and Tokai; Kinki; Chugoku and Shikoku; and Kyushu), size of residential area (city with a population ⩾1 million; city with a population <1 million; and town and village), current smoking (yes or no), current alcohol drinking (yes or no), oral medication usage (yes or no), physical activity level (quintiles) and energy intake (quintiles).
[d]Further adjusted for total water and magnesium intake (quintiles).
[e]Further adjusted for total dietary fiber and magnesium intake (quintiles).
[f]Further adjusted for total dietary fiber and total water intake (quintiles).

between the intake of water (as a nutrient) and constipation. In contrast, experimental studies have shown that low water intake may be an etiologic factor for constipation, although the potential beneficial effect of extra water intake is unclear (Klauser *et al.*, 1990; Anti *et al.*, 1998; Young *et al.*, 1998; Chung *et al.*, 1999; Arnaud, 2003).

Further, while we are unaware of previous studies examining the association between magnesium intake and constipation, we found that a low intake of magnesium was associated with an increasing prevalence of this condition. Magnesium might form sulfate or citrate salts that would promote fluid retention in the digestive tract and indirectly alter motility, and thereby act as a light laxative (Saez, 1991). The effect of magnesium on constipation warrants further examination.

Several limitations of our study can be identified. First, generally, given that increased intake of dietary fiber and fluid is a widely recommended treatment for constipation (Muller-Lissner *et al.*, 2005), subjects suffering from constipation might be expected to increase their intake of dietary fiber and water (from fluids). Such dietary change is particularly likely in our subjects, who were dietetic students and therefore may have been highly health conscious. In fact, a considerably large percentage of female Japanese dietetic students considered a high intake of dietary fiber and water beneficial for preventing constipation (81 and 42%, respectively) (Ohya and Yoneda, 1995). Thus, the null associations between dietary fiber, total water and water from fluids and constipation observed in the present study might have been due to a possible increase in intake of dietary fiber and water (from fluids) in subjects defined as having constipation. However, because water from foods and magnesium are generally unlikely to be recognized as having an effect on constipation, it is reasonable to consider that our subjects suffering from constipation neither increased nor decreased their intakes of water from foods and magnesium.

Second, all self-reported dietary assessment methods are subject to measurement error and selective underestimation and overestimation of dietary intake (Livingstone and Black, 2003). However, to minimize these possibilities, we used a previously validated DHQ (Sasaki *et al.*, 1998a, b, 2000), although the validity of total water and water from fluid was somewhat insufficient, which might explain the observed null association between these dietary variables and constipation. Additionally, the same tendency of associations between dietary variables and constipation was observed in a repeated analysis of 2717 subjects with a 'physiologically plausible' energy intake, namely those possessing a ratio of reported energy intake to estimated basal metabolic rate (standard value of basal metabolic rate for Japanese women aged 18–29 years (99 kJ/kg of body weight/day) multiplied by body weight of each subjects (kg) (Ministry of Health, Labour, and Welfare, 2005)) of 1.2–2.5 (Black *et al.*, 1996) (data not shown). Thus, although the effect of measurement error and selective underestimation or overestimation of dietary intake can never be excluded, data inaccuracy is unlikely to have had a major impact on our findings.

Third, given that our subjects were selected female dietetic students, our results might not be extrapolatable to general populations. Additionally, although we attempted to adjust for a wide range of potential confounding variables, we cannot rule out residual confounding owing to these or poorly measured variables such as physical activity level, which were assessed by a limited number of non-validated questions, as well as other unknown variables.

In conclusion, after adjustment for a variety of potential confounders, low intake of water from foods and of magnesium was independently associated with an increased prevalence of functional constipation among young women whose dietary fiber intake was relatively low. Because the cross-sectional nature of the present study precludes any causal inferences, however, further studies using prospective designs are required to clarify these relationships.

Acknowledgements

We thank the students for their generous participation in the study. The members of the Freshmen in Dietetic Courses Study II Group (in addition to the authors) are as follows (shown in alphabetical order of the affiliation): S Awata (Beppu University); T Watanabe and A Suzuki (Chiba College of Health Science); T Abe (Doshisha Women's College); H Hayabuchi (Fukuoka Women's University); R Ueda (Futaba Nutrition College); N Takeda and T Matsubara (Hiroshima Bunkyo Women's University); H Ohwada and K Hirayama (Ibaraki Christian University); C Maruyama (Japan Women's University); M Makino (Jin-ai Women's College); S Tanaka and N Nagasawa (Jumonji University); F Tonozuka and S Osada (Junior College of Kagawa Nutrition University); K Uenishi (Kagawa Nutrition University); T Sagara (Kanazawa Gakuin College); Y Enomoto, K Okayama and H Ooe (Kitasato Junior College of Health and Hygienic Sciences); K Nakayama and M Furuya (Kochi Gakuen College); N Yagi and K Soeda (Koshien University); J Ikeda (Kyoto Bunkyo Junior College); I Kitagawa (Kyoto Koka Women's University); K Yokoyama and R Nakayama (Kyoto Women's University); A Miura (Kwassui Women's College); K Baba (Mie Chukyo University Junior College); Y Sugiyama and M Furuki (Minami Kyushu University); T Oyama (Miyagi Gakuin Women's University); Y Naito and M Kato (Mukogawa Women's University); N Hirota (Nagano Prefectural College); T Tsuji and K Washino (Nagoya Bunri University); T Yawata and C Shimamura (Nara Saho College); N Murayama (Niigata University of Health and Welfare); R Watanabe (Niigata Women's College); M Yamasaki (Nishikyusyu University); M Kitamura (Osaka Aoyama College); T Iwamoto (Prefectural University of Hiroshima); I Suzuki and Y Sugishima (Prefectural University of Kumamoto); M Aoki (Sanyo Gakuen College); S Nishi (Seibo Jogakuin Junior College); K Toyama and R Amamoto (Seinan Jo Gakuin University); N Takahashi and R Sasaki (Sendai Shirayuri Women's College); N Kakibuchi (Setouchi Junior College); M Goto (Shokei Gakuin College); M Watanabe and M Yokotsuka (Showa Women's University); M Kimura (Takasaki University of Health and Welfare); M Hara and N Kiya (Tenshi College); J Hirose, T Fukui and K Shibata (The University of Shiga Prefecture); R Nishiyama (Toita Women's College); N Tomita (Tokiwa Junior College); J Oka and T Ide (Tokyo Kasei University); T Uemura and T Furusho (Tokyo University of Agriculture); A Notsu and Y Yokoyama (Tottori College); T Kuwamori (Toyama College); S Shirono (Ube Frontier College); T Goda (University of Shizuoka); K Suizu (Yamaguchi Prefectural University); H Okamoto (Yamanashi Gakuin Junior College).

References

Ainsworth BE, Haskell WL, Leon AS, Jacobs Jr DR, Montoye HJ, Sallis JF *et al.* (1993). Compendium of physical activities: classification of energy costs of human physical activities. *Med Sci Sports Exerc* 25, 71–80.
Ainsworth BE, Haskell WL, Whitt MC, Irwin ML, Swartz AM, Strath SJ *et al.* (2000). Compendium of physical activities: an update of

activity codes and MET intensities. *Med Sci Sports Exerc* **32** (Suppl 9), S498–S504.
Anti M, Pignataro G, Armuzzi A, Valenti A, Iascone E, Marmo R *et al.* (1998). Water supplementation enhances the effect of high-fiber diet on stool frequency and laxative consumption in adult patients with functional constipation. *Hepatogastroenterology* **45**, 727–732.
Arnaud MJ (2003). Mild dehydration: a risk factor of constipation? *Eur J Clin Nutr* **57** (Suppl 2), S88–S95.
Black AE, Coward WA, Cole TJ, Prentice AM (1996). Human energy expenditure in affluent societies: an analysis of 574 doubly-labelled water measurements. *Eur J Clin Nutr* **50**, 72–92.
Campbell AJ, Busby WJ, Horwath CC (1993). Factors associated with constipation in a community based sample of people aged 70 years and over. *J Epidemiol Community Health* **47**, 23–26.
Chung BD, Parekh U, Sellin JH (1999). Effect of increased fluid intake on stool output in normal healthy volunteers. *J Clin Gastroenterol* **28**, 29–32.
Dukas L, Willett WC, Giovannucci EL (2003). Association between physical activity, fiber intake, and other lifestyle variables and constipation in a study of women. *Am J Gastroenterol* **98**, 1790–1796.
Garrigues V, Galvez C, Ortiz V, Ponce M, Nos P, Ponce J (2004). Prevalence of constipation: agreement among several criteria and evaluation of the diagnostic accuracy of qualifying symptoms and self-reported definition in a population-based survey in Spain. *Am J Epidemiol* **159**, 520–526.
Higgins PD, Johanson JF (2004). Epidemiology of constipation in North America: a systematic review. *Am J Gastroenterol* **99**, 750–759.
Klauser AG, Beck A, Schindlbeck NE, Muller-Lissner SA (1990). Low fluid intake lowers stool output in healthy male volunteers. *Z Gastroenterol* **28**, 606–609.
Livingstone MBE, Black AE (2003). Markers of the validity of reported energy intake. *J Nutr* **133** (Suppl 3), 895S–920S.
Locke III GR, Pemberton JH, Phillips SF (2000). AGA technical review on constipation. American Gastroenterological Association. *Gastroenterology* **119**, 1766–1778.
Matsuzawa Y, Inoue S, Ikeda Y, Sakata T, Saito Y, Sato Y *et al.* (2000). The judgment criteria for new overweight, and the diagnostic standard for obesity. *Obes Res* **6**, 18–28. (in Japanese).
Ministry of Health, Labour, and Welfare (2004). *The National Nutrition Survey in Japan, 2002.* Daiichi Shuppan Publishing Co., Ltd: Tokyo (in Japanese).
Ministry of Health, Labour, and Welfare (2005). *Dietary Reference Intakes for Japanese, 2005.* Daiichi Shuppan Publishing Co., Ltd: Tokyo (in Japanese).
Muller-Lissner SA, Kamm MA, Scarpignato C, Wald A (2005). Myths and misconceptions about chronic constipation. *Am J Gastroenterol* **100**, 232–242.
Murakami K, Okubo H, Sasaki S (2006). Dietary intake in relation to self-reported constipation among Japanese women aged 18–20 years. *Eur J Clin Nutr* **60**, 650–657.
Ohya Y, Yoneda Y (1995). Relationship between constipation and food intake and eating habits consciousness. *Jpn J Nutr* **53**, 385–394 (in Japanese with English abstract).
Pare P, Ferrazzi S, Thompson WG, Irvine EJ, Rance L (2001). An epidemiological survey of constipation in Canada: definitions, rates, demographics, and predictors of health care seeking. *Am J Gastroenterol* **96**, 3130–3137.
Saez LR (1991). Therapeutic proposals for the treatment of idiopathic constipation. *Ital J Gastroent* **23**, 30–35.
Sanjoaquin MA, Appleby PN, Spencer EA, Key TJ (2004). Nutrition and lifestyle in relation to bowel movement frequency: a cross-sectional study of 20 630 men and women in EPIC-Oxford. *Public Health Nutr* **7**, 77–83.
Sasaki S, Ushio F, Amano K, Morihara M, Todoriki T, Uehara Y *et al.* (2000). Serum biomarker-based validation of a self-administered diet history questionnaire for Japanese subjects. *J Nutr Sci Vitaminol* **46**, 285–296.
Sasaki S, Yanagibori R, Amano K (1998a). Self-administered diet history questionnaire developed for health education: a relative validation of the test-version by comparison with 3-day diet record in women. *J Epidemiol* **8**, 203–215.
Sasaki S, Yanagibori R, Amano K (1998b). Validity of a self-administered diet history questionnaire for assessment of sodium and potassium: comparison with single 24-h urinary excretion. *Jpn Circ J* **62**, 431–435.
Science and Technology Agency (2000). *Standard Tables of Food Composition in Japan*,5th edn, Printing Bureau of the Ministry of Finance: Tokyo (in Japanese).
Talley NJ (2004). Definitions, epidemiology, and impact of chronic constipation. *Rev Gastroenterol Disord* **4** (Suppl 2), S3–S10.
Thompson WG, Longstreth GF, Drossman DA, Heaton KW, Irvine EJ, Muller-Lissner SA (1999). Functional bowel disorders and functional abdominal pain. *Gut* **4** (Suppl 2), II43–II47.
Towers AL, Burgio KL, Locher JL, Merkel IS, Safaeian M, Wald A (1994). Constipation in the elderly: influence of dietary, psychological, and physiological factors. *J Am Geriatr Soc* **42**, 701–706.
Whitehead WE, Chaussade S, Corazziari E, Kumar D (1991). Report of an international workshop on management of constipation. *Gastroenterol Int* **4**, 99–113.
Wong ML, Wee S, Pin CH, Gan GL, Ye HC (1999). Sociodemographic and lifestyle factors associated with constipation in an elderly Asian community. *Am J Gastroenterol* **94**, 1283–1291.
Young RJ, Beerman LE, Vanderhoof JA (1998). Increasing oral fluids in chronic constipation in children. *Gastroenterol Nurs* **21**, 156–161.

J Nutr Sci Vitaminol, **53**, 30–36, 2007

Food Intake and Functional Constipation: A Cross-Sectional Study of 3,835 Japanese Women Aged 18–20 Years

Kentaro MURAKAMI[1], Satoshi SASAKI[1,*], Hitomi OKUBO[2], Yoshiko TAKAHASHI[1], Yoko HOSOI[1], Mami ITABASHI[1] and the Freshmen in Dietetic Courses Study II Group

[1] *Nutritional Epidemiology Program, National Institute of Health and Nutrition, Tokyo 162–8636, Japan*
[2] *Department of Nutrition Sciences, Kagawa Nutrition University, Saitama 350–0288, Japan*

(Received July 14, 2006)

Summary Although we previously observed significant associations between intakes of several foods and constipation, definition of constipation was completely based on subjective perception assessed by a quite simple and single question: do you often have constipation? In this study, we examined the associations between food intake and functional constipation as defined according to symptom-based criteria (Rome I criteria: straining, hard stools, incomplete evacuation, and infrequency of bowel movement). Subjects were 3,835 female Japanese dietetic students aged 18–20 y from 53 institutions in Japan. Dietary intake was estimated with a validated, self-administered diet history questionnaire. The prevalence of functional constipation was 26.2%. Dietary intakes of several foods were significantly associated with functional constipation. A multivariate adjusted odds ratio (95% confidence interval; p for trend) for women in the highest quintile of dietary intake compared with those in the lowest was 0.59 (0.46–0.75; <0.0001) for rice, 0.77 (0.61–0.97; 0.003) for pulses, 1.64 (1.30–2.08; <0.0001) for confectioneries, and 1.41 (1.11–1.78; 0.01) for bread. In conclusion, intake of rice and pulse was negatively and that of confectioneries and bread was positively associated with functional constipation among a population of young Japanese women, which was generally consistent with our previous study where constipation was assessed by a quite simple question.

Key Words dietary fiber, food, rice, functional constipation, epidemiology

Constipation is a common health problem (*1–4*), and food intake is considered to be a major modifiable lifestyle factors associated with this condition (*5, 6*). Foods related to constipation in previous observational studies include dairy products (*7*), beans (*7*), meats (*7*), fruits (*7*), vegetables (*7*), rice (*3, 8, 9*), eggs (*9*), confectioneries (*8*), and several nonalcoholic beverages (*3, 7, 8, 10, 11*). However, while most previous studies have defined constipation according to the infrequency of bowel movement only (*10–13*) or the subjective perception of patients (*7, 8*), a consensus definition of constipation consists of straining, hard stools, and incomplete evacuation in addition to infrequency (Rome criteria) (*14*). Further, although Wong et al. (*3*) and Nakaji et al. (*9*) defined constipation using the Rome criteria and original subjective criteria, respectively, they assessed diet with a non-validated, relatively simple food frequency questionnaire. Moreover, although we previously observed associations between intakes of several foods and constipation (*11*), using a previously validated, self-administered, diet history questionnaire (DHQ) (*15–17*), the definition of constipation was completely based on subjective perception assessed by a quite simple and single question: do you often have constipation? Thus, to our knowledge, no study has so far investigated the relationship of food intake, as assessed with a validated assessment method, to functional constipation, as defined using symptom-based criteria. Here, we examined the associations between food intake, estimated using DHQ, and functional constipation as defined according to the Rome criteria (*14*).

SUBJECTS AND METHODS

Subjects and survey procedure. The present study was based on a self-administered questionnaire survey among dietetic students (n=4,679) from 54 institutions in Japan. Staff at each institution distributed a dietary assessment questionnaire (i.e., DHQ) and another questionnaire on other lifestyle items during the preceding month to students during an orientation session or a first lecture designed for freshman students entering dietetic courses in April 2005; in most institutions, this was carried out within 2 wk after the course began to minimize the influence of new school year life on the answers. Students filled out the questionnaires during the session, lecture, or at home and then submitted the completed forms to staff at each institution. Questionnaires used in the present study included the explanation on how to answer questions. To standardize the survey procedure, when students asked how to answer questionnaires, staff at each institution did not

*To whom correspondence should be addressed.
E-mail: stssasak@nih.go.jp

provide any advice and only asked students to read the explanation on questionnaires carefully. In addition to the two questionnaires for the preceding month, a third questionnaire on lifestyle during the previous 6 y (i.e., junior high school and high school) was also distributed and answered in a similar fashion; in most institutions, this was carried out within 4 wk after the course began because it was considered burdensome for subjects to answer all three questionnaires at the same time and it was considered unlikely that new school year life would influence the answers for lifestyle during the previous 6 y.

The staff at each institution checked the responses according to the survey protocol. When missing answers or logical errors were identified, the student was asked to complete the questionnaire again. The staff at each institution mailed the questionnaires to the survey center. Staff at the survey center checked the answers again, and when necessary returned problematic questionnaires to staff at the respective institution, and the student was asked to complete the questionnaires again. All questionnaires were thus checked at least once by staff at each institution and by staff at the survey center. Most surveys were completed by May 2005. The protocol of the present study was approved by the Ethics Committee of the National Institute of Health and Nutrition.

In total, 4,286 students (4,066 women and 220 men) answered all three questionnaires (91.6%). For the current analysis, we selected female subjects aged 18–20 y (n=3,967) because of the small number of male subjects and women aged >20 y. We then excluded women who were in an institution where the survey had been conducted at the end of May (n=97) because the answers were likely influenced by the new school year life. We further excluded those with extremely low or high energy intake (<500 kcal/d or >4,000 kcal/d) (n=23) because their estimated dietary intake was likely unreliable. We finally excluded those with missing information on the variables used (n=24) for the purpose of multivariate analyses. As some subjects were in more than one exclusion category, the final analysis sample comprised 3,825 women. Although intentional dietary change or use of oral laxatives might have influence on dietary intake or constipation, further exclusion of subjects with intentional dietary change within the preceding year (n=649), those habitually using oral laxatives (n=231), or both did not materially alter the findings, and these subjects were therefore included in the analyses.

Dietary intake. Dietary habits during the previous month were assessed using a previously validated, self-administered DHQ (*15–17*). This is a 16-page structured questionnaire that consists of the following seven sections: general dietary behavior; major cooking methods; consumption frequency and amount of six alcoholic beverages; consumption frequency and semi-quantitative portion size of 121 selected food and non-alcoholic beverage items; dietary supplements; consumption frequency and semi-quantitative portion size of 19 staple foods (rice, bread, and noodles) and miso (fermented soybean paste) soup; and open-ended items for foods consumed regularly (≥once/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 (*18*) and several recipe books for Japanese dishes (*15*).

Estimates of dietary intake for 147 food and beverage items and energy were calculated using an ad hoc computer algorithm for the DHQ, which was based on the Standard Tables of Food Composition in Japan (*19*). Information on dietary supplements and data from the open-ended questionnaire items were not used in the calculation of dietary intake. The food and nonalcoholic beverage items were grouped into the 18 food groups (as shown in Table 2). Detailed descriptions of the methods used for calculating dietary intake and the validity of the DHQ have been published elsewhere (*15–17*). The Pearson correlation coefficient (*20*) between DHQ and 3-d estimated dietary records was 0.48 for energy among 47 women (*15*). In addition, the mean value of the Spearman correlation coefficients (*20*) for energy-adjusted intakes (g/1,000 kcal) of 16 food groups was 0.35 (range: 0.05–0.59) among 92 women (Sasaki S, unpublished observations, 2004).

Constipation. A constipation questionnaire was developed based on a previous study (*2*) and incorporated into the 20-page questionnaire for lifestyle during the previous 6 y. We used the definition of functional constipation recommended by an international workshop on the management of constipation (Rome I criteria) (*14*). Although the Rome I criteria were modified in 1999 (Rome II criteria) (*21*), epidemiologic studies have consistently shown that the latter may be too restrictive for the diagnosis of constipation (*2*, *4*); we therefore used the former. The Rome I criteria are a consensus definition of constipation consisting of various symptoms including bowel movement frequency (as shown below) (*14*), and have become the research standard for the definition of constipation (*1*). The following four questions were used to assess Rome I-defined functional constipation: 1) Do you strain during a bowel movement?; 2) Do you feel an incomplete emptying sensation after a bowel movement?; 3) How often are your stools hard?; and 4) How many bowel movements do you usually have each week? These questions referred to the last 12 mo. For questions 1–3, four answers were offered: never, sometimes (<25% of the time), often (≥25% of the time), and always. Functional constipation was defined as meeting two or more of the four criteria [an answer of *often* or *always* to questions 1–3 and <3 bowel movements per week (question 4)].

Confounding factors. In epidemiologic research, it is usual to divide the main dependent variables (food intake in the present study) and confounding factors (other lifestyle factors described below in the present study) based on previous studies (*1–13*). Thus, we assessed not only dietary intake but also several lifestyle factors described below in the present survey. In the questionnaires, subjects reported body weight and

Table 1. Characteristics of subjects.[a]

Variable	All (*n*=3,825)	Subjects with functional constipation[b] (*n*=1,002)	Subjects without functional constipation (*n*=2,823)	p^c
Body mass index (kg/m^2)	21.0±2.8	20.8±2.5	21.0±2.9	0.08
<18.5	557 (14.6)	139 (13.9)	418 (14.8)	0.19
18.5–24.9	2,976 (77.8)	798 (79.6)	2,178 (77.2)	
≧25	292 (7.6)	65 (6.5)	227 (8.0)	
Residential block				
Hokkaido and Tohoku	375 (9.8)	93 (9.3)	282 (10.0)	0.20
Kanto	1,310 (34.3)	351 (35.0)	959 (34.0)	
Hokuriku and Tokai	537 (14.0)	159 (15.9)	378 (13.4)	
Kinki	765 (20.0)	203 (20.3)	562 (19.9)	
Chugoku and Shikoku	421 (11.0)	99 (9.9)	322 (11.4)	
Kyushu	417 (10.9)	97 (9.7)	320 (11.3)	
Size of residential area				
City with a population ≧1 million	745 (19.5)	195 (19.5)	550 (19.5)	0.98
City with a population <1 million	2,495 (65.2)	652 (65.1)	1,843 (65.3)	
Town and village	585 (15.3)	155 (15.5)	430 (15.2)	
Current smoking				
No	3,769 (98.5)	980 (97.8)	2,789 (98.8)	0.02
Yes	56 (1.5)	22 (2.2)	34 (1.2)	
Current alcohol drinking				
No	3,097 (81.0)	770 (76.9)	2,327 (82.4)	0.0001
Yes	728 (19.0)	232 (23.2)	496 (17.6)	
Oral medication usage				
No	3,447 (90.1)	840 (83.8)	2,607 (92.4)	<0.0001
Yes	378 (9.9)	62 (16.2)	216 (7.7)	
Physical activity level	1.45±0.15	1.45±0.16	1.45±0.15	0.56
Quintile 1 (<1.36)	758 (19.8)	200 (20.0)	558 (19.8)	0.96
Quintile 2 (1.36–1.38)	772 (20.2)	205 (20.5)	567 (20.1)	
Quintile 3 (1.39–1.42)	765 (20.0)	206 (20.6)	559 (19.8)	
Quintile 4 (1.43–1.49)	765 (20.0)	196 (19.6)	569 (20.2)	
Quintile 5 (>1.49)	765 (20.0)	195 (19.5)	570 (20.2)	
Energy intake (kcal/d)	1,819±502	1,835±531	1,814±491	0.26
Quintile 1 (<1,407)	765 (20.0)	206 (20.6)	559 (19.8)	0.19
Quintile 2 (1,407–1,636)	765 (20.0)	195 (19.5)	570 (20.2)	
Quintile 3 (1,637–1,869)	765 (20.0)	191 (19.1)	574 (20.3)	
Quintile 4 (1,870–2,181)	765 (20.0)	186 (18.6)	579 (20.5)	
Quintile 5 (>2,182)	765 (20.0)	224 (22.4)	541 (19.2)	

[a] Values are mean±standard deviation or *n* (%).
[b] Defined according to the Rome I criteria (*14*).
[c] For continuous variables, independent *t*-test was used; for categorical variables, chi-square test was used.

height, residential area, current smoking (yes or no), and oral medication usage (yes or no). Body mass index (BMI) was calculated as weight (kg) divided by the square of height (m). We classified BMI into three categories (<18.5, 18.5–24.9, and ≥25 kg/m^2) according to the Japan Society for the Study of Obesity (*22*). The reported residential areas were grouped into six categories (Hokkaido and Tohoku; Kanto; Hokuriku and Tokai; Kinki; Chugoku and Shikoku; and Kyushu) based on the regional blocks used in the National Nutrition Survey in Japan (*23*) (hereafter referred to as 'residential block'). The residential areas were also grouped into three categories according to population size (city with population ≥1 million; city with population <1 million; and town and village) (hereafter referred to as 'size of residential area').

Additionally, subjects reported the time when they usually went to bed and arose in the morning, which was used to calculate sleeping hours, and the frequency and duration of high- and moderate-intensity activities, walking, and sedentary activities. Each activity was assigned a metabolic equivalent (MET) value (*24, 25*). The 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. Physical activity level was then calculated by dividing total MET-hour score (kcal/kg of body weight/d) by the standard value of basal metabolic rate for Japanese women aged 18–29 y (23.6 kcal/kg of body weight/d) (*26*).

Statistical analysis. Associations between functional constipation (the dependent variable) and energy-

Table 2. Multivariate adjusted odds ratios (ORs) and 95% confidence intervals (CIs) for functional constipation[a] by quintiles of food intake[b] (n=3,825).

	Quintile category of food intake					p for trend
	1	2	3	4	5	
Rice (g/1,000 kcal)[c]	78 [0–101]	119 [101–135]	152 [135–169]	188 [169–214]	251 [214–448]	
n with/without functional constipation	247/518	206/559	191/574	197/568	161/604	
Multivariate adjusted OR (95% CI)[d]	1.00	0.81 (0.65–1.02)	0.73 (0.58–0.92)	0.76 (0.60–0.96)	0.59 (0.46–0.75)	<0.0001
Bread (g/1,000 kcal)[c]	4 [0–9]	14 [9–18]	23 [18–28]	34 [28–41]	53 [41–171]	
n with/without functional constipation	178/587	199/566	206/559	195/570	224/541	
Multivariate adjusted OR (95% CI)[d]	1.00	1.16 (0.92–1.47)	1.27 (1.00–1.61)	1.17 (0.92–1.49)	1.41 (1.11–1.78)	0.01
Noodles (g/1,000 kcal)[c]	0 [0–11]	16 [11–24]	31 [24–38]	47 [38–59]	79 [59–355]	
n with/without functional constipation	204/561	211/554	207/558	185/580	195/570	
Multivariate adjusted OR (95% CI)[d]	1.00	1.06 (0.84–1.33)	1.02 (0.81–1.29)	0.90 (0.71–1.14)	0.94 (0.75–1.19)	0.30
Potatoes (g/1,000 kcal)[c]	6 [0–8]	10 [8–11]	13 [11–15]	18 [15–22]	29 [22–165]	
n with/without functional constipation	199/566	169/596	206/559	218/547	210/555	
Multivariate adjusted OR (95% CI)[d]	1.00	0.80 (0.63–1.02)	1.03 (0.82–1.30)	1.10 (0.87–1.38)	1.04 (0.83–1.31)	0.15
Confectioneries[e] (g/1,000 kcal)[c]	18 [1–24]	29 [24–33]	37 [33–42]	47 [42–54]	63 [54–142]	
n with/without functional constipation	162/603	185/580	191/574	224/541	240/525	
Multivariate adjusted OR (95% CI)[d]	1.00	1.17 (0.92–1.50)	1.20 (0.94–1.53)	1.51 (1.19–1.92)	1.64 (1.30–2.08)	<0.0001
Fat and oil (g/1,000 kcal)[c]	7 [1–8]	10 [8–11]	12 [11–14]	15 [14–18]	21 [18–67]	
n with/without functional constipation	196/569	210/555	205/560	194/571	197/568	
Multivariate adjusted OR (95% CI)[d]	1.00	1.14 (0.91–1.44)	1.11 (0.88–1.40)	1.04 (0.82–1.32)	1.03 (0.81–1.31)	0.90
Pulses[f] (g/1,000 kcal)[c]	7 [0–10]	13 [10–17]	20 [17–25]	30 [25–37]	48 [37–174]	
n with/without functional constipation	234/531	216/549	174/591	181/584	197/568	
Multivariate adjusted OR (95% CI)[d]	1.00	0.90 (0.72–1.12)	0.64 (0.50–0.80)	0.68 (0.54–0.86)	0.77 (0.61–0.97)	0.003
Fish and shellfish (g/1,000 kcal)[c]	11 [0–16]	20 [16–24]	27 [24–31]	35 [31–41]	50 [41–164]	
n with/without functional constipation	209/556	208/557	194/571	184/581	207/558	
Multivariate adjusted OR (95% CI)[d]	1.00	1.00 (0.80–1.26)	0.92 (0.73–1.16)	0.88 (0.70–1.11)	0.98 (0.78–1.23)	0.54
Meats (g/1,000 kcal)[c]	15 [0–20]	23 [20–27]	31 [27–35]	39 [35–46]	55 [46–134]	
n with/without functional constipation	199/566	192/573	194/571	219/546	198/567	
Multivariate adjusted OR (95% CI)[d]	1.00	0.98 (0.78–1.24)	1.03 (0.81–1.29)	1.17 (0.93–1.47)	1.03 (0.81–1.30)	0.39
Eggs (g/1,000 kcal)[c]	3 [0–5]	8 [5–13]	15 [13–20]	25 [20–29]	36 [29–127]	
n with/without functional constipation	192/573	211/554	197/568	200/565	202/563	
Multivariate adjusted OR (95% CI)[d]	1.00	1.12 (0.89–1.42)	1.02 (0.80–1.29)	1.04 (0.82–1.31)	1.12 (0.89–1.42)	0.58
Dairy products (g/1,000 kcal)[c]	16 [0–26]	38 [26–52]	66 [52–82]	100 [82–123]	172 [123–596]	
n with/without functional constipation	212/553	200/565	198/567	193/572	199/566	
Multivariate adjusted OR (95% CI)[d]	1.00	0.90 (0.72–1.14)	0.88 (0.70–1.11)	0.87 (0.69–1.10)	0.91 (0.72–1.15)	0.39
Vegetables[g] (g/1,000 kcal)[c]	49 [2–67]	80 [67–95]	110 [95–126]	146 [126–173]	221 [173–1142]	
n with/without functional constipation	218/547	201/564	187/578	197/568	199/566	
Multivariate adjusted OR (95% CI)[d]	1.00	0.89 (0.71–1.12)	0.81 (0.64–1.02)	0.84 (0.67–1.06)	0.86 (0.68–1.09)	0.18
Fruits (g/1,000 kcal)[c]	8 [0–14]	20 [14–27]	36 [27–45]	57 [45–74]	104 [74–614]	
n with/without functional constipation	224/541	189/576	201/564	176/589	212/553	
Multivariate adjusted OR (95% CI)[d]	1.00	0.80 (0.64–1.01)	0.84 (0.67–1.06)	0.70 (0.55–0.89)	0.87 (0.69–1.09)	0.11
Water (g/1,000 kcal)[c]	0 [0]	11 [2–14]	34 [14–62]	96 [62–185]	319 [185–1649]	
n with/without functional constipation	319/950	62/199	205/560	203/562	213/552	
Multivariate adjusted OR (95% CI)[d]	1.00	0.93 (0.68–1.28)	1.05 (0.85–1.29)	1.04 (0.84–1.28)	1.10 (0.89–1.35)	0.36
Japanese and Chinese tea[h] (g/1,000 kcal)[c]	44 [0–80]	124 [80–189]	237 [189–288]	366 [288–459]	635 [459–1806]	
n with/without functional constipation	212/553	190/575	188/577	210/555	202/563	
Multivariate adjusted OR (95% CI)[d]	1.00	0.87 (0.69–1.09)	0.86 (0.68–1.09)	1.00 (0.79–1.26)	0.93 (0.74–1.17)	0.97
Black tea[i] (g/1,000 kcal)[c]	0 [0]	11 [2–14]	25 [14–40]	72 [40–1,069]		
n with/without functional constipation	482/1,351	108/354	206/559	206/559		
Multivariate adjusted OR (95% CI)[d]	1.00	1.02 (0.83–1.24)	0.83 (0.63–1.09)	1.02 (0.81–1.28)		0.99
Coffee (g/1,000 kcal)[c]	0 [0]	13 [4–29]	65 [29–1,282]			
n with/without functional constipation	638/1,800	171/451	193/572			
Multivariate adjusted OR (95% CI)[d]	1.00	1.10 (0.91–1.34)	1.11 (0.87–1.42)			0.41
Other nonalcoholic beverages (g/1,000 kcal)[c]	0 [0–0.002]	4 [0.002–10]	18 [10–29]	42 [29–61]	96 [61–860]	
n with/without functional constipation	197/568	212/553	178/587	198/567	217/548	
Multivariate adjusted OR (95% CI)[d]	1.00	1.11 (0.88–1.40)	0.87 (0.69–1.11)	1.02 (0.81–1.29)	1.11 (0.88–1.40)	0.60

[a] Defined according to the Rome I criteria (*14*).
[b] Except for water (5 categories), black tea (4 categories), and coffee (3 categories) because of more than one fifth nonconsumers.
[c] Values are median [range].
[d] Adjusted for body mass index (<18.5, 18.5–24.9, and ≧25 kg/m^2), residential block (Hokkaido and Tohoku; Kanto; Hokuriku and Tokai; Kinki; Chugoku and Shikoku; and Kyushu), size of residential area (city with a population ≧1 million; city with a population <1 million; and town and village), current smoking (yes or no), current alcohol drinking (yes or no), oral medication usage (yes or no), physical activity level (quintiles), and energy intake (quintiles).
[e] Including sugar and sweeteners.
[f] Including nuts.
[g] Including mushrooms and sea vegetables.
[h] Non- and semifermented tea.
[i] Fermented tea.

adjusted intakes (g/1,000 kcal) of the 18 food groups (as shown in Table 2) were examined. We calculated both crude and multivariate adjusted odds ratios (ORs) and 95% confidence intervals for functional constipation for each quintile category of dietary variables (except for several drinks because more than one-fifth of subjects were nonconsumers) using logistic regression analysis (*20*). Multivariate adjusted ORs were calculated by adjusting for BMI, residential block, size of residential area, current smoking, current alcohol drinking (yes or no, because of extremely low alcohol intake: mean=0.8 g/d), oral medication usage, physical activity level (quintiles), and energy intake (quintiles). As results for the crude and multivariate analyses were similar for all variables analyzed, we presented only those derived from the multivariate models. Trend of association was assessed by a logistic regression model assigning scores to the levels of the independent variable. All statistical analyses were performed using SAS statistical software, version 8.2 (SAS Institute Inc., Cary, NC, USA). All reported p values are 2-tailed, and a p value of <0.05 was considered statistically significant.

RESULTS

Basic characteristics of the subjects are shown in Table 1. Mean (±standard deviation) age, body height, and body weight was 18.1±0.3 y, 157.9±5.3 cm, and 52.3±7.7 kg, respectively. A total of 1,002 women (26.2%) were classified as having constipation. There were more current smokers, alcohol drinkers, and oral medication users among subjects with constipation. Table 2 shows the association between food intake and constipation. There was a clear dose-response relationship between an increased intake of rice and a decreased prevalence of constipation. In comparison with women in the 1st (lowest) quintile of rice consumption, the multivariate adjusted OR for women in the 2nd, 3rd, 4th, and 5th quintiles were 0.81, 0.73, 0.76, and 0.59, respectively (p for trend <0.0001). Pulse intake was also inversely associated with constipation. Multivariate OR in the 2nd, 3rd, 4th, and 5th quintiles compared with the 1st quintile were 0.90, 0.64, 0.68, and 0.77, respectively (p for trend=0.003). In contrast, the prevalence of constipation clearly increased with increasing intake of confectioneries. In comparison with women in the 1st quintile, the multivariate adjusted OR for women in the 2nd, 3rd, 4th, and 5th quintiles were 1.17, 1.20, 1.51, and 1.64, respectively (p for trend <0.0001). A positive relationship was also seen between bread intake and constipation. Multivariate OR in the highest quintile was 1.41 compared with those in the lowest quintile (p for trend=0.01). No clear associations were observed between constipation and the intake of other foods examined.

DISCUSSION

To our knowledge, this study is the first to examine food intake as assessed by a validated assessment method (DHQ in the present study) in relation to functional constipation, as defined according to the Rome I criteria. We found that after controlling for a series of potential confounding factors, the consumption of rice and pulses and of confectioneries and bread were negatively and positively associated with functional constipation, respectively, among this group of young women.

The prevalence of Rome I-defined functional constipation in the present group was 26.2%. A similar prevalence by these criteria has been observed in Canadian (21.0%) (*4*) and Spanish (28.6%) (*2*) women, whereas a somewhat smaller ratio was seen in elderly Singaporean women (10.5%) (*3*).

We found clear dose-response relationships between increased intake of rice with a decreased prevalence of constipation (Table 2). The favorable effect of rice on constipation has been consistently reported in previous studies conducted in Asian countries, where rice is the main staple food (*3, 8, 9*). The reason for the association is unknown. Nakaji et al. (*9*) hypothesized that the effect of rice is due to its dietary fiber, given that rice is the largest source of dietary fiber for Japanese people (*27*). In contrast, Wong et al. (*3*) hypothesized that the effect is explained by the increased energy intake because rice is the largest source of energy. These hypotheses could not be investigated further, however, because the authors used a simple diet questionnaire which did not allow the estimation of dietary intake (*3, 9*). Our previous results (*8*) do not support these hypotheses because the association between rice and constipation was not dependent on either energy or dietary fiber intake. Additionally, in the present study, the association between rice and constipation was independent of energy intake; mean dietary fiber intake (11.8 g/d) was much lower than the Dietary Goal of dietary fiber of the Dietary Reference Intakes for Japanese, 2005 for this age range (17 g/d) (*26*), and the contribution of rice to dietary fiber was only 10% (the top contributor was vegetables (37%)). These findings suggest that the effect of rice on constipation is unlikely due to its energy or dietary fiber. Relation of dietary fiber to functional constipation in this population is published elsewhere (*28*). Rice is a staple food in Japan and a major contributor of many nutrients; some constituents of rice may, either alone or combination, exert a preventive effect on constipation. Alternatively, rice intake might merely reflect an overall healthier lifestyle that may not have been accurately captured and controlled in our analysis.

An inverse association between pulse intake and constipation was observed (Table 2). A similar finding has been reported in a study of the US (*7*). We also found an adverse effect of confectionery intake (Table 2), which is in agreement with our previous study of young Japanese women (*8*). Additionally, a positive association of bread intake to constipation was found (Table 2), although we are not aware of any previous report of this association. It is unclear why these foods had such effects on constipation. Given the large number of statistical analyses conducted in the present study, our findings regarding these foods may have been due to chance alone. Alternatively, their intake may be a marker of other unknown lifestyle factors that were not addressed in the present study.

In contrast to previous studies (*3, 7–11*), we found no association between constipation and the intake of dairy products, meats, fruits, vegetables, eggs, Japanese and Chinese tea, black tea, coffee, and other nonalcoholic beverages (Table 2). These discrepancies may be at least partly explained by the different populations investigated, different dietary assessment methods used, different definitions of constipation, and differences in the number and type of variables used as confounding factors.

Because it is possible that subjects suffering from constipation might change their diet, our findings, particularly those regarding foods significantly associated with the presence or absence of constipation (rice, pulses, confectioneries, and bread), should be interpreted with caution. We cannot deny the possibility that the associations merely reflect dietary behaviors changed after, not before, the development of constipation, although these foods are not generally considered to influence constipation. As mentioned above, however, previous studies have shown similar findings for rice (*3, 8, 9*), pulses (*7*), and confectioneries (*8*), but not bread.

All self-reported dietary assessment methods are subject to measurement error and selective under- and overestimation of dietary intake (*29*). To minimize these possibilities, we used a previously validated DHQ (*15–17*). Additionally, the same tendency of associations between food intakes and constipation was observed in a repeated analysis of 2,717 subjects with a 'physiologically plausible' energy intake, namely those possessing a ratio of reported energy intake to estimated basal metabolic rate [standard value of basal metabolic rate for Japanese women aged 18–29 y (23.6 kcal/kg of body weight/d) multiplied by body weight of each subjects (kg) (*26*)] of 1.2 to 2.5 (*30*) (data not shown). Thus, although the possibility of measurement error and selective under- or overestimation of dietary intake can never be excluded, data inaccuracy is unlikely to have had a major impact on the findings in the present study.

Given that our subjects were selected female dietetic students who may be highly health conscious, our results are likely not extrapolatable to general populations. Additionally, although we attempted to adjust for a wide range of potential confounding variables, we cannot rule out residual confounding due to these or poorly measured variables such as physical activity level, which was assessed by a limited number of nonvalidated questions, or other unknown variables.

In conclusion, after adjustment for a variety of potential confounders, the intake of rice and pulses and that of confectioneries and bread were negatively and positively associated with functional constipation, respectively, among young women. However, owing to the cross-sectional nature of the present study, which precludes any causal inferences, and the lack of biological explanation for these relationships, further observational and experimental studies are required to clarify these relationships.

Member list of the Freshmen in Dietetic Courses Study II Group

The members of the Freshmen in Dietetic Courses Study II Group (in addition to the authors) are as follows (shown in alphabetical order of the affiliation): Shiro Awata (Beppu University); Tomoko Watanabe and Ayuho Suzuki (Chiba College of Health Science); Tomoko Abe (Doshisha Women's College); Hitomi Hayabuchi (Fukuoka Women's University); Reiko Ueda (Futaba Nutrition College); Noriko Takeda and Tomoko Matsubara (Hiroshima Bunkyo Women's University); Hiroko Ohwada and Kumi Hirayama (Ibaraki Christian University); Chizuko Maruyama (Japan Women's University); Miyuki Makino (Jin-ai Women's College); Shigeru Tanaka and Nobue Nagasawa (Jumonji University); Fumiko Tonozuka and Sanae Osada (Junior College of Kagawa Nutrition University); Kazuhiro Uenishi (Kagawa Nutrition University); Takiko Sagara (Kanazawa Gakuin College); Yusuke Enomoto, Kazuyo Okayama, and Hideo Ooe (Kitasato Junior College of Health and Hygienic Sciences); Kazuko Nakayama and Michi Furuya (Kochi Gakuen College); Noriko Yagi and Kumiko Soeda (Koshien University); Junko Ikeda (Kyoto Bunkyo Junior College); Ikumi Kitagawa (Kyoto Koka Women's University); Keiko Yokoyama and Reiko Nakayama (Kyoto Women's University); Ayako Miura (Kwassui Women's College); Keiko Baba (Mie Chukyo University Junior College); Yoshiko Sugiyama and Mika Furuki (Minami Kyushu University); Tamami Oyama (Miyagi Gakuin Women's University); Yoshihiko Naito and Makoto Kato (Mukogawa Women's University); Naoko Hirota (Nagano Prefectural College); Tomiko Tsuji and Kaei Washino (Nagoya Bunri University); Takiko Yawata and Chiho Shimamura (Nara Saho College); Nobuko Murayama (Niigata University of Health and Welfare); Reiko Watanabe (Niigata Women's College); Mitsuyo Yamasaki (Nishikyusyu University); Mari Kitamura (Osaka Aoyama College); Tamami Iwamoto (Prefectural University of Hiroshima); Isao Suzuki and Yuki Sugishima (Prefectural University of Kumamoto); Mieko Aoki (Sanyo Gakuen College); Shoko Nishi (Seibo Jogakuin Junior College); Kenji Toyama and Rie Amamoto (Seinan Jo Gakuin University); Nobuko Takahashi and Ruriko Sasaki (Sendai Shirayuri Women's College); Naoko Kakibuchi (Setouchi Junior College); Miyoko Goto (Shokei Gakuin College); Mariko Watanabe and Masako Yokotsuka (Showa Women's University); Michiyo Kimura (Takasaki University of Health and Welfare); Michiko Hara and Nobuko Kiya (Tenshi College); Junko Hirose, Tomiho Fukui, and Katsumi Shibata (The University of Shiga Prefecture); Ryoko Nishiyama (Toita Women's College); Noriyo Tomita (Tokiwa Junior College); Jun Oka and Tomoko Ide (Tokyo Kasei University); Takamoto Uemura and Tadasu Furusho (Tokyo University of Agriculture); Akiko Notsu and Yae Yokoyama (Tottori College); Toyomi Kuwamori (Toyama College); Setsuko Shirono (Ube Frontier College); Toshinao Goda (University of Shizuoka); Kumiko

Suizu (Yamaguchi Prefectural University); Hiroko Okamoto (Yamanashi Gakuin Junior College).

REFERENCES

1) Higgins PD, Johanson JF. 2004. Epidemiology of constipation in North America: a systematic review. *Am J Gastroenterol* **99**: 750–759.
2) Garrigues V, Galvez C, Ortiz V, Ponce M, Nos P, Ponce J. 2004. Prevalence of constipation: agreement among several criteria and evaluation of the diagnostic accuracy of qualifying symptoms and self-reported definition in a population-based survey in Spain. *Am J Epidemiol* **159**: 520–526.
3) Wong ML, Wee S, Pin CH, Gan GL, Ye HC. 1999. Sociodemographic and lifestyle factors associated with constipation in an elderly Asian community. *Am J Gastroenterol* **94**: 1283–1291.
4) Pare P, Ferrazzi S, Thompson WG, Irvine EJ, Rance L. 2001. An epidemiological survey of constipation in Canada: definitions, rates, demographics, and predictors of health care seeking. *Am J Gastroenterol* **96**: 3130–3137.
5) Talley NJ. 2004. Definitions, epidemiology, and impact of chronic constipation. *Rev Gastroenterol Disord* **4**: S3–S10.
6) Locke GR 3rd, Pemberton JH, Phillips SF. 2000. AGA technical review on constipation. American Gastroenterological Association. *Gastroenterology* **119**: 1766–1778.
7) Sandler RS, Jordan MC, Shelton BJ. 1990. Demographic and dietary determinants of constipation in the US population. *Am J Public Health* **80**: 185–189.
8) Murakami K, Okubo H, Sasaki S. 2006. Dietary intake in relation to self-reported constipation among Japanese women aged 18–20 years. *Eur J Clin Nutr* **60**: 650–657.
9) Nakaji S, Tokunaga S, Sakamoto J, Todate M, Shimoyama T, Umeda T, Sugawara K. 2002. Relationship between lifestyle factors and defecation in a Japanese population. *Eur J Nutr* **41**: 244–248.
10) Dukas L, Willett WC, Giovannucci EL. 2003. Association between physical activity, fiber intake, and other lifestyle variables and constipation in a study of women. *Am J Gastroenterol* **98**: 1790–1796.
11) Sanjoaquin MA, Appleby PN, Spencer EA, Key TJ. 2004. Nutrition and lifestyle in relation to bowel movement frequency: a cross-sectional study of 20630 men and women in EPIC-Oxford. *Public Health Nutr* **7**: 77–83.
12) Towers AL, Burgio KL, Locher JL, Merkel IS, Safaeian M, Wald A. 1994. Constipation in the elderly: influence of dietary, psychological, and physiological factors. *J Am Geriatr Soc* **42**: 701–706.
13) Campbell AJ, Busby WJ, Horwath CC. 1993. Factors associated with constipation in a community based sample of people aged 70 years and over. *J Epidemiol Commun Health* **47**: 23–26.
14) Whitehead WE, Chaussade S, Corazziari E, Kumar D. 1991. Report of an international workshop on management of constipation. *Gastroenterol Int* **4**: 99–113.
15) Sasaki S, Yanagibori R, Amano K. 1998. Self-administered diet history questionnaire developed for health education: a relative validation of the test-version by comparison with 3-day diet record in women. *J Epidemiol* **8**: 203–215.
16) Sasaki S, Yanagibori R, Amano K. 1998. Validity of a self-administered diet history questionnaire for assessment of sodium and potassium: comparison with single 24-hour urinary excretion. *Jpn Circ J* **62**: 431–435.
17) Sasaki S, Ushio F, Amano K, Morihara M, Todoriki T, Uehara Y, Toyooka T. 2000. Serum biomarker-based validation of a self-administered diet history questionnaire for Japanese subjects. *J Nutr Sci Vitaminol* **46**: 285–296.
18) Ministry of Health and Welfare. 1994. The National Nutrition Survey in Japan, 1992. Ministry of Health and Welfare, Tokyo (in Japanese).
19) Science and Technology Agency. 2000. Standard Tables of Food Composition in Japan, 5th revised ed. Printing Bureau of the Ministry of Finance, Tokyo (in Japanese).
20) Altman DG. 1991. Practical Statistics for Medical Research. Chapman and Hall, New York.
21) Thompson WG, Longstreth GF, Drossman DA, Heaton KW, Irvine EJ, Muller-Lissner SA. 1999. Functional bowel disorders and functional abdominal pain. *Gut* **45**: II43–II47.
22) Matsuzawa Y, Inoue S, Ikeda Y, Sakata T, Saito Y, Sato Y, Shirai K, Ono M, Miyazaki S, Tokunaga K, Fukagawa K, Yamanouchi K, Nakamura T. 2000. The judgment criteria for new overweight, and the diagnostic standard for obesity. *Himan Kenkyu* **6**: 18–28 (in Japanese).
23) Ministry of Health, Labour, and Welfare. 2004. The National Nutrition Survey in Japan, 2002. Ministry of Health, Labour, and Welfare, Tokyo (in Japanese).
24) Ainsworth BE, Haskell WL, Leon AS, Jacobs DR Jr, Montoye HJ, Sallis JF, Paffenbarger RS Jr. 1993. Compendium of physical activities: classification of energy costs of human physical activities. *Med Sci Sports Exerc* **25**: 71–80.
25) Ainsworth BE, Haskell WL, Whitt MC, Irwin ML, Swartz AM, Strath SJ, O'Brien WL, Bassett DR Jr, Schmitz KH, Emplaincourt PO, Jacobs DR Jr, Leon AS. 2000. Compendium of physical activities: an update of activity codes and MET intensities. *Med Sci Sports Exerc* **32**: S498–S504.
26) Ministry of Health, Labour, and Welfare, Japan. 2005. Dietary Reference Intakes for Japanese, 2005. Daiichi Shuppan Publishing Co., Ltd., Tokyo (in Japanese).
27) Sasaki S, Matsumura Y, Ishihara J, Tsugane S. 2003. Validity of a self-administered food frequency questionnaire used in the 5-year follow-up survey of the JPHC Study Cohort I to assess dietary fiber intake: comparison with dietary records. *J Epidemiol* **13**: S106–S114.
28) Murakami K, Sasaki S, Okubo H, Takahashi Y, Hosoi Y, Itabashi M, the Freshmen in Dietetic Courses Study II Group. 2006. Association between dietary fiber, water and magnesium intake and functional constipation among young Japanese women. *Eur J Clin Nutr* (advance online publication, December 6, 2006; doi:10.1038/sj.ejcn. 1602573).
29) Livingstone MBE, Black AE. 2003. Markers of the validity of reported energy intake. *J Nutr* 133: 895S–920S.
30) Black AE, Coward WA, Cole TJ, Prentice AM. 1996. Human energy expenditure in affluent societies: an analysis of 574 doubly-labelled water measurements. *Eur J Clin Nutr* **50**: 72–92.