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.

Available online at www.sciencedirect.com
SCIENCE DIRECT
ELSEVIER
Preventive Medicine 43 (2006) 14–19
Preventive Medicine
www.elsevier.com/locate/ypmed

Maintenance of a low-sodium, high-carotene and -vitamin C diet after a 1-year dietary intervention: The Hiraka Dietary Intervention Follow-up Study

Yoshiko Takahashi [a,b], Satoshi Sasaki [b], Shunji Okubo [c], Masato Hayashi [c], Shoichiro Tsugane [a,*]

[a] Epidemiology and Prevention Division, Research Center for Cancer Prevention and Screening, National Cancer Center, 5-1-1 Tsukiji, Chuo-ku, Tokyo 104-0045, Japan
[b] National Institute of Health and Nutrition, Tokyo, Japan
[c] Hiraka General Hospital, Akita, Japan

Available online 16 May 2006

Abstract

Background. The importance of dietary modification for disease prevention is widely accepted. The difficulty of implementing and sustaining long-term changes is also well documented. Nevertheless, a few studies have attempted to achieve significant dietary change for extended periods.

Methods. The Hiraka Dietary Intervention Study was a community-based randomized cross-over trial designed to develop an effective dietary modification tool and system in an area with high mortality for stomach cancer and stroke in 1998–2000. The main study subjects were 550 healthy volunteers, who were randomized into two groups and given tailored dietary education aimed at decreasing the intake of sodium and increasing that of carotene and vitamin C in either the first or second year. Four (first intervention group) and three (second intervention group) years after the intervention ended, 308 subjects were selected for this follow-up dietary survey.

Results. The low-sodium, high-vitamin C and -carotene diet was maintained with only a small, nonsignificant reversal from post-intervention to follow-up ($P = 0.082–0.824$). Significant changes from pre-intervention to follow-up were also maintained ($P < 0.01$).

Conclusion. This dietary intervention program was maintained well over 4 years after the termination of the intervention sessions.

Keywords: Follow-up studies; Intervention studies; Dietary; Maintenance; Sodium; Carotene; Vitamin C

Introduction

Although the incidence of stomach cancer and stroke is decreasing, they remain major causes of death in Japanese (The Research Group for Population-based Cancer Registration in Japan, 1998; Liu et al., 2001). Primary prevention through lifestyle modification is regarded as an important strategy for reducing these diseases at the population level. The two diseases have common dietary etiologic factors: a high sodium and salted food intake is a probable risk factor for both, and hypertension is the major risk factor for the latter (Report of a joint FAO/WHO Experts Consultation, 2003; Tsugane et al., 2004). A high fruit and vegetable intake is possibly preventive for both (Report of a joint FAO/WHO Experts Consultation, 2003). Dietary intervention methods able to modify the intake of these nutrients are therefore urgently needed in Japan.

The Hiraka Dietary Intervention Study was a community-based randomized cross-over trial designed to develop an effective dietary modification tool and system in an area with high mortality for stomach cancer and stroke (Takahashi et al., 2003). Just after the intervention, favorable modifications were observed in all targeted nutrients.

The importance of dietary change for disease prevention is widely accepted. The difficulty of implementing and sustaining long-term changes is also often documented. Nevertheless, a few previous studies have attempted to achieve significant dietary modification for extended periods (Bowen and Beresford, 2002). The aim of the present study was to determine the degree

* Corresponding author. Fax: +81 3 3547 8578.
E-mail address: ststugane@ncc.go.jp (S. Tsugane).

0091-7435/$ - see front matter © 2006 Elsevier Inc. All rights reserved.
doi:10.1016/j.ypmed.2006.03.023

Table 1
Subject characteristics of Hiraka Dietary Intervention Follow-up Study (Akita, Japan, 1998–2003) at the pre-intervention point

Characteristic	Main study subjects (n = 550)	Follow-up study (n = 308)			P values[a]
		Participants (n = 278)	Non-responders (n = 30)	P values[b]	
Age (years)[c]	56.2 (7.7)	55.3 (7.7)	53.8 (7.8)	0.298	0.064
Sex (%female)	67.0	66.9	51.5	0.087	0.909
Body height (cm)[c]	155.6 (7.9)	156.8 (7.5)	158.5 (7.4)	0.200	0.220
Body weight (kg)[c]	57.3 (9.0)	57.5 (8.5)	60.5 (7.1)	0.092	0.837
Body mass index (kg/m^2)[c]	23.6 (2.8)	23.4 (2.7)	24.1 (3.1)	0.217	0.925
Smoker (%current)	11.5	12.7	8.0	0.334	0.544
Alcohol drinker (%current)	49.0	49.4	56.0	0.080	0.961

[a] P values for comparison between follow-up study participants (n = 308) and main study participants (n = 550).
[b] P values for comparison between participants (n = 278) and non-responder (n = 30) at follow-up.
[c] Values are means (standard deviation).

of maintenance of the diet at 3 and 4 years after completion of the intervention. We also examined the level of maintenance among the nutrients and foods examined.

Methods

Overview of the Hiraka dietary intervention study

The Hiraka Dietary Intervention Study was a community-based randomized cross-over trial held in 1998–2000. Subjects were 550 healthy volunteers (202 men and 348 women, aged 40–69 years) living in two rural villages, Taiyu and Sannai, in Akita Prefecture, Japan. They were randomized into two groups and provided tailored dietary education to encourage a decrease in sodium intake and an increase in vitamin C and carotene intake either in the first year (first intervention group, n = 274) or second year (second intervention group, n = 276).

Members of the intervention group received two individual 15-min dietary counseling sessions from trained dietitians, as well as one group lecture and two newsletters. The face-to-face individual counseling was prepared based on the results of a dietary assessment and health check-up conducted at the initiation of the study. The individual feedback sheets consisted of a summary of dietary habits and nutrient intakes and a check-list of dietary behaviors. Further, four or five leaflets were also tailored to individual dietary intake level and dietary behavior by a computer system. These feedback sheets and leaflets were checked by the trained dietitians and were modified when necessary. In the counseling, each subject was provided with detailed advice in consideration of the individual's dietary habits and preferences. To encourage an increase in carotene and vitamin C intake, subjects were advised to increase their intake of fruit and vegetables based on the individual's dietary intakes and preferences. Similarly, to decrease sodium intake, they were primarily instructed to decrease their intake of salted foods. During the first year, changes differed significantly between the intervention (first intervention group) and control group (second intervention group) for both dietary sodium intake and urinary sodium excretion. Although favorable net changes were also observed in dietary carotene and vitamin C intake, serum level differences were modest. A detailed description of the intervention program and its short-term effects is provided elsewhere (Takahashi et al., 2003). After completion of the intervention, an annual newsletter about the results of the trial was mailed to all subjects to check for changes in address and to disseminate information about the present follow-up study.

Sample collection for the follow-up study

Three hundred and ten subjects living in Taiyu village who completed the main dietary intervention study from 1998 to 2000 were asked to participate in the present study. One subject died and a second moved away from the village before the start of the study, giving 308 subjects (155 first intervention and 153 second intervention group) agreeing to participate. Signed informed consent was obtained from all participants.

Table 2
Reported mean body weight and daily intake of energy and selected nutrients at each point in the Hiraka Dietary Intervention Follow-up Study: Akita, Japan, 1998–2003[a,b]

	Pre-intervention	Post-intervention	Follow-up	Change from pre- to post-intervention		Change from post-intervention to follow-up		Change from pre-intervention to follow-up	
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	P value	Mean (SD)	P value	Mean (SD)	P value
Body weight (kg)	57.5 (8.5)	57.5 (8.5)	57.5 (8.8)	0.0 (2.5)	0.584	0.0 (3.0)	0.426	0.0 (2.9)	0.752
Nutrient intake									
Energy (kcal/day)	2054 (635)	1948 (596)	1982 (605)	−106 (462)	<0.001	34 (447)	0.209	−72 (468)	0.011
Protein (percent of energy)	15.3 (2.8)	15.3 (2.7)	15.4 (2.7)	0.0 (2.4)	0.990	0.1 (2.6)	0.473	0.1 (2.6)	0.471
Carbohydrates (percent of energy)	56.7 (7.1)	56.8 (7.1)	56.5 (7.2)	0.0 (6.3)	0.918	−0.3 (7.1)	0.490	−0.3 (7.4)	0.564
Fat (percent of energy)	23.0 (5.8)	23.4 (5.5)	23.4 (6.0)	0.4 (4.8)	0.171	0.1 (4.9)	0.771	0.5 (5.8)	0.167
Alcohol (percent of energy)	3.7 (6.2)	3.3 (5.7)	3.4 (5.9)	−0.4 (3.5)	0.046	0.1 (3.6)	0.664	−0.3 (3.7)	0.151
Dietary fiber (g/1000 kcal)	7.6 (2.4)	8.0 (2.4)	8.3 (2.7)	0.4 (2.1)	0.001	0.2 (2.2)	0.069	0.7 (2.5)	<0.001
Soluble dietary fiber	1.1 (0.4)	1.2 (0.5)	1.3 (0.5)	0.1 (0.4)	0.001	0.1 (0.5)	0.011	0.2 (0.5)	<0.001
Insoluble dietary fiber	6.0 (1.8)	6.3 (1.8)	6.4 (1.9)	0.3 (1.6)	0.004	0.1 (1.5)	0.348	0.4 (1.8)	0.001
Sodium (mg/1000 kcal)	2852 (795)	2651 (660)	2700 (729)	−201 (713)	<0.001	49 (698)	0.243	−152 (753)	0.001
Potassium (mg/1000 kcal)	1361 (381)	1419 (388)	1401 (389)	58 (310)	0.002	−18 (315)	0.338	40 (326)	<0.001
Carotene (μg/1000 kcal)	1380 (1008)	1625 (1047)	1672 (1118)	245 (1027)	<0.001	48 (1079)	0.462	292 (1090)	<0.001
Alpha-carotene (μg/1000 kcal)	156 (141)	205 (170)	187 (142)	49 (163)	<0.001	−18 (176)	0.082	31 (156)	0.001
Beta-carotene (μg/1000 kcal)	1215 (911)	1410 (925)	1477 (1029)	195 (924)	0.001	67 (978)	0.253	262 (1002)	<0.001
Vitamin C (mg/1000 kcal)	66 (40)	78 (41)	78 (55)	12 (36)	<0.001	−1 (49)	0.824	11 (52)	<0.001

[a] Values are means (standard deviation, SD).
[b] Results with the combined data of first (4 years from the end of the intervention, n = 142) and second intervention group (3 years from the end of the intervention, n = 136).

Table 3
Daily food intake (g/1000 kcal) at each point in the Hiraka Dietary Intervention Follow-up Study: Akita, Japan, 1998–2003[a,b]

	Pre-intervention	Post-intervention	Follow-up	Change from pre- to post-intervention		Change from post-intervention to follow-up		Change from pre-intervention to follow-up	
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	*P* value	Mean (SD)	*P* value	Mean (SD)	*P* value
Salted foods									
Miso[c]	13.9 (6.9)	11.7 (6.3)	12.0 (5.7)	−2.3 (7.2)	<0.001	0.4 (6.8)	0.365	−1.9 (7.6)	<0.001
Salted pickles	29.1 (21.7)	24.4 (18.5)	26.6 (24.0)	−4.8 (21.6)	<0.001	2.2 (22.3)	0.098	−2.5 (26.7)	0.116
Green and yellow vegetables[d]	5.9 (9.3)	4.3 (6.8)	5.6 (9.6)	−1.6 (9.1)	0.004	1.4 (10.0)	0.022	−0.2 (12.1)	0.762
Other vegetables	23.3 (17.5)	20.1 (16.7)	21.0 (19.3)	−3.2 (18.2)	0.004	0.8 (18.4)	0.448	−2.3 (20.7)	0.064
Salted fish	18.6 (14.7)	17.0 (12.8)	17.3 (11.6)	−1.6 (14.1)	0.057	0.3 (13.5)	0.691	−1.3 (15.4)	0.159
Seasonings	21.4 (22.4)	20.4 (20.7)	21.4 (25.2)	−3.2 (45.9)	0.241	1.5 (46.9)	0.605	−18 (59.0)	0.615
Fruits and vegetables									
Vegetables	149.8 (80.4)	166.7 (94.5)	160.3 (83.0)	16.9 (89.8)	0.002	−6.4 (87.9)	0.227	10.5 (82.1)	0.034
Green and yellow vegetables[e]	66.8 (51.6)	80.3 (71.3)	78.3 (55.3)	13.5 (71.8)	0.002	−2.0 (70.6)	0.643	11.5 (56.7)	<0.001
Other vegetables	83.0 (45.7)	86.4 (49.2)	82.0 (43.4)	3.4 (47.7)	0.232	−4.4 (47.8)	0.124	−1.0 (44.3)	0.707
Fruits	53.8 (41.0)	63.6 (44.9)	54.6 (42.9)	9.8 (41.3)	<0.001	−9.0 (44.1)	<0.001	0.8 (44.9)	0.757

[a] Values are means (standard deviation, SD).
[b] Results with the combined data of first (4 years from the end of the intervention, n = 142) and second intervention group (3 years from the end of the intervention, n = 136).
[c] Fermented and salted soy-bean paste.
[d] Includes salted pickles made of dark-green leafy vegetables or carrots.
[e] Include dark-green leafy vegetables, carrots, pumpkin, tomatoes, broccoli, sweet peppers, tomato juice, and vegetable juice.

Data collection

Data for the follow-up study were collected from April to July 2003 using the same procedures as in the main study. A validated self-administered diet history questionnaire (DHQ) was used to estimate average nutrient intakes. The DHQ surveyed dietary habits for the previous 1 month, with questions on the semi-quantitative frequency and quantity for 127 selected food items, dietary behavior, major cooking methods for vegetables, fish and meats, and open-ended questions (Sasaki et al., 1998a,b, 2000). Nutrient and food intake were calculated using a specially developed computer program. The DHQ was completed just before the annual health check-up by all subjects. Medical history, smoking status and anthropometric data were also collected at the health check-up. Body mass index (BMI) was calculated as self-reported weight (kg) divided by height (m) squared.

Statistical analysis

A total of 93% (144 of 155 subjects) of the first intervention group subjects and 90% (138 of 153) of the second completed the follow-up questionnaire. The remaining subjects were lost to follow-up for various reasons, including death, serious illness, nursing of family members and work demands. Subjects were excluded from analysis if their estimated energy intake was less than 50% of that

Table 4
Daily fruit and vegetable intake (g/1000 kcal) at each point in the Hiraka Dietary Intervention Follow-up Study: Akita, Japan, 1998–2003[a,b]

	Pre- intervention	Post- intervention	Follow-up	Change from pre- to post-intervention		Change from post-intervention to follow-up		Change from pre-intervention to follow-up	
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	*P* value	Mean (SD)	*P* value	Mean (SD)	*P* value
Vegetables									
Broccoli	3.9 (5.6)	4.8 (6.6)	5.2 (11.0)	0.8 (6.5)	0.033	0.4 (11.4)	0.585	1.2 (11.3)	0.073
Dark-green leafy vegetable	21.1 (24.5)	24.0 (24.8)	30.1 (31.0)	2.9 (25.4)	0.059	6.1 (30.3)	<0.001	9.0 (30.2)	<0.001
Carrot	6.1 (6.0)	7.9 (6.9)	7.4 (6.1)	1.9 (6.7)	<0.001	−0.5 (7.5)	0.271	1.4 (6.7)	<0.001
Squash	3.0 (6.4)	4.5 (6.4)	3.6 (4.9)	1.5 (8.1)	0.002	−0.9 (7.1)	0.028	0.6 (6.5)	0.143
Tomato	13.7 (23.1)	13.1 (16.2)	13.3 (20.6)	−0.6 (19.2)	0.576	0.2 (20.0)	0.878	−0.5 (24.9)	0.757
Sweet pepper	4.1 (6.2)	4.5 (5.0)	3.8 (5.8)	0.4 (5.5)	0.200	−0.6 (6.0)	0.079	−0.2 (6.6)	0.591
Salted pickles[c]	5.8 (9.3)	4.3 (6.8)	5.7 (9.7)	−1.6 (9.1)	0.005	1.5 (10.0)	0.016	−0.1 (12.2)	0.885
Tomato/Vegetable juice	9.1 (21.3)	17.2 (58.6)	9.2 (24.6)	8.1 (60.6)	0.026	−8.0 (59.4)	0.025	0.1 (26.3)	0.951
Fruits									
Citrus fruits	9.1 (13.6)	11.9 (14.5)	13.1 (17.8)	2.8 (15.3)	0.002	1.2 (18.3)	0.271	4.0 (18.4)	<0.001
Banana	9.5 (12.3)	12.8 (14.4)	11.1 (13.0)	3.2 (13.3)	<0.001	−1.7 (15.1)	0.060	1.5 (14.8)	0.086
Apple	10.5 (23.3)	12.5 (24.2)	10.3 (20.5)	2.0 (23.6)	0.157	−2.2 (22.1)	0.093	−0.2 (23.2)	0.869
Strawberry	5.7 (15.0)	7.2 (13.7)	7.5 (15.7)	1.5 (15.0)	0.090	0.3 (19.3)	0.796	1.8 (20.7)	0.140
Other fruits	19.0 (16.9)	19.2 (17.2)	12.6 (10.5)	0.1 (16.5)	0.891	−6.6 (15.7)	<0.001	−6.4 (15.0)	<0.001

[a] Values are means (standard deviation, SD).
[b] Results with the combined data of the first (4 years from the end of the intervention, n = 142) and second intervention group (3 years from the end of the intervention, n = 136).
[c] Includes salted pickles made of dark-green leafy vegetables or carrots.

required for a sedentary lifestyle or greater than 150% of that required for a vigorous lifestyle. A total of 92% (142 of 155 subjects) of the first intervention group subjects and 89% (136 of 153) of the second were included in this analysis.

Subjects were divided into two groups by time of intervention, namely the first intervention group at 4 years from the end of the intervention and the second at 3 years. Mean daily intake of selected nutrients and foods pre- and post-intervention (1 year from pre-intervention) and at follow-up was calculated by group. As maintenance of the diet between the groups was similar, the results are given as a combination of data for the first and second intervention groups. For vegetable intake, the intakes of carotene- and vitamin C-rich vegetables (green and yellow vegetables) and of others (other vegetables) were calculated separately. The definitions used referred to the guidelines proposed by the Ministry of Health and Welfare, Japan, 1993, with "green and yellow vegetables" including dark-green leafy vegetables, carrots, squash, broccoli, tomatoes, sweet peppers and tomato/vegetable juice. Intake of major salted foods such as miso (fermented and salted soy-bean paste), salted fish, salted vegetables pickles and seasonings were also calculated, and the mean values at follow-up were compared with pre- and post-intervention values using the paired t test.

Results

Table 1 shows the demographic characteristics of the follow-up study and the main study subjects at baseline. There were no statistically significant differences in subject characteristics between the main study and follow-up study participants. In the follow-up study, the non-responders were younger and had higher BMI and higher male-to-female ratio than the participants, although these differences did not reach statistical significance.

Table 2 shows nutrient intake at each point and their net changes. Body weight did not remarkably change throughout the trial or follow-up period. Energy intake decreased significantly after intervention (−106 kcal/day, $P < 0.001$). The only difference between the post-intervention and follow-up points was a slight increase in sodium intake (+49 ± 698 mg/1000 kcal, $P = 0.243$). However, differences between the pre-intervention and follow-up points remained significant (−152 ± 753 mg/1000 kcal, $P < 0.001$). Carotene and vitamin C intake significantly increased after intervention and this change remained at the follow-up point. Differences between the pre-intervention and follow-up points were significant (+292 ± 1090 μg/1000 kcal, $P < 0.001$ for carotene and +11 ± 52 mg/1000 kcal, $P < 0.001$ for vitamin C). Dietary fiber intake increased significantly at the post-intervention point, and this was well-sustained at the follow-up point. Intake of the other nutrients did not change between the trial and follow-up points.

The intake of salted foods, fruits and vegetables at each point is shown in Table 3. Miso intake decreased significantly after intervention, and this change remained at follow-up point. Salted pickles intake decreased after intervention, but increased thereafter at the follow-up point (difference between the post-intervention and the follow-up points: +2.2 g/1000 kcal, $P = 0.098$), although not to the pre-intervention level (difference between the pre-intervention and the follow-up points: −2.5 g/1000 kcal, $P = 0.116$). Although vegetable and fruit intake significantly increased at the end of the intervention, fruit intake subsequently returned to the values at the pre-intervention point.

Table 4 presents the intake of individual fruit and green and yellow vegetable items. Dark-green leafy vegetables significantly increased between the post-intervention and the follow-up points (+6.1 g/1000 kcal, $P < 0.001$). Although the intake of squash, sweet pepper and tomato/vegetables juice was significantly increased just after the intervention, it decreased thereafter to close to the pre-intervention values.

Discussion

The Hiraka Dietary Intervention Study was successful in bringing about substantial changes in all targeted nutrients shortly after the intervention (Takahashi et al., 2003). Moreover, the present follow-up study results show that the effects of the intervention were maintained well for 4 years after the termination of intervention. Additional modifications were difficult to achieve, but those which were obtained were mostly maintained until follow-up. Although our intervention scheme was computerized to the greatest extent possible, the greater part of the program's success in maintaining long-term dietary modification may have actually owed to the dietitian's personal instructions, made in consideration of the individual characteristics of each subject.

A few previous studies with large sample sizes have attempted to achieve dietary modifications for long periods of time. These targeted dietary fat intake, and used intensive interventions (Gorder et al., 1997; Women's Health Initiative Study Group, 2004). The present study is unique, however, in that it investigated the long-term effect of a moderate intensity dietary intervention in healthy free-living subjects that targeted sodium, vitamin C and carotene.

Maintenance of low-sodium diet

In the intervention trial, subjects were primarily instructed to decrease their intake of miso, salted vegetable pickles, salted fish and seasonings, which were their main sources of dietary sodium. Consumption of all foods except seasonings decreased at the end of the intervention, of which only that for miso was maintained until follow-up. Because salted pickles vegetables and salted fish are 'traditional and familiar staple foods' in the study area, their avoidance may be difficult to maintain, notwithstanding that intake decreased temporarily just after intervention. They are highly salted foods, with salt contents of 5–15% by weight in salted fish, for example, and of 1–10% in salted pickled vegetables. From the viewpoint of stomach cancer prevention, because not only salt per se but also these highly salted foods are probable risk factors of stomach cancer (Tsugane et al., 2004), the achievement of any long-term modification may require the adoption of continuous reinforcement.

Maintenance of a high-carotene and vitamin C (fruit and vegetable) diet

Although the consumption of fruit and vegetables decreased at the follow-up point, that of dark-green leafy vegetables, broccoli, citrus fruits and strawberry actually increased at this time. These foods are relatively rich in carotene and vitamin C compared to other fruits and vegetables. As a consequence of these changes, carotene and vitamin C intake were sustained until follow-up.

The pattern of change differed between fruits and vegetables. Consumption of dark-green leafy vegetables further increased at follow-up, whereas that of squash, sweet pepper and tomato/vegetable juice returned to near pre-intervention values. Although it is unclear why, foods whose intake returned to the pre-intervention point seemed to be unpopular among the subjects. The average intake of these foods at the pre-intervention point was relatively lower than that of the other fruits and vegetables, i.e., 3.0, 4.1, 9.1 g/1000 kcal for squash, sweet pepper and tomato/vegetable juice, respectively. On the contrary, that of dark-green leafy vegetables at pre-intervention was relatively higher than that of the other vegetables, i.e., 21.1 g/1000 kcal. In Japan, many kinds of dark-green leafy vegetable prepared by various cooking methods are eaten throughout the year. The adoption of unpopular foods such as tomato/vegetable juice, sweet pepper and squash may require strong accustomization to the new taste and the knowledge of cooking method and recipes. The choice of culturally acceptable alternatives to unpopular foods in a target population therefore seems important to achieving the long-term maintenance of dietary modification. The example in this study was a large variety of green-leafy vegetables. Nevertheless, the reason for the marked increase in dark-green leafy vegetable consumption at follow-up study is unclear. Food choices are the result of complex interplays among sociodemographic, psychosocial, environmental, cultural, taste preference and economic factors (Nestle et al., 1998; Gedrich, 2003). Fruit and vegetable intake are related to taste preference, cost and availability (Brug et al., 1995; Treiman et al., 1996; Keim et al., 1997; Glanz and Yaroch, 2004; Glanz and Hoelscher, 2004). These factors may have influenced the long-term maintenance of dietary modification.

Study limitations

The primary limitation of this study is the use of self-reported dietary data, which may be biased as a result of greater social desirability and intervention-associated bias (Hebert et al., 1995; Kristal et al., 1998). In our main study, the effects of dietary intervention were assessed not only from responses to a self-administered questionnaire but also with the corresponding biomarkers, such as serum concentrations of ascorbic acid and carotenoids and urinary excretion of sodium. We did not use these biomarkers in the follow-up study, however, because blood sampling and urinary collection were found to be a serious burden on free-living healthy participants. Further, our main study results showed that serum concentrations of vitamin C and carotene were insufficiently sensitive for the detection of small dietary changes in a moderate intensity dietary intervention. We asked the subjects to answer the dietary assessment questionnaire as honestly as possible because the individualized results would be fedback into the system and used in subsequent dietary counseling. This was done partly to reduce the impact of social desirability on the answers. However, the real impact is unknown.

Other limitations to the interpretation of our results are related to the study design. The main study was conducted as a randomized cross-over trial. The short-term intervention effects were examined using data of the first half of the trial; in other words, the group receiving dietary intervention in the first year was used as the intervention group, while the other group was used as the control group. In the absence of a control group, the results of this follow-up study might have been affected by unknown factors, and should therefore be interpreted with caution.

Conclusion

The effects of this dietary intervention program on targeted nutrient intake were maintained well at 4 years after the termination of the intervention. The results are generally encouraging for the feasibility of future dietary intervention trials. However, it is unknown whether the same or similar results can be achieved in other populations with other targeted nutrients. Further studies are required.

Acknowledgments

This study was supported in part by Grants-in-aid for Cancer Research and for the Second- and Third-Term Comprehensive 10-year Strategy for Cancer Control from the Ministry of Health, Labor and Welfare of Japan. We thank all participants in this study. We also thank staff members at Yokote Health Center, Taiyu Village, Hiraka General Hospital.

References

Bowen, D.J., Beresford, S.A., 2002. Dietary interventions to prevent disease. Annu. Rev. Public Health 23, 255–286.

Brug, J., Lechner, L., De Vries, H., 1995. Psychological determinants of fruit and vegetable consumption. Apptite 25, 285–296.

Gedrich, K., 2003. Determinants of nutritional behavior: a multitude of levers for successful intervention? Appetite 41, 231–238.

Glanz, K., Hoelscher, D., 2004. Increasing fruit and vegetable intake by changing environments, policy and pricing: restaurant-based research, strategies, and recommendations. Prev. Med. 39, S88–S93 (Suppl).

Glanz, K., Yaroch, A.L., 2004. Strategies for increasing fruit and vegetable intake in grocery stores and communities: policy, pricing, and environmental change. Prev. Med. 39, S75–S80 (Suppl).

Gorder, D.D., Bartsch, G.E., Tillotson, J.L., Grandits, G.A., Stamler, J., 1997. Food group and macronutrient intakes, trial years 1–6, in the special intervention and usual care groups in the multiple risk factor intervention trial. Am. J. Clin. Nutr. 65, 258S–271S (Suppl).

Hebert, J.R., Clemow, L., Pbert, L., Okckene, I.S., Ockene, J.K., 1995. Social desirability bias in dietary self-report may compromise the validity of dietary intake measure. Int. J. Epidemiol. 24, 389–398.

Keim, K.S., Stewart, B., Voichick, J., 1997. Vegetable and fruit intake and perceptions of selected young adults. J. Nutr. Educ. 29, 80–85.

Kristal, A.R., Andrilla, H.A., Koepsell, T.D., Dihr, P.H., Cheadle, A., 1998. Dietary assessment instruments are susceptible to intervention-associated response set bias. J. Am. Diet Assoc. 98, 40–43.

Liu, L., Ikeda, K., Yamori, Y., 2001. Changes in stroke mortality rates for 1950 to 1997: a great slowdown of decline trend in Japan. Stroke 32, 1745–1749.

Nestle, M., Wing, R., Birch, L., et al., 1998. Behavioral and social influences on food choice. Nutr. Rev. 56, S50–S74.

Report of a joint FAO/WHO Experts Consultation, 2003. Diet. Nutrition and the Prevention of Chronic Diseases, vol. 797. World Health Organization, Geneva.

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-hour urinary excretion. Jpn. Circ. J. 62, 431–435.
Sasaki, S., Ushio, F., Amano, K., et al., 2000. Serum biomarker-based validation of a self-administered diet history questionnaire for Japanese subjects. J. Nutr. Sci. Vitaminol. 46, 285–296.
Takahashi, Y., Sasaki, S., Takahashi, M., Okubo, S., Hayashi, M., Tsugane, S., 2003. A population-based dietary intervention trial in a high-risk area for stomach cancer and stroke: changes in intakes and related biomarkers. Prev. Med. 37, 432–441.
The Research Group for Population-based Cancer Registration in Japan, 1998. Cancer incidence in Japan in 1991: estimates based on data from population-based cancer registries. Jpn. J. Clin. Oncol. 28, 574–577 (5-3).
Treiman, K., Freimuth, V., Damron, D., et al., 1996. Attitudes and behaviors related to fruits and vegetables among low-income women in the WIC program. J. Nutr. Educ. 28, 149–156.
Tsugane, S., Sasazuki, S., Kobayashi, M., Sasaki, S., 2004. Salt and salted food intake and subsequent risk of gastric cancer among middle-aged Japanese men and women. Br. J. Cancer 12, 128–134.
Women's Health Initiative Study Group, 2004. Dietary adherence in the women's health initiative dietary modification trial. J. Am. Diet. Assoc. 104, 654–658.

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

Hitomi Okubo, Satoshi Sasaki, Hyogo Horiguchi, Etsuko Oguma, Kayoko Miyamoto, Yoko Hosoi, Mi-kyung Kim, and Fujio Kayama

ABSTRACT

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

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

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

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

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

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

INTRODUCTION

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

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

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

[1] From the National Institute of Health and Nutrition, Tokyo, Japan (HO and SS); the Division of Environmental Immunology and Toxicology, Department of Health Science, Jichi Medical School, Tochigi, Japan (HH, KM, YH, and FK); the Core Research for Evolutional Science and Technology, Japan Science Technology Agency, Honmachi, Kawaguchi, Japan (HH, EO, and FK); and the Cancer Prevention & Early Detection Branch, Division of Cancer Control & Epidemiology, National Cancer Center Research Institute, Gyeonggi-do, Korea (M-KK).

[2] Supported by grants from the Ministry of Health, Labor and Welfare, the Ministry of Agriculture and Forestry, and Core Research for Evolutional Science and Technology, Japan Science Technology Agency.

[3] Address reprint requests to F Kayama, 3311-1 Yakushiji, Minamikawachi-machi, Tochigi 329-0498, Japan. E-mail: kayamaf@jichi.ac.jp.

Received August 22, 2005.
Accepted for publication January 30, 2006.

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

SUBJECTS AND METHODS

Study population

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

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

Dietary assessment and food grouping

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

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

Measurement of bone mineral density

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

Measurement of confounding factors

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

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

Statistical analysis

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

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

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

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

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

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

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

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

TABLE 2
Characteristics of study subjects[1]

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

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

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

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

RESULTS

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

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

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

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

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

The American Journal of Clinical Nutrition

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

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

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

DISCUSSION

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

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

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

TABLE 4

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

	Healthy		Japanese traditional		Western		Beverage and meats	
	Q1	Q5	Q1	Q5	Q1	Q5	Q1	Q5
Age (y)	45.3 ± 3.7[2]	47.3 ± 3.7[3]	45.8 ± 4.2	46.2 ± 3.6	47.2 ± 4.0	45.6 ± 3.3[4]	47.2 ± 3.8	45.8 ± 3.7
Grasping power (kg)	29.5 ± 4.0	27.5 ± 4.0[4]	30.0 ± 5.0	28.8 ± 5.0	28.5 ± 4.4	28.9 ± 4.1	29.4 ± 5.0	28.8 ± 4.5
Forearm bone mineral density (g/cm²)	0.482 ± 0.054	0.495 ± 0.052	0.496 ± 0.058	0.495 ± 0.048	0.499 ± 0.055	0.482 ± 0.059	0.479 ± 0.061	0.496 ± 0.051
Forearm bone mineral mass (g)	3.19 ± 0.51	3.28 ± 0.44	3.29 ± 0.48	3.18 ± 0.50	3.34 ± 0.48	3.17 ± 0.46	3.13 ± 0.48	3.29 ± 0.45
Age at menarche (y)	12.9 ± 1.3	13.1 ± 1.2	13.0 ± 1.2	13.2 ± 1.3	12.8 ± 1.1	13.0 ± 1.2	13.2 ± 1.3	12.9 ± 1.2
Parity (*n*)	2.5 ± 1.0	2.4 ± 0.8	2.4 ± 0.7	2.7 ± 0.9	2.4 ± 0.9	2.5 ± 0.8	2.5 ± 1.1	2.5 ± 0.9
BMI (kg/m²)	24.6 ± 3.6	24.0 ± 3.3	24.3 ± 3.4	23.7 ± 3.1	23.8 ± 4.1	24.0 ± 3.5	23.9 ± 3.6	24.5 ± 3.0
< 18.5 [*n* (%)]	2 (3.5)	2 (3.5)	1 (1.7)	2 (3.5)	1 (1.7)	2 (3.5)	3 (5.2)	0 (0)
18.5–24.9 [*n* (%)]	33 (56.9)	34 (58.6)	37 (63.8)	39 (67.2)	37 (63.8)	36 (62.1)	36 (62.1)	33 (56.9)
≥ 25.0 [*n* (%)]	23 (39.7)	22 (37.9)	20 (34.5)	17 (29.3)	20 (34.5)	20 (34.5)	19 (32.8)	25 (43.1)
Smoking status [*n* (%)]								
Current	1 (1.7)	3 (5.2)	2 (3.5)	2 (3.5)	3 (5.2)	2 (3.5)	1 (1.7)	4 (6.9)
Former	2 (3.5)	0 (0)	1 (1.7)	0 (0)	1 (1.7)	1 (1.7)	1 (1.7)	2 (3.5)
Never	55 (94.8)	55 (94.8)	55 (94.8)	56 (96.7)	54 (93.1)	55 (94.8)	56 (96.6)	52 (89.7)
Calcium supplement use [*n* (%)]	2 (3.5)	4 (6.9)	2 (3.5)	4 (6.9)	1 (1.7)	6 (10.3)[5]	3 (5.2)	3 (5.2)
Multivitamin supplement use [*n* (%)]	3 (5.2)	4 (6.9)	5 (8.6)	2 (3.5)[5]	3 (5.2)	4 (6.9)	2 (3.5)	2 (3.5)
History of fracture [*n* (%)]	8 (13.8)	3 (5.3)	8 (14.0)	4 (6.9)	3 (5.2)	7 (12.3)	7 (12.1)	4 (6.9)
Hormone replacement therapy [*n* (%)]	0 (0)	1 (1.7)	0 (0)	0 (0)	1 (1.7)	0 (0)	1 (1.7)	0 (0)

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

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

The current study has several limitations. First, the DHQ assessed dietary habits only in the previous month, which was too short a time for the examination of a nutrient–bone mass association. Therefore, as in our previous report, we included only those subjects who had maintained stable dietary habits for ≥3 y (6). Second, the classification of menopausal status was self-reported according to 3 categories (regular, irregular, or no menstrual cycle). We did not ask the irregularly menstruating or nonmenstruating women about the length of time since their last menses. Therefore, given its clear effect on bone metabolism, we also considered age in the definition of menstrual status. Moreover, because the BMD of the perimenopausal women showed no decrease and did not differ significantly from that of the premenopausal women (0.492 and 0.486 g/cm², respectively; $P = 0.14$), we evaluated women with regular and irregular cycles together as premenopausal women. Third, 4 of the 5 selected districts were cadmium-polluted areas, in which low-to-moderate cadmium contamination of rice has been detected.

TABLE 5

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

	Factor 1: Healthy	Factor 2: Japanese traditional	Factor 3: Western	Factor 4: Beverage and meats
Forearm bone mineral density (g/cm²)	0.05	0.01	−0.08	0.08
Nutrient intakes				
Carbohydrate (% of energy)	−0.39	0.20	−0.55	0.06
Protein (% of energy)	0.65	−0.01	0.18	−0.10
Fat (% of energy)	0.25	−0.22	0.54	−0.03
Potassium (mg/d)	0.82	0.14	0.05	0.19
Magnesium (mg/d)	0.69	0.22	0.00	0.02
Calcium (mg/d)	0.51	0.07	−0.07	0.12
Phosphorus (mg/d)	0.70	0.09	0.10	0.06
Vitamin C (mg/d)	0.51	0.11	−0.07	−0.03
Vitamin D (μg/d)	0.53	−0.01	−0.02	−0.26
Vitamin K (μg/d)	0.48	0.31	−0.03	−0.04
Isoflavone (mg/d)	0.28	0.49	−0.08	−0.21
Alcohol (g/d)	0.22	−0.15	0.19	−0.01

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

TABLE 6

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

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

[1] Model 1: multivariate models were adjusted for age, BMI (kg/m^2), grasping power, and current smoking. Model 2: further adjusted for fracture history, the use of hormone replacement therapy, age at menarche, and parity. Model 3: further adjusted for the use of calcium and multivitamin supplements.

[2] $\bar{x}$ ± SE (all such values).

[3,4] Significantly different from Q1: [3] $P < 0.01$, [4] $P < 0.05$.

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

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

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

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

REFERENCES

1. Ministry of Health, Labor and Welfare. Comprehensive survey of living conditions of the people on Health and Welfare. Section 3 2001. Internet: http://www.mhlw.go.jp/toukei/saikin/hw/k-tyosa/k-tyosa01/3-2.html (accessed 1 December 2004).
2. New SA, Bolton-Smith C, Grubb DA, Reid DM. Nutritional influences on bone mineral density: a cross-sectional study in premenopausal women. Am J Clin Nutr 1997;65:1831–9.
3. Tucker KL, Hannan MT, Chen H, Cupples LA, Wilson PW, Kiel DP.

Potassium, magnesium, and fruit and vegetable intakes are associated with greater bone mineral density in elderly men and women. Am J Clin Nutr 1999;69:727–36.

4. New SA, Robins SP, Campbell MK, et al. Dietary influences on bone mass and bone metabolism: further evidence of a positive link between fruit and vegetable consumption and bone health? Am J Clin Nutr 2000; 71:142–51.
5. Booth SL, Tucker KL, Chen H, et al. Dietary vitamin K intakes are associated with hip fracture but not with bone mineral density in elderly men and women. Am J Clin Nutr 2003;77:512–6.
6. Sasaki S, Yanagibori R. Association between current nutrient intakes and bone mineral density at calcaneus in pre- and postmenopausal Japanese women. J Nutr Sci Vitaminol (Tokyo) 2001;47:289–94.
7. Macdonald HM, New SA, Golden MH, Campbell MK, Reid DM. Nutritional associations with bone loss during the menopausal transition: evidence of a beneficial effect of calcium, alcohol, and fruit and vegetable nutrients and of a detrimental effect of fatty acids. Am J Clin Nutr 2004;79:155–65.
8. Freudenheim JL, Johnson NE, Smith EL. Relationships between usual nutrient intake and bone-mineral content of women 35–65 years of age: longitudinal and cross-sectional analysis. Am J Clin Nutr 1986;44:863–76.
9. Devine A, Criddle RA, Dick IM, Kerr DA, Prince RL. A longitudinal study of the effect of sodium and calcium intakes on regional bone density in postmenopausal women. Am J Clin Nutr 1995;62:740–5.
10. Greendale GA, FitzGerald G, Huang MH, et al. Dietary soy isoflavones and bone mineral density: results from the study of women's health across the nation. Am J Epidemiol 2002;155:746–54.
11. Nagata C, Shimizu H, Takami R, Hayashi M, Takeda N, Yasuda K. Soy product intake and serum isoflavonoid and estradiol concentrations in relation to bone mineral density in postmenopausal Japanese women. Osteoporos Int 2002;13:200–4.
12. Prentice A. Diet, nutrition and the prevention of osteoporosis. Public Health Nutr 2004;7:227–43.
13. Slattery ML, Boucher KM, Caan BJ, Potter JD, Ma KN. Eating patterns and risk of colon cancer. Am J Epidemiol 1998;148:4–16.
14. Newby PK, Tucker KL. Empirically derived eating patterns using factor or cluster analysis: a review. Nutr Rev 2004;62:177–203.
15. Tucker KL, Chen H, Hannan MT, et al. Bone mineral density and dietary patterns in older adults: the Framingham Osteoporosis Study. Am J Clin Nutr 2002;76:245–52.
16. Uchida K, Tomonou M, Hayashi M, Shirota T. Relationships of the nutritional intake and other factors with the bone mineral density among elderly residents of Hisayama. Jpn J Nutr Diet 2003;61:307–15 (in Japanese).
17. Horiguchi H, Oguma E, Sasaki S, et al. Dietary exposure to cadmium at close to the current provisional tolerable weekly intake does not affect renal function among female Japanese farmers. Environ Res 2004;95: 20–31.
18. Horiguchi H, Oguma E, Sasaki S, et al. Environmental exposure to cadmium at a level insufficient to induce renal tubular dysfunction does not affect bone density among female Japanese farmers. Environ Res 2005;97:83–92.
19. 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.
20. Sasaki S, Ushio F, Amano K, et al. Serum biomarker-based validation of a self-administered diet history questionnaire for Japanese subjects. J Nutr Sci Vitaminol (Tokyo) 2000;46:285–96.
21. Science and Technology Agency. Standard tables of food composition in Japan. 5th ed. Tokyo, Japan: Printing Bureau, Ministry of Finance, 2000 (in Japanese).
22. Ministry of Health and Welfare. Kokumin Eiyou no Genjou (Annual Report of the National Nutrition Survey in 2000). Tokyo, Japan: Ministry of Health and Welfare, 2002 (in Japanese).
23. Ministry of Health and Welfare. Recommended dietary allowance for Japanese: dietary reference intakes. 6th ed. Tokyo, Japan: Ministry of Health and Welfare, 1999 (in Japanese).
24. FAO/WHO/UNU. Energy and protein requirements. Report of a Joint FAO/WHO/UNU Expert Consultation. World Health Organ Tech Rep Ser 1985;724:1–206.
25. SAS Institute Inc. SAS/STAT user's guide, version 6.0, Vol 2. Cary, NC: SAS Institute Inc. 1989.
26. Willett WC. Implications of total energy intake for epidemiologic analysis. In: Willett WC, ed. Nutritional epidemiology. 2nd ed. New York: Oxford University Press, 1998:273–301.
27. Kim J-O, Mueller CW. Factor analysis: statistical methods and practical issues. Thousand Oaks, CA: Sage Publications, Inc. 1978.
28. Sellmeyer DE, Stone KL, Sebastian A, Cummings SR. A high ratio of dietary animal to vegetable protein increases the rate of bone loss and the risk of fracture in postmenopausal women. Study of Osteoporotic Fractures Research Group. Am J Clin Nutr 2001;73:118–22.
29. Krieger NS, Sessler NE, Bushinsky DA. Acidosis inhibits osteoblastic and stimulates osteoclastic activity in vitro. Am J Physiol 1992;262: F442–8.
30. Frassetto LA, Todd KM, Morris RC Jr, Sebastian A. Estimation of net endogenous noncarbonic acid production in humans from diet potassium and protein contents. Am J Clin Nutr 1998;68:576–83.
31. New SA, MacDonald HM, Campbell MK, et al. Lower estimates of net endogenous non-carbonic acid production are positively associated with indexes of bone health in premenopausal and perimenopausal women. Am J Clin Nutr 2004;79:131–8.
32. Martinez ME, Marshall JR, Sechrest L. Invited commentary: factor analysis and the search for objectivity. Am J Epidemiol 1998;148:17–21.
33. Newby PK, Muller D, Hallfrisch J, Andres R, Tucker KL. Food patterns measured by factor analysis and anthropometric changes in adults. Am J Clin Nutr 2004;80:504–13.
34. Kim MK, Sasaki S, Sasazuki S, Tsugane S. Japan Public Health Center-based Prospective Study Group. Prospective study of three major dietary patterns and risk of gastric cancer in Japan. Int J Cancer 2004;110:435–42.
35. Hu FB, Rimm E, Smith-Warner SA, et al. Reproducibility and validity of dietary patterns assessed with a food-frequency questionnaire. Am J Clin Nutr 1999;69:243–9.
36. Terry P, Hu FB, Hansen H, Wolk A. Prospective study of major dietary patterns and colorectal cancer risk in women. Am J Epidemiol 2001; 154:1143–9.
37. Masaki M, Sugimori H, Nakamura K, Tadera M. Dietary patterns and stomach cancer among middle-aged male workers in Tokyo. Asian Pac J Cancer Prev 2003;4:61–6.

The American Journal of Clinical Nutrition

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

Kentaro Murakami, Satoshi Sasaki, Yoshiko Takahashi, Hitomi Okubo, Yoko Hosoi, Hyogo Horiguchi, Etsuko Oguma, and Fujio Kayama

ABSTRACT

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

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

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

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

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

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

INTRODUCTION

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

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

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

[1] From the National Institute of Health and Nutrition, Tokyo, Japan (KM, SS, YT, and YH); the Department of Nutrition Sciences, Kagawa Nutrition University, Saitama, Japan (HO); the Division of Environmental Medicine, Center for Community Medicine, Jichi Medical University, Tochigi, Japan (HH, EO, and FK); and Core Research for Evolutional Science and Technology, Japan Science and Technology Cooperation, Kawaguchi City, Japan (EO and FK).

[2] Supported mainly by grants from the Japanese Ministry of Health, Labor and Welfare, the Ministry of Agriculture and Forestry, and Core Research for Evolutional Science and Technology, Japan Science and Technology Cooperation.

[3] Address reprint requests to F Kayama, Division of Environmental Medicine, Center for Community Medicine, Jichi Medical University, 3311-1 Yakushiji, Minami-Kawachi, Kawachi-gun, Tochigi 329-0498, Japan. E-mail: kayamaf@jichi.ac.jp.

Received November 28, 2005.
Accepted for publication January 17, 2006.