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The influence of age and body mass index on relative accuracy of energy intake among Japanese adults

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Abstract

Objective: To examine relationships between the ratio of energy intake to basal metabolic rate (EI/BMR) and age and body mass index (BMI) among Japanese adults.
Design: Energy intake was assessed by 4-day semi-weighed diet records in each of four seasons (16 days in total). The EI/BMR ratio was calculated from reported energy intake and estimated basal metabolic rate as an indicator of reporting accuracy.
Setting: Residents in three areas in Japan, namely Osaka (urban), Nagano (rural inland) and Tottori (rural coastal).
Subjects: One hundred and eighty-three healthy Japanese men and women aged ≥30 years.
Results: The oldest age group (≥60 years) had higher EI/BMR values than the youngest age group (30–39 years) in both sexes (1.74 vs. 1.37 for men; 1.65 vs. 1.43 for women). In multiple regression analyses, age correlated positively (partial correlation coefficient, $\beta = 0.012$, $P < 0.001$ for men; $\beta = 0.011$, $P < 0.001$ for women) and BMI correlated negatively ($\beta = -0.031$, $P < 0.001$ for men; $\beta = -0.025$, $P < 0.01$ for women) with EI/BMR.
Conclusion: Age and BMI may influence the relative accuracy of energy intake among Japanese adults.

Keywords
Energy intake
Underreporting
Age
Body mass index
Japanese adults

Reliable dietary information plays a critical role in many aspects of human nutrition. Investigators have often relied on self-reported dietary data assessed by diet records, 24-hour dietary recalls and food-frequency questionnaires to interpret the associations between diet and disease. However, the results of various studies applying different assessment methods and investigating different populations have shown common problems such as reporting bias[1,2]. In particular, underreporting of energy intake is a serious threat to the validity of self-reported dietary assessment data. Studies using the doubly labelled water technique as an external biomarker of energy intake not only reveal underreporting of energy intake, but also identify the subject characteristics and factors associated with underreporting[3,4]. Moreover, other studies using the ratio of energy intake to basal metabolic rate (EI/BMR) as an alternative approach to identify the low energy reporters have shown similar results[5,6].

Most studies found a higher proportion of underreporting among women and older subjects[7,8]. Moreover, underreporting of energy intake was common among obese subjects[9–11], but was also observed in non-obese subjects[12,13]. Other factors such as body image, health consciousness, social desirability, educational level and smoking status also affected reporting accuracy[2,14,15]. However, all of these studies were conducted in Western countries. The only study conducted in Japan showed a significantly negative correlation between BMI and EI/BMR among women aged 18–20 years[16]. Thus the purpose of the present study was to examine the relative accuracy of self-reported energy intake among various age ranges in the Japanese population.

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Subjects and methods

Subjects

We selected three areas which have different geographical conditions in Japan: Osaka (urban), Nagano (rural inland) and Tottori (rural coastal). We invited 32 healthy married women aged 30–69 years from each of the three areas to distribute eight women equally in each age class of 30–39, 40–49, 50–59 and 60–69 years. The total number of women recruited was 96. Their husbands (aged 31–76 years) were also invited to participate in the study. None of the subjects was currently receiving or had recently received diet counselling from a doctor or dietitian, nor had a history of educational hospitalisation for diabetes. The subjects were not randomly sampled but asked by local study staff to participate in the study. Here, subject recruitment was continued until a sufficient number of subjects was obtained. Prior to the study, we held group orientations for the subjects where we explained the study purposes and protocol. All subjects giving written informed consent were finally considered eligible for the study.

Dietary assessment

The subjects completed 4-day semi-weighed diet records four times at 3-month intervals from November 2002 to August 2003. Dietary intake was assessed from four randomly assigned days, including one weekend day and three weekdays. A digital scale (Tanita KD-173; ± 2 g precision for 0–250 g and ± 4 g precision for 250–1000 g) was given to each couple to weigh all the foods eaten. When measurement was difficult, e.g. when eating out, we instructed them to record in as much detail as possible the size and quantity of foods they ate. For each recording day, the subjects were asked to fax the completed forms to the local staff (dietitians). The study staff checked the submitted forms and asked the subjects to add and/or modify the records as necessary by telephone or fax. In some cases, the responses were handed directly to the study staff rather than faxed.

All the collected diet records were checked by trained dietitians in each local centre and then in the study centre. The diet records were analysed for nutrient intake by trained dietitians using the food composition table of Japanese foods, 5th edition[17].

Physical activity level and anthropometric measurements

Physical activity level was obtained from a questionnaire which queried information about each subject's occupation and leisure-time activity. One answer was chosen from four categories, i.e. 'low', 'relatively low', 'moderate' and 'heavy' physical activity level. This classification was referenced to the recommended dietary allowance for Japanese, 6th edition[18]. The gross energy expenditure of each category was considered to require 1.3, 1.5, 1.7 and 1.9 times the BMR, respectively[18]. Therefore, we converted the categorical classification of physical activity level to the ratio of BMR based on above values, and expressed as it as a score for easy interpretation.

Body weight and height were measured to the nearest 0.1 kg and 0.1 cm, respectively, with subjects wearing light clothing and no shoes. BMI was calculated as body weight (kg) divided by the square of body height (m^2). We classified BMI into four categories: $<18.5\,kg\,m^{-2}$, 18.5–24.9 $kg\,m^{-2}$, 25.0–27.9 $kg\,m^{-2}$ and $\geq 28\,kg\,m^{-2}$. Because the proportion of obese subjects (BMI $\geq 30\,kg\,m^{-2}$) was very low ($n = 1$ for men aged 40–49 years; $n = 0$ for women), BMI $\geq 28\,kg\,m^{-2}$ was used as the highest category instead of $\geq 30\,kg\,m^{-2}$ in the present analysis.

BMR was estimated for each subject using formulas based on body weight given by the Food and Agriculture Organization/World Health Organization/United Nations University (FAO/WHO/UNU)[19] as follows.

- Men aged 30–60 years:
  BMR = 0.0485 × bodyweight (kg) + 3.67.
- Men aged >60 years:
  BMR = 0.0565 × bodyweight (kg) + 2.04.
- Women aged 30–60 years:
  BMR = 0.0364 × bodyweight (kg) + 3.47.
- Women aged >60 years:
  BMR = 0.0439 × bodyweight (kg) + 2.49.

Statistical analysis

We included 183 subjects (91 women and 92 men) with complete 16-day diet records living in the Osaka (29 women and 30 men), Nagano (31 women and 31 men) and Tottori (31 women and 31 men) areas in the present analysis.

We calculated the ratio EI/BMR to evaluate the relative accuracy of the reported energy intake. Subjects were allocated into quintiles of EI/BMR to compare 'low energy reporters' with 'high energy reporters'. Low ratios describe subjects reporting comparatively low energy intake relative to their energy requirement. To compare the relative degree of under- and overreporting, we temporarily used the values defined by FAO/WHO/UNU: the minimum survival level of 1.27, the sedentary level for men of 1.55 and women of 1.56, and the maximum sustainable lifestyle level of 2.0–2.4.

Results are given as mean ± standard deviation. Student's *t*-test and one-way analysis of variance (ANOVA) were used to test for differences between the groups. When ANOVA indicated a difference among the groups, Dunnett's *t*-test was applied to compare to the first group as a control. The chi-square test was used to test for proportionate differences between categories. Multivariate evaluation of the simultaneous effects of age, BMI, physical activity level and living area on EI/BMR was performed by a stepwise multiple regression analysis.

We also computed the partial correlation coefficients between each independent variable and EI/BMR adjusting for other independent variables.

All statistical analyses were performed using version 8.2 of the SAS software package (SAS Institute, Inc., Cary, NC, USA). A P-value of <0.05 was considered significant.

Results

Table 1 presents a summary of the physical characteristics of the subjects. Mean age was 52.8 ± 12.1 (range 31–76) years in men and 49.5 ± 11.4 (range 31–69) years in women. Mean values of EI/BMR were not different between sexes (1.55 for men vs. 1.48 for women, $P = 0.12$). Men had a higher BMI (23.3 vs. 22.1 kg m^{-2}, $P < 0.01$) and a higher proportion of overweight (21% vs. 11% for BMI of 25.0–27.9 kg m^{-2} and 10% vs. 2% for BMI ≥28 kg m^{-2}, $P = 0.03$) than women. Men had a higher physical activity level than women (1.48 vs. 1.43, $P = 0.02$), and 38% and 59% of women were classified into low and relatively low physical activity levels, respectively.

Table 2 presents a summary of the physical characteristics of men and women in the four age groups (30–39, 40–49, 50–59 and ≥60 years). Body height decreased with increasing age in both sexes. Body weight and BMR increased as age increased to 40–49 years, and then decreased with increasing age group in both sexes. Although BMI was lowest among the youngest age group in both sexes, a statistically significant difference between age groups was observed only for women ($P < 0.01$). Energy intake was not different between age groups in either sex. On the other hand, mean EI/BMR became significantly higher with increase in age for men

Table 1 Characteristics of study subjects* ($n = 183$)

	Men ($n = 92$)	Women ($n = 91$)	P-value†
Age (years)	52.8 ± 12.1	49.5 ± 11.4	0.06
Body height (cm)	168.0 ± 6.7	155.6 ± 5.9	<0.001
Body weight (kg)	66.2 ± 11.2	53.4 ± 7.2	<0.001
Reported EI (MJ day^{-1})	9.9 ± 1.8	7.8 ± 1.2	<0.001
BMR (MJ day^{-1})‡	6.5 ± 0.9	5.3 ± 0.4	<0.001
EI/BMR	1.55 ± 0.31	1.48 ± 0.24	0.12
BMI (kg m^{-2})	23.3 ± 3.1	22.1 ± 2.6	<0.01
<18.5	4 (4)	6 (7)	0.03§
18.5–24.9	60 (65)	73 (80)	
25.0–27.9	19 (21)	10 (11)	
≥28.0	9 (10)	2 (2)	
Physical activity level	1.48 ± 0.19	1.43 ± 0.11	0.02
Low	37 (40)	35 (38)	<0.001§
Relatively low	36 (39)	54 (59)	
Moderate	11 (12)	2 (2)	
Heavy	8 (9)	0 (0)	

EI – energy intake; BMR – basal metabolic rate; BMI – body mass index.
*Values are expressed as mean ± standard deviation or n (%).
† Significant difference between sexes (t-test).
‡ BMR was calculated using formulas given by the Food and Agriculture Organization/World Health Organization/United Nations University (1985)[19].
§ Significant difference between sexes in all categories (chi-square test).

Table 2 Characteristics of study subjects according to age group in 92 men and 91 women†

	Men					Women				
	30–39 years‡ ($n = 16$)	40–49 years ($n = 24$)	50–59 years ($n = 20$)	≥60 years ($n = 32$)	P-value§	30–39 years‡ ($n = 23$)	40–49 years ($n = 22$)	50–59 years ($n = 23$)	≥60 years ($n = 23$)	P-value§
Age (years)	36.1 ± 2.2	44.0 ± 3.2	54.8 ± 2.3	66.4 ± 4.6	<0.001	35.7 ± 2.7	43.1 ± 3.2	54.1 ± 2.6	64.7 ± 3.0	<0.001
Body height (cm)	171.8 ± 5.7	171.0 ± 5.8	168.5 ± 7.0	163.7 ± 5.1***	<0.001	158.6 ± 5.7	156.1 ± 5.9	155.6 ± 6.0	152.0 ± 4.0***	<0.01
Body weight (kg)	64.7 ± 11.3	70.1 ± 12.7	69.3 ± 10.7	62.0 ± 9.0	0.02	51.2 ± 6.1	55.3 ± 7.0	55.0 ± 7.8	52.3 ± 7.2	0.14
Reported EI (MJ day^{-1})	9.3 ± 1.2	10.2 ± 2.5	10.5 ± 1.7	9.6 ± 1.3	0.15	7.7 ± 1.3	7.6 ± 1.3	7.9 ± 0.8	7.9 ± 1.2	0.76
BMR (MJ day^{-1})¶	6.8 ± 0.6	7.1 ± 0.6	7.0 ± 0.5	5.5 ± 0.5***	<0.001	5.3 ± 0.2	5.5 ± 0.3	5.5 ± 0.3	4.8 ± 0.3***	<0.001
EI/BMR	1.37 ± 0.21	1.44 ± 0.33	1.50 ± 0.28	1.74 ± 0.25***	<0.001	1.43 ± 0.23	1.39 ± 0.22	1.45 ± 0.14	1.65 ± 0.26***	<0.001
Physical activity level	1.50 ± 0.21	1.51 ± 0.23	1.48 ± 0.17	1.44 ± 0.15	0.59	1.44 ± 0.11	1.44 ± 0.10	1.42 ± 0.10	1.41 ± 0.12	0.82
BMI (kg m^{-2})	21.8 ± 3.0	23.9 ± 3.5	24.3 ± 2.8*	23.1 ± 2.7	0.07	20.3 ± 2.0	22.7 ± 2.9**	22.7 ± 2.2**	22.6 ± 2.7**	<0.01
<18.5	1 (6)	1 (4)	1 (5)	1 (3)	0.27‖	5 (22)	1 (5)	0 (0)	0 (0)	0.03‖
18.5–24.9	13 (81)	14 (58)	9 (45)	24 (75)		18 (78)	16 (73)	20 (87)	19 (83)	
25.0–27.9	1 (6)	5 (21)	8 (40)	5 (16)		0 (0)	4 (18)	3 (13)	3 (13)	
≥28.0	1 (6)	4 (17)	2 (10)	2 (6)		0 (0)	1 (5)	0 (0)	1 (4)	

EI – energy intake; BMR – basal metabolic rate; BMI – body mass index.
† Values are expressed as mean ± standard deviation or n (%).
‡ Significant difference compared with 30–39 year category between age groups within sex (Dunnett's t-test): *, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$.
§ Significant difference between age groups within sexes (analysis of variance).
¶ BMR was calculated using formulas given by the Food and Agriculture Organization/World Health Organization/United Nations University (1985)[19].
‖ Significant difference between age groups within sexes in all categories (chi-square test).

Table 3 Anthropometric characteristics and lifestyle variables by quartile of EI/BMR ratio†

	Men					Women				
	First quartile ($n=23$)‡	Second quartile ($n=18$)	Third quartile ($n=22$)	Fourth quartile ($n=29$)	*P*-value§	First quartile ($n=22$)‡	Second quartile ($n=28$)	Third quartile ($n=24$)	Fourth quartile ($n=17$)	*P*-value§
EI/BMR	1.17 ± 0.12	1.41 ± 0.05	1.57 ± 0.05	1.90 ± 0.17		1.19 ± 0.09	1.42 ± 0.05	1.58 ± 0.05	1.83 ± 0.14	
Age (years)	44.8 ± 8.8	51.8 ± 10.3	54.6 ± 15.0*	58.3 ± 9.8***	<0.001	44.5 ± 9.8	47.2 ± 9.9	53.1 ± 118*	54.5 ± 12.5*	0.01
Body height (cm)	171.2 ± 4.8	168.8 ± 5.7	168.4 ± 6.7	164.7 ± 7.3**	<0.01	154.0 ± 5.4	156.9 ± 5.7	155.1 ± 5.8	156.0 ± 6.7	0.36
Body weight (kg)	72.0 ± 10.4	68.1 ± 7.4	64.5 ± 12.5	61.6 ± 11.0**	<0.01	53.7 ± 7.4	54.6 ± 6.5	54.1 ± 8.4	50.4 ± 5.5	0.27
EI ($MJ\,day^{-1}$)	8.3 ± 1.0	9.5 ± 0.6*	9.9 ± 1.6***	11.4 ± 1.7***	<0.001	6.4 ± 0.7	7.6 ± 0.6***	8.3 ± 0.7***	9.1 ± 0.8***	<0.001
BMR ($MJ\,day^{-1}$)¶	7.1 ± 0.6	6.7 ± 0.6	6.3 ± 0.9**	6.0 ± 0.9***	<0.001	5.4 ± 0.3	5.4 ± 0.3	5.3 ± 0.4	5.0 ± 0.4**	<0.01
Physical activity level	1.47 ± 0.19	1.41 ± 0.12	1.47 ± 0.18	1.53 ± 0.21	0.16	1.41 ± 0.10	1.43 ± 0.11	1.45 ± 0.09	1.42 ± 0.12	0.60
BMI ($kg\,m^{-2}$)	24.5 ± 3.0	24.0 ± 2.8	22.6 ± 3.2	22.6 ± 3.0	0.06	22.6 ± 2.9	22.2 ± 2.4	22.5 ± 3.0	20.7 ± 1.7	0.11
< 18.5	0 (0)	0 (0)	1 (5)	3 (10)	0.34§	1 (5)	2 (7)	2 (8)	1 (6)	0.82§
18.5–24.9	13 (57)	11 (61)	14 (63)	22 (76)		17 (77)	22 (79)	18 (75)	16 (94)	
25.0–27.9	7 (30)	5 (28)	5 (23)	2 (7)		3 (14)	4 (14)	3 (13)	0 (0)	
≥ 28.0	3 (13)	2 (11)	2 (9)	2 (7)		1 (5)	0 (0)	1 (4)	0 (0)	

EI – energy intake; BMR – basal metabolic rate; BMI – body mass index.
† Values are expressed as mean ± standard deviation or *n* (%).
‡ Significant difference compared with the first quartile of EI/BMR (Dunnett's *t*-test): *, $P<0.05$, **, $P<0.01$; ***, $P<0.001$.
§ Significant difference between quartile within sexes (analysis of variance).
¶ BMR was calculated using formulas given by the Food and Agriculture Organization/World Health Organization/United Nations University (1985)[19].

($P<0.001$). Although women aged 40–49 years had the lowest EI/BMR among the women, the trend of the relationship between mean EI/BMR and age was almost the same as that of men ($P<0.001$).

Table 3 presents the mean values of anthropometric characteristics by quartile of EI/BMR. Age and reported energy intake increased significantly with the increase in EI/BMR in both sexes (all $P<0.001$ except for age in women, where $P<0.01$). However, with increasing EI/BMR quartile, body height and body weight decreased significantly in men (both $P<0.01$), as did BMR in both sexes ($P<0.001$ for men, $P<0.01$ for women). BMI was slightly lower in the lowest category of EI/BMR than in the other categories in men, although it was not significant.

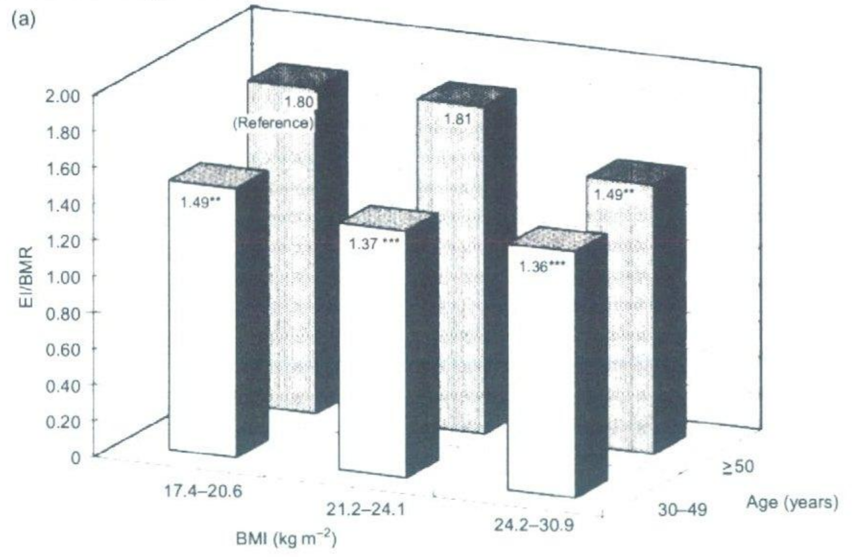
Table 4 shows the results of multiple regression analyses with EI/BMR as the dependent variable to examine the prediction for relative accuracy of reporting. For men, age and physical activity level correlated positively (partial regression coefficient, $\beta=0.012$, $P<0.001$ and $\beta=0.377$, $P=0.01$, respectively), and BMI and living area (urban) correlated negatively ($\beta=-0.031$, $P<0.001$ and $\beta=-0.114$, $P=0.045$, respectively), with EI/BMR. On the other hand, age and body height correlated positively ($\beta=0.011$, $P<0.001$ and $\beta=0.011$, $P=0.01$, respectively) and BMI correlated negatively ($\beta=-0.025$, $P<0.01$) with EI/BMR for women. All the independent variables explained 35.7% and 25.7% of the variation in EI/BMR for men and women, respectively.

Figures 1a and 1b show the joint effect of age and BMI on EI/BMR values by cross-classifying subjects by both variables. Compared with subjects classified into the lowest BMI and oldest age group, subjects in the highest

Table 4 Results of stepwise multiple regression analyses with EI/BMR ratio as dependent variable*

Independent variable	β†	SE‡	*P*-value	Partial R^2 (%)§
Men ($n=92$)				
Age (years)	0.012	0.002	<0.001	17.9
BMI ($kg\,m^{-2}$)	−0.031	0.009	<0.001	9.9
Physical activity level	0.377	0.145	0.01	4.8
Living area (rural coastal area as reference)				
Urban	−0.114	0.056	0.05	3.1
Women ($n=91$)				
Age (years)	0.011	0.002	<0.001	12.1
BMI ($kg\,m^{-2}$)	−0.025	0.009	0.005	7.0
Body height (cm)	0.011	0.004	0.01	6.6

EI – energy intake; BMR – basal metabolic rate; BMI – body mass index.
*Age (as a continuous variable), BMI (as a continuous variable), height (as a continuous variable), physical activity level (as a continuous variable) and area of living (rural coastal, rural inland, urban) were entered into the model as independent variables.
† Partial regression coefficient; change in the dependent variable related to a one-unit change in the independent variable.
‡ Standard error of the regression coefficient.
§ Explained variance; adjusted R^2 and *P*-values are for independent variables in multiple regression analysis. R^2 value for EI/BMR was 35.7% and 25.7% for men and women, respectively, when all variables were included in the model.



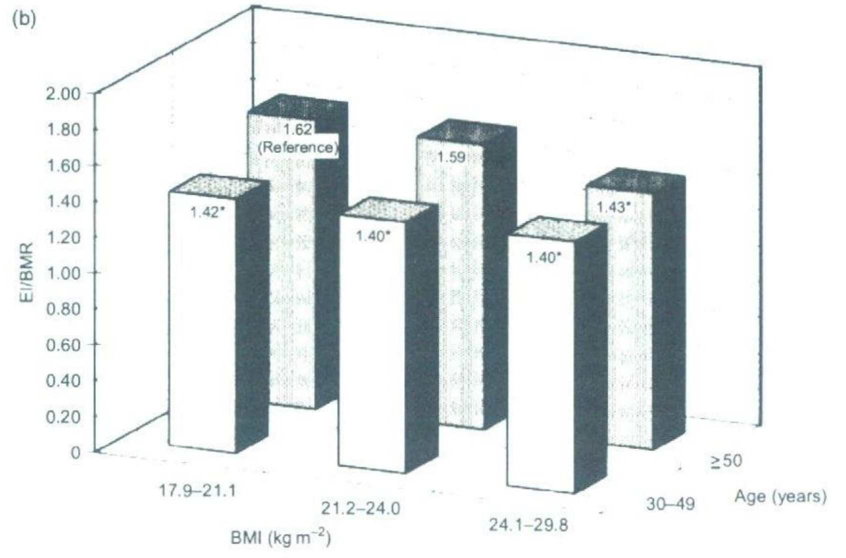


Fig. 1 The interaction of age and body mass index (BMI) in relationships with the ratio of reported energy intake to estimated basal metabolic rate (EI/BMR). Mean value of EI/BMR by tertile of BMI and age group (30–49, ≥50 years) in (a) Japanese men aged 32–76 years ($n = 92$) and (b) Japanese women aged 31–69 years ($n = 91$). EI/BMR values were adjusted for physical activity level and living area. Significance of difference compared with the oldest age and lowest BMI group (Dunnett's t-test of one-way analysis of variance): *, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$

BMI and youngest age group had EI/BMR that was 24% and 14% lower in men and women, respectively.

Discussion

To our knowledge, this is the first report to evaluate EI/BMR values over a wide age range of Japanese men and women. We conducted semi-weighed diet records for 4 days in four seasons, which is often considered to be the most accurate and precise method for determining energy intake. Furthermore, fax delivery was used so that we could check the diet records immediately on each survey day. Therefore, we believe that the data have higher precision than in any other such survey conducted in Japan. The EI/BMR in our study was 1.55 among men and 1.48 among women. Although we refrained from using a specific cut-off value to identify underreporters, 20% and 23% of men and women, respectively, showed EI/BMR below 1.27, the minimum survival level reported by FAO/WHO/UNU[19]. Moreover, the proportion of subjects with EI/BMR < 1.27 decreased with increasing age in both sexes, except in the 40–49 year age group in women. However, 10% and 4% of men and women, respectively, showed EI/BMR exceeding 2.0 as the maximum level. Even when physical activity level was considered, the proportion of subjects with EI/BMR > 2.0 increased with increasing age, and was especially more pronounced in the age group ≥60 years for both sexes. This indicates that older Japanese men and women tend to relatively overestimate energy intake rather than underreport.

The main finding of this study was that age and BMI independently affect EI/BMR as a positive and a negative factor, respectively. The statistical power of these findings became stronger after adjustment for potentially confounding factors such as physical activity level and living area (urban or rural) for both sexes (Figs 1a and 1b). According to previous studies, physiological and psychological factors are also related to reporting accuracy; for example, smoking habits, education level, socio-economic status and obesity-related behaviours[14,15,20–22]. However, we did not examine the effect of these factors on reporting accuracy because of a lack of information.

Most studies conducted in Western countries revealed that underreporting of energy intake was more prevalent among older subjects than among younger counterparts[7,23,24]. The tendency was completely opposite in this Japanese population. To our knowledge, no previous study has found underreporting to be more prevalent among younger compared with older subjects, either in Western or Asian countries. Possible factors affecting reporting accuracy may include dietary consciousness and knowledge of foods and diet. According to the National Nutrition Survey in Japan[25], the percentage of subjects who paid high attention to diet and nutrition was 12.1%, 17.5%, 24.4% and 27.2% among 30–39-, 40–49-, 50–59- and ≥60-year-old men, respectively, and 27.5%, 35.7% 42.9%, and 48.6%, respectively, among women. The capability to recognise foods and diet may be related to recording as correctly as possible. Some previous studies reported that cultural, behavioural and psychological factors affect reporting accuracy[14,15,20–22]. The results were, however, inconsistent and differed among the populations examined. Further research focusing on dietary consciousness and behaviours connected with food and the process of dietary assessment is needed.

Our study has several limitations. First, the subjects may not be representative because they were not randomly sampled from the general Japanese population. Moreover, the participants might be highly health-conscious because almost all of them completed the study despite the strict study design. Second, the sample size was relatively small. Therefore, the results may arise by chance. Third, we cannot exclude the possibility that the subjects changed their dietary behaviour or food choices during the recording periods. However, the relationships between EI/BMR and age and body weight did not change materially when the dietary record data of the first four days were used in the analysis (data not shown). Fourth, we used body height to take into consideration body size although body height is not an ideal marker of body size. Fifth, the reliability of the BMR prediction from the FAO/WHO/UNU formulas may be inappropriate when applied to the Japanese population[26]. The validity of the self-reported physical activity levels from the 6th Japanese recommended dietary allowance is questionable because of the lack of a validation study[18].

In summary, the results of the present study suggest that age and BMI may influence the relative accuracy of reported energy intake among Japanese adults. The positive correlation found between age and EI/BMR was especially interesting because almost all previous studies conducted in Western populations showed a negative correlation. This indicates that the factors related to reporting accuracy of energy intake may depend on population characteristics. Further studies are needed to examine whether or not this is a consistent tendency in Asian or Japanese populations.

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

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

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

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

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SUBJECTS AND METHODS

Subjects and survey procedure. The present study was based on a self-administered questionnaire survey among dietetic students (n=4,679) from 54 institutions in Japan. Staff at each institution distributed a dietary assessment questionnaire (i.e., DHQ) and another questionnaire on other lifestyle items during the preceding month to students during an orientation session or a first lecture designed for freshman students entering dietetic courses in April 2005; in most institutions, this was carried out within 2 wk after the course began to minimize the influence of new school year life on the answers. Students filled out the questionnaires during the session, lecture, or at home and then submitted the completed forms to staff at each institution. Questionnaires used in the present study included the explanation on how to answer questions. To standardize the survey procedure, when students asked how to answer questionnaires, staff at each institution did not provide any advice and only asked students to read the explanation on questionnaires carefully. In addition to the two questionnaires for the preceding month, a third questionnaire on lifestyle during the previous 6 y (i.e., junior high school and high school) was also distributed and answered in a similar fashion; in most institutions, this was carried out within 4 wk after the course began because it was considered burdensome for subjects to answer all three questionnaires at the same time and it was considered unlikely that new school year life would influence the answers for lifestyle during the previous 6 y.

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

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

Dietary intake. Dietary habits during the previous month were assessed using a previously validated, self-administered DHQ (*15–17*). This is a 16-page structured questionnaire that consists of the following seven sections: general dietary behavior; major cooking methods; consumption frequency and amount of six alcoholic beverages; consumption frequency and semi-quantitative portion size of 121 selected food and nonalcoholic beverage items; dietary supplements; consumption frequency and semi-quantitative portion size of 19 staple foods (rice, bread, and noodles) and miso (fermented soybean paste) soup; and open-ended items for foods consumed regularly (≥once/wk) but not appearing in the DHQ. The food and beverage items and portion sizes in the DHQ were derived primarily from data in the National Nutrition Survey of Japan (*18*) and several recipe books for Japanese dishes (*15*).

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

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

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

Table 1. Characteristics of subjects.[a]

Variable	All (n=3,825)	Subjects with functional constipation[b] (n=1,002)	Subjects without functional constipation (n=2,823)	p[c]
Body mass index (kg/m²)	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/m²) 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/m²), 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

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

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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

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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.

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