Table 3. Summary of association between dietary factors and incidence of type 2 diabetes: food and food group.

Dietary factors examined	Study (*n*)	Significant positive association (*n*)		Significant inverse association (*n*)	
		Highest vs. lowest categories	Trend	Highest vs. lowest categories	Trend
Grain	3			3	3
Whole grain	4			2	3
Rye	1				
Dark bread	1			1	1
Whole-grain breakfast cereal	1			1	1
Popcorn	1				
Cooked oatmeal	1				
Brown rice	1				1
Wheat germ	1				1
Bran	1			1	1
Other whole grain	2			1	1
Refined grain	4				
Refined grain from wheat	1				
Refined/whole grain	1	1	1		
Meat	2	1			
Processed meat	2	2	2		
Bacon	2	2	2		
Hot dogs	2	1	1		
Sausage etc.[1]	2	1	2		
Red meat	1				
Beef or lamb as MD	1				
Pork as MD	1				
Hamburgers	1	1	1		
Beef, pork, or lamb as SW or XD	1				
Fruit and vegetables	3			1	
Vegetables	2				
Fruit	2				
Mature beans	1				
Nuts	1			1	1
Peanut butter	1			1	1
Coffee	8			5	4
Decaffeinated coffee	2				2
Tea	2				
Dietary score[2]	1			1	
Prudent pattern score[3]	1				
Western pattern score[4]	1	1	1		

[1] Sausage, salami, bologna, other processed meats.
[2] The intakes of trans fat and cereal fiber, the glycemic load, and the ratio of polyunsaturated fat intake to saturated fat intake were categorized into quintiles. Each woman was assigned a score for each variable on the basis of her quintile of intake (a higher score represented a lower risk), then the four scores were summed, and the total score was categorized into quintiles.
[3] A dietary pattern characterized by high consumption of vegetables, legumes, fruit, whole grains, fish, and poultry.
[4] A dietary pattern characterized by high consumption of red meat, processed meat, refined grains, French fries, high-fat dairy products, sweets and desserts, high-sugar drinks, and eggs.
Abbreviations: MD, main dish; SW, sandwich; XD, mixed dish.

be inappropriate to extrapolate these findings to people in non-Western countries.

Specific types of dietary fat rather than total fat appeared to play an important role in the development of type 2 diabetes. While no appreciable association between total fat and the risk of type 2 diabetes was observed in any study, several studies found decreased risk with vegetable fat and polyunsaturated fatty acid and increased risk with trans fatty acid. As vegetable fat consists of fats commonly found in non-animal foods including fruit, vegetable, grains, and nuts, it can be considered that vegetable fat represents a combination of several potentially healthful fat subtypes including polyunsaturated and monounsaturated fatty acids (24). An inverse association between the ratio of polyunsaturated to saturated fatty acid and the risk of type 2 diabetes was also found in one study. Thus, consuming a diet high in unsaturated fats (such as those in natural vegetable oils, nuts, and seeds) and low in saturated fat (such as those in animal products) and trans fat (such as those in vegetable shortening and hard margarine) could have substantial benefits for type 2 diabetes (*4*). Because there are some studies neither supporting nor denying this possibility, however, more research must be done on the relation between fat and type 2 diabetes.

Soluble fiber causes the slow absorption and digestion of carbohydrates that leads to a reduced demand for insulin (*41*), and insoluble fiber shortens the intestinal transit, allowing less time for carbohydrates to be absorbed (*42*); thus, dietary fiber is one nutrient that may provide protection against type 2 diabetes. A beneficial effect of dietary fiber was found in several studies. In particular, cereal fiber appeared to be more effective for the prevention of type 2 diabetes than fibers derived from other foods. Therefore, it may be recommended to increase the intake of dietary fiber, especially that derived from cereal products, for the prevention of the disease.

Magnesium is an important component of many unprocessed foods including whole grains and nuts (*43*), and is a cofactor for several enzymes critical for glucose metabolism (*44*). Several studies found an inverse association between magnesium and type 2 diabetes, while no report indicated an increased risk from magnesium intake. A particularly beneficial effect of magnesium was observed in two large cohort studies where diet was assessed multiple times during follow-up (*14*); therefore, further research should be undertaken to gather stronger evidence.

The relation between caffeine, which is abundant in coffee, and the risk of type 2 diabetes was investigated in only two studies where a beneficial effect of caffeine was indicated. Caffeine is a strong stimulant of pancreatic beta cells (*45*), which may be beneficial for people at risk of type 2 diabetes who usually have impaired insulin secretion (*46*). Additionally, the thermogenic effect of caffeine may increase energy expenditure, which may facilitate weight reduction and maintenance (*47*). As only a limited number of studies are available at present, further investigation is needed before drawing a firm conclusion.

Type 2 diabetes is a common manifestation of hemochromatosis, a disease of massive iron overload (*48*); it can be speculated that excessive iron stores may promote insulin resistance and lead to the development of type 2 diabetes (*20*). Only two studies examined the association between iron and risk of type 2 diabetes, both of which showed that heme iron increased the risk (no association was found between intakes of total iron, non-heme iron, or iron from supplements and the incidence of type 2 diabetes). In one study, however, heme iron intake from red meat was positively associated with the risk of type 2 diabetes while heme iron intake from sources other than red meat was not associated with the risk of the disease; therefore, the association between heme iron and type 2 diabetes may have been confounded by other components of red meat intake (*20*). Thus, more research is needed to identify heme iron as a risk factor for type 2 diabetes. Moreover, even after establishing heme iron as a risk factor for the disease, application of this finding to the prevention of type 2 diabetes should be carried out with caution, because insufficient intake of iron (particularly heme iron) is a risk factor for iron deficiency anemia (*49*).

Oxidative stress may contribute to the pathogenesis of type 2 diabetes by increasing insulin resistance or impairing insulin secretion (*50*); thus, dietary antioxidants may have a protective effect against the development of the disease by inhibiting the peroxidation chain reactions (*32*). The relation between antioxidant vitamins and the risk of type 2 diabetes was investigated in only two studies where beneficial effects of several nutrients examined (vitamin E, α-tocopherol, γ-tocopherol, β-tocotrienol, total carotenoid, and β-cryptoxanthin) were found. Unfortunately, the number of subjects examined in these two studies was relatively small (n=895, 4,304); therefore, more research is required before drawing a firm conclusion.

Dietary carbohydrate may be associated with the development of type 2 diabetes by affecting blood glucose and insulin concentration (*23*). However, no study investigating the association between total carbohydrate and the risk of type 2 diabetes found a clear association, while both glycemic index and glycemic load were positively related to the risk of type 2 diabetes in several studies. Additionally, while beliefs that added sugar, primarily sucrose, should be avoided and that naturally occurring sugars should be restricted in the diabetic diet are prevalent (*29*), the results of two studies on sugar and type 2 diabetes were not consistent, and in fact, only one of the two studies showed that glucose and fructose were positively related and sucrose was inversely related to the risk of type 2 diabetes. Although a firm conclusion should be drawn after the accumulation of more findings, it is suggested that dietary sugar, if consumed within a normal range of quantity, may not be associated with the risk of type 2 diabetes. However, it should be emphasized that only moderate sugar intake should be incorporated within the boundaries of acceptable energy intake in a well-balanced diet because excessive sugar may not only cause an excessive energy intake, but also adversely affect the entire dietary balance (for instance, by reducing fruit consumption and main meals) (*29*).

Although several studies assessed the effect of energy intake on the risk of type 2 diabetes, no study indicated a clear association. These results may be partly accounted for by the fact that accurate assessment of energy intake is quite challenging in dietary surveys (*51*). In fact, many studies have indicated that overweight and obesity are the most important risk factor for type 2 diabetes (*52*, *53*); therefore, an excess of energy intake, which may cause a positive imbalance of energy metabolism, can be considered a risk factor of type 2 diabetes.

An inverse association between consumption of grain (particularly whole grain) and the development of type 2 diabetes was observed in several studies (no study found a positive association). Whole-grain products are a good source of several vitamins, minerals, and fiber, which may contribute to the inverse association between whole-grain intake and the disease (*17*). Furthermore, one study indicated a positive correlation between the ratio of refined grain to whole grain and the risk of type 2 diabetes. Thus, it can be considered that substituting whole grain for refined grain may reduce the risk of type 2 diabetes.

Five out of eight analyses supported a beneficial effect of coffee on the development of type 2 diabetes, while no analysis found an adverse effect. However, higher consumption of coffee may adversely affect health in other aspects. For instance, some cohort studies have shown an increased risk of coronary heart disease in heavy coffee drinkers (*54–56*), although in others no increase in risk has been found (*57–59*). Additionally, the biological mechanism behind the inverse association between coffee and the risk of the disease is unknown (*37*). Thus, even if a beneficial effect of coffee against type 2 diabetes is established, increased coffee intake should be recommended only with caution.

While findings regarding total meat and red meat were not consistent, higher consumption of processed meat consistently increased the risk of type 2 diabetes in two studies that explored this issue. This positive association was largely independent of not only the intake of nutrients associated with processed meat, but also the Western pattern, which was characterized by high intakes of red and processed meat and which has been associated with diabetes risk. The increased risk by processed meat, therefore, may be due to the components of processed meat such as nitrites and advanced glycation end-products typically administered or developed in processing and preparation (*35*). However, as only a few studies have investigated this issue, confirmation from other studies is needed.

Nuts are high in nutrients that may decrease the risk of type 2 diabetes such as polyunsaturated fatty acid, dietary fiber, and magnesium, and may be beneficial for glucose and insulin homeostasis (*13*). Only one study investigated the association between nut consumption and the risk of type 2 diabetes where a beneficial effect of nuts was found. Higher nut consumption may lead to more weight gain because of high fat content, but no association between nut consumption and weight change was found in this study (*13*). Additionally, although one may speculate that frequent nut consumption results in increased risk of coronary heart disease because of its high fat content, several cohort studies have consistently indicated an inverse association between nuts and the risk of the disease (*60–62*). The establishment of the beneficial effect of nuts may make it possible to recommend regular nut consumption as a replacement for refined grain products or red or processed meats that may increase the risk of chronic disease (*13*). Thus, further investigation is warranted.

Fruits, vegetables, and beans are good sources of dietary fiber, minerals such as magnesium, and antioxidant nutrients such as carotenoids, which may lower the risk of developing diabetes (*26*). Only a small number of studies examined the relation of these foods to type 2 diabetes, and only one of eight analyses showed a beneficial effect (fruits and vegetables). Since an adequate intake of fruits and vegetables appears to lower the risks of mortality from cancer (*63*) and cardiovascular disease (*64*), the relation of fruits and vegetables with type 2 diabetes should be further investigated.

Although many studies have focused on the role of single nutrients, foods, or food groups in disease prevention or promotion, recent evidence suggests that there are health benefits from food patterns that include mixtures of food containing multiple nutrients and nonnutrients (*65*). While this approach makes it difficult to elucidate the mechanisms through which the diet composition affects a particular health outcome, it does represent a practical approach to making realistic nutrition recommendations for improving health (*65*). For type 2 diabetes, a diet low in trans fatty acid intake and glycemic load and high in cereal fiber intake and the ratio of polyunsaturated to saturated fatty acid appeared to decrease the risk of type 2 diabetes (in one study), while a diet high in consumption of red meat, processed meat, refined grain, French fries, high-fat dairy products, sweets and desserts, high-sugar drinks, and eggs appeared to increase the risk (in one study).

In the present paper, as the literature search was limited to only one database MEDLINE (PubMed) with a manual check of the reference lists of included papers, articles appearing in the journals that were not included in the MEDLINE and/or written in languages other than English have not been identified. Additionally, research with a negative result may likely be unpublished (publication bias). Furthermore, we examined only 15 individual cohort studies since we considered as research appropriate for the present study only highly reliable studies that included, for example, quantitative dietary assessment, clear definition of the incidence of diabetes, and adjustment using known factors associated with diabetes. Thus, one may speculate that it would have been better to examine a greater number of studies by broadening the inclusion criteria. Given the difficulties of dietary assessment, however, it may not be worth referring to studies in which an insufficiently accurate dietary assessment method is used. From this point of view, the findings from the studies examined here may be as reliable as possible.

It may be interesting to conduct a meta-analysis. However, our review showed that there are relatively a limited number of cohort studies (one to eight studies for each dietary factor). Additionally, a reliable meta-analysis requires the homogeneity of subjects examined and methods used, which has not necessarily been met in the existing research. Thus, we consider that it is too early to conduct a meta-analysis of cohort studies on diet and diabetes.

When comparing and/or summarizing the results of several studies, the differences among studies of subjects examined and methods used should be taken into account. As diabetes is a disease the incidence of which is difficult to define, various methods were used to define the incidence of type 2 diabetes in the 15 studies examined in the present paper. While oral glucose tolerance testing (≥11.1 mmol/L (200 mg/dL)) (study 7) or fasting blood glucose level (≥7.0 mmol/L (126 mg/dL)) (studies 4 and 14) was used in the several relatively small studies, three studies in Finland (studies 10, 11, and 15) used a nationwide register because in Finland all diabetic persons needing drug therapy are entitled to reimbursement of drug costs. Other studies used documents such as death certificate (studies 1 and 6) or questionnaire (the definition of NDDG (*38*) and WHO (*39*) (≥7.8 mmol/L (140 mg/dL)) (studies 2, 3, and 13), the definition of ADA (*40*) (≥7.0 mmol/L (126 mg/dL)) (study 9), or self-reports of symptom and use of drugs (studies 5 and 8)). The questionnaire used in studies 2, 3, and 13 and that used in study 9 showed good validity (97–98% of the self-reported diabetes cases using a questionnaire were confirmed by medical record review), while diabetes tended to be overreported by the questionnaire used in study 5 (only 64% of subjects who reported diabetes in the questionnaire were confirmed as being diabetic by their physician) and the validity of the questionnaire for diabetes was not indicated in study 8. Such differences in the definition and the method used to identify a case of diabetes may have influenced the results on the association between dietary factors and the risk of type 2 diabetes.

Dietary assessment methods also varied among studies. In most of the studies examined, relatively accurate methods such as validated self-administered questionnaire (studies 2, 3, 5, 8, 9, and 13), validated food frequency interview (studies 4 and 7), and diet history interview (study 10) were applied. However, several studies used less accurate methods such as non-validated questionnaire (studies 1, 11, 12, 14, and 15) and one 24-h recall (study 6). The difference in the dietary assessment method used may also have some impact on the results of diet and diabetes association.

As mentioned previously, relatively accurate dietary assessment instruments were applied in many studies examined in the present paper. Unfortunately, the underestimation of energy intake is a serious problem in dietary surveys. In particular, evidence suggests that obese subjects are likely to underestimate energy intake to a large extent (*66*). If all foods and nutrients were underestimated to the same degree when energy intake was underestimated, however, the solution would be relatively simple because techniques such as energy adjustment should improve food and nutrition intake estimates (*67–69*). If, on the other hand, certain types of foods and nutrients are selectively underestimated, the methods of energy adjustment cannot solve all the problems (*67–69*). Actually, several studies where the accuracy of reported energy intake was assessed against the total energy expenditure measured by the doubly labeled water method (the gold standard for measuring energy intake) have found that the percentage of energy intake from fat decreased and the percentage of energy intake from protein increased as energy intake underestimation increased, suggesting selective underestimation of fat intake and selective overestimation of protein intake (*70, 71*). Additionally, in some studies using not only the total energy expenditure measured by the doubly labeled water method but also using the 24-h urinary nitrogen excretion (the gold standard for protein intake), the magnitude of underestimation of energy intake was greater than that of protein intake, indicating selective underestimation of other energy-yielding nutrients (fat, carbohydrate, and alcohol) (*72, 73*). Moreover, a similar finding was observed in a study using total energy expenditure estimated by body composition and self-reported physical activity and 24-h urinary nitrogen excretion (*74*). Although this problem has not been given sufficient attention in nutritional epidemiology (*69*), selective underestimation of dietary intake may generate misleading conclusions with regard to diet and health relationships. Therefore, although differential underestimation of specific foods and nutrients is quite difficult to investigate, further research on this issue is needed.

Very recently, the associations of diet and nutrition to the risk of type 2 diabetes have been reviewed and summarized (*75*). In that review, non-starch polysaccharide (which is identical with dietary fiber in practice) was considered to 'probably' decrease the risk of the disease, which was consistent with the finding obtained in the present paper. An apparently different conclusion from ours, however, was drawn regarding saturated fats, which were regarded as a 'probable' risk factor in that review. In the present paper, however, several studies found an increased risk from processed meat, which was not only high in saturated fat but also frequently consumed in normal life. Thus, although it may be difficult to draw a firm conclusion as to whether saturated fat directly influences the development of type 2 diabetes, our finding is similar to the summary of the review in terms of an increased risk from foods high in saturated fat. Although beneficial or adverse effects of several other nutrients/foods are indicated at lower levels of evidence ('possible' or 'insufficient'), some of which are consistent with the findings in the present paper, further research is needed to corroborate the data.

As a result of systematically reviewing relatively reliable cohort studies on the association between dietary factors and the risk of type 2 diabetes, the following findings may be considered as low-to-medium level evidence: for nutrients, decreased risk with vegetable fat, polyunsaturated fatty acid, dietary fiber (particularly cereal fiber), magnesium, and caffeine, and increased risk with trans fatty acid and heme iron; for foods and food groups, decreased risk with grain (particularly whole grain) and coffee, and increased risk with processed meat. However, these conclusions depend on the findings of studies conducted in Western countries, suggesting that the application of the findings to people in other countries may not be appropriate. Additionally, as findings from only a limited number of cohort studies are available, more research with a prospective design is needed particularly from other than Western countries.

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

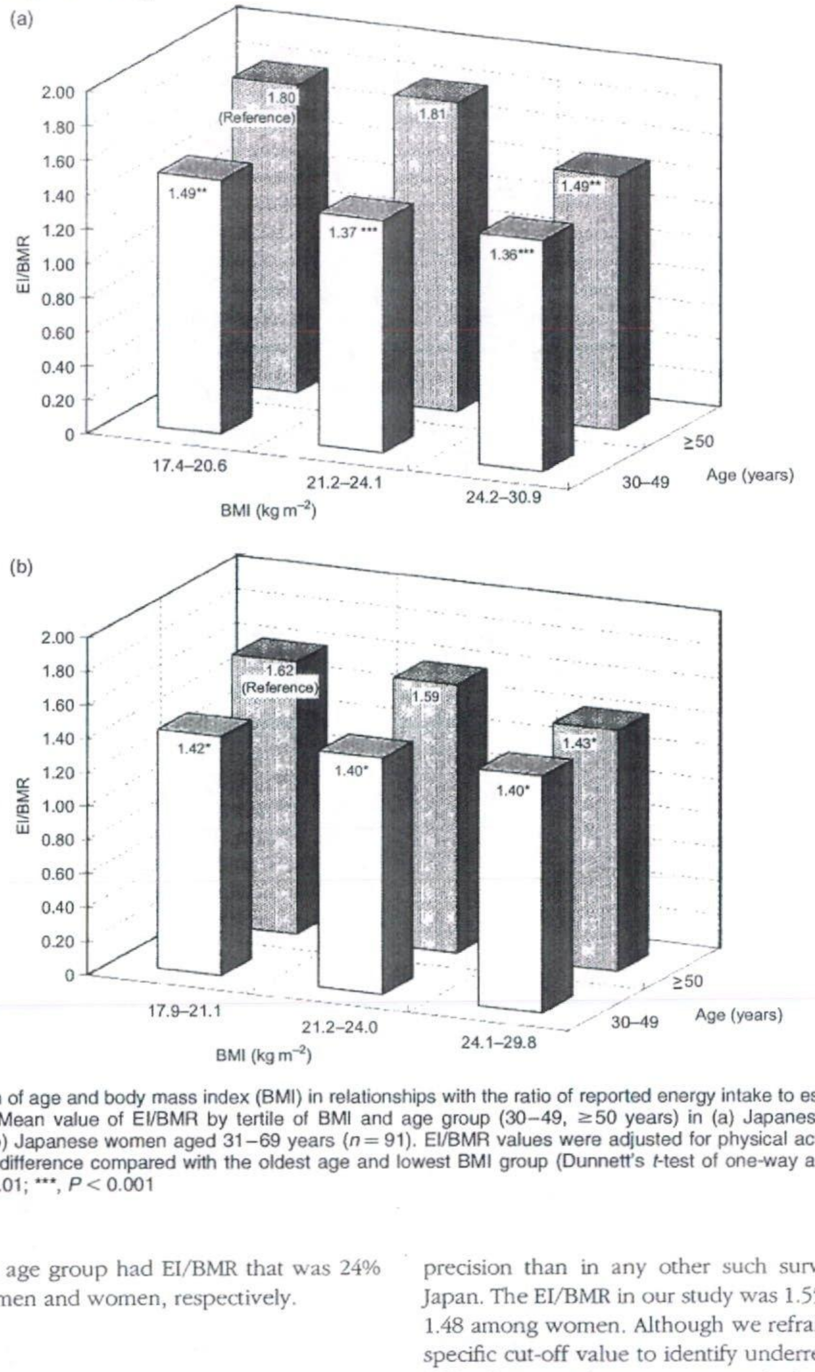

Fig. 1 The interaction of age and body mass index (BMI) in relationships with the ratio of reported energy intake to estimated basal metabolic rate (EI/BMR). Mean value of EI/BMR by tertile of BMI and age group (30–49, ≥50 years) in (a) Japanese men aged 32–76 years ($n = 92$) and (b) Japanese women 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*).

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

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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.

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