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The Relationship between Functional Constipation and Dietary Habits in School-Age Japanese Children

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Summary Functional constipation negatively affects school-related quality of life for children and adolescents. We investigated the association between functional constipation, defined according to the Rome criteria version III, and dietary habits. The subjects of this cross-sectional study were 1,140 5th graders and 1,054 8th graders attending schools in Shunan City, Japan in 2012. Functional constipation was defined as having two or more symptoms of constipation. Dietary habits were assessed using a brief questionnaire. Self-reported biological, demographic and lifestyle information was obtained. Using multiple logistic models, dose-dependent associations among subgroups stratified with quintiles of nutrient and food intake were examined. The prevalence of functional constipation ranged from 3.7% to 8.3% across the grades. The most prevalent symptom was pain or hard stools. There was a link between higher rates of functional constipation and lower levels of dietary fiber intake, vegetables, and fruits (p_{trend}=0.010–0.030). Associations with vegetables and fruits attenuated when controlling for dietary fiber intake (p_{trend}=0.074–0.150). When 5th and 8th graders were separately analyzed, intake of dietary fiber, water from foods, and vegetables had beneficial effects on functional constipation in 8th graders (p_{trend}=0.005–0.038), and fruit intake had a beneficial effect in 5th graders (p_{trend}=0.012). Modification of dietary habits may have a positive effect in reducing functional constipation in school-age children. Diets rich in fiber, vegetables, and fruits, have the potential to improve functional constipation in Japanese children and adolescents.

Key Words cross-sectional study, dietary fiber, fruits, functional constipation, vegetables

Constipation is a common pediatric problem which deteriorates health-related quality of life (*1–3*), and increases school absenteeism (*4*, *5*). The prevalence of constipation among children has been reported as ranging from 0.7% to 29.6% (mean=14%; median=12%) (*6*). Moreover, most children with constipation do not receive treatment (*7*).

Diet, physical activity levels, toilet behaviors, social environment factors, and family history have been considered as causes of child constipation (*8–10*). Several nutrients and foods have been examined as factors lowering constipation prevalence in school-age children (*11–15*), as well as in pre-school children and college students (*16–20*).

The wide range in the prevalence of constipation is partly due to the presence of a variety of definitions. Some studies used a single symptom as a definition, (e.g. defecation frequency or stool character) (*11*, *13*, *14*, *20*), while others used a combination of these symptoms as functional constipation (e.g. Rome criteria) (*12*, *18*, *19*). The prevalence based on the Rome criteria version II and the Rome criteria version III (Rome III) is different (*21–23*). While version IV has just been released, Rome III, with the same items as version IV and its timeframe longer than that of version IV (2 mo vs. 1 mo), has been widely used in several studies that reported the prevalence of child constipation (*6*, *24*, *25*). Few studies have investigated the association between dietary habits and constipation based on the Rome III criteria; only one study of Korean toddlers used this measure and they found that dietary habits were related to functional constipation (*19*).

The purpose of the present study was to use the Rome III criteria to examine functional constipation and dietary habits in 5th and 8th graders in Shunan City, Japan. Specifically, in this study, we investigated the association between dietary nutrient/food intake and functional constipation, defined according to the Rome III criteria, in school-age children and adolescents.

MATERIALS AND METHODS

Subjects. This study plan, in accordance with the Declaration of Helsinki, was approved by the Institutional Review Board, Yamaguchi University Hospital (H22-158), and we obtained written informed assent from the students and informed consent from the guardians. This cross-sectional study was conducted in all 51 schools in Shunan City, Japan. Overall, 2,706 5th and 8th grade students (1,368 5th graders, and 1,338 8th graders) were enrolled in these schools in 2012. We distributed questionnaires to students in each school between May and June 2012, and asked students to complete them at home. The completed questionnaires were collected at school, and we obtained anonymized

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Table 1. Characteristics of the subjects.

	5th graders				8th graders			
	Boys, n=599		Girls, n=541		Boys, n=538		Girls, n=516	
Age, y	10.6±0.3		10.6±0.3		13.6±0.3		13.6±0.3	
BMI, kg/m^2	17.4±2.5		17.0±2.3		18.8±2.4		19.3±2.5	
Secondary maturation	22	3.7%	36	6.7%	363	67.5%	443	85.9%
Siblings, One	72	12.0%	61	11.3%	65	12.1%	63	12.2%
Two	287	47.9%	274	50.6%	263	48.9%	274	53.1%
More than 2	240	40.1%	206	38.1%	210	39.0%	179	34.7%
Exercise frequency <3/wk	313	52.3%	387	71.5%	56	10.4%	175	33.9%
Single parent	76	12.7%	88	16.3%	103	19.1%	101	19.6%
Waking up after 6:30 AM	399	66.6%	389	71.9%	264	49.1%	258	50.0%
TV watching ≥2 h on weekdays	368	61.4%	357	66.0%	307	57.1%	319	61.8%
Energy intake	1,912±435		1,682±432		2,520±748		2,016±673	
Functional constipation	39	6.5%	43	7.9%	20	3.7%	43	8.3%
Infrequency	17	2.8%	25	4.6%	26	4.8%	43	8.3%
Soiling of underwear	4	0.7%	10	1.8%	0	0.0%	0	0.0%
Retentive posturing	40	6.7%	48	8.9%	31	5.8%	46	8.9%
Pain or hard stools	113	18.9%	129	23.8%	75	13.9%	96	18.6%
Presence of large stools	13	2.2%	12	2.2%	9	1.7%	11	2.1%
Obstructive stools	29	4.8%	21	3.9%	20	3.7%	19	3.7%

Mean±standard deviation, or counts and percentage.

data of 2,403 students from the Shunan City Education Board (See Fig. S1, Supplemental Online Material). Out of 2,403, 22 students received medical treatment for diabetes, dyslipidemia, hypertension, heart disease, or kidney disease. The data for analysis did not include students who received diet advice from doctors or nurses according to their self-report.

Questionnaires. Functional constipation was defined as two or more of the following symptoms for 2 mo based on Rome III: low defecation frequency (≤2 per week), soiling of underwear (at least 1 per week), retentive posturing (at least 1 per week), pain or hard stools, presence of a large fecal mass, large stool obstructing toilet (*26*). Options of each question were taken from the self-reported Rome III Diagnostic Questionnaire for the Pediatric Functional Gastrointestinal (GI) Disorders (*27*).

Dietary intake was assessed using the Brief-Type Self-Administered Diet History Questionnaire for children and adolescents (*28–30*). This questionnaire contains 90 items that assess frequency of food intake in addition to dietary-related items such as frequency, habits, and preparation of foods consumed in a previous month. The version for children and adolescents was validated using biomarkers (*28–30*). Based on this information and the Japanese food composition table, we estimated daily intake of nutrients and foods in the subjects.

Protein, fat, and carbohydrate were indicated as percentage of energy (%E); other nutrients were indicated as g/1,000 kcal, or mg/1,000 kcal (energy density method; total, insoluble, and water-soluble dietary fiber, water, water from foods and beverages, magnesium, iron, and zinc). Foods were indicated as g/1,000 kcal (rice, breads, noodles, confectionaries, pulses, vegetables, fruits, green tea, sweetened beverages, dairy products, meats, and fish). Since there is no means by which to identify over- or under-reporters, the subjects with energy intake less than 600 kcal or more than 5,000 kcal were excluded from the analysis as outliers, and the final population for analysis consisted of 1,140 5th graders (599 boys, and 541 girls), and 1,054 8th graders (538 boys, and 516 girls; See Fig. S1, Supplemental Online Material). The subjects were stratified by sex and grade, and classified into five categories by quintiles based on each nutrient or food intake datum (Q1, Q2, Q3, Q4, and Q5 in increasing order).

Covariates. Body height and weight were self-reported in the questionnaire, which were validated elsewhere (*31*), and body mass index (BMI) was calculated as body weight (kg)/square of body height (m^2). Sexual maturation at puberty was determined based on self-report. It was defined as the grade at which the voice cracked for boys and the grade at which menarche appeared for girls. Number of siblings (one, two, and three or more), the presence of a single parent as a social factor, and weekly frequency of exercise (less than 3 times, and 3 or more times), TV watching time on a weekday (less than 2 h, and 2 or more hours), and typical morning awakening time (before, and after 6:30 AM) were also asked.

Statistical analysis. Measured variables were expressed as mean±standard deviation, median, or percentage. Odds ratios were obtained from logistic regression models to examine the association between functional constipation and dietary nutrient and food intake. In the models, grade, sex, BMI, sexual maturation, number of siblings, single parent status, exercise frequency, TV watching, and morning awakening time were adjusted. A linear trend along with 5 categories of each intake was also examined to obtain p for trend (p_{trend}). Post-hoc analysis was conducted with additional

Table 2. Dietary intake of nutrients and foods stratified using quintiles.

	5th graders					8th graders				
	Q1	Q2	Q3	Q4	Q5	Q1	Q2	Q3	Q4	Q5
Energy, kcal	1,314	1,611	1,772	1,940	2,334	1,406	1,936	2,229	2,611	3,317
Total dietary fiber, g/1,000 kcal	4.8	5.5	6.1	6.7	7.7	3.7	4.5	5.2	5.9	7.1
Insoluble dietary fiber, g/1,000 kcal	3.5	4.0	4.4	4.8	5.5	2.7	3.3	3.7	4.2	5.0
Soluble dietary fiber, g/1,000 kcal	1.1	1.4	1.5	1.7	2.0	0.8	1.1	1.3	1.5	1.8
Water, g/1,000 kcal	786.2	886.2	962.9	1,044.2	1,177.8	670.1	788.1	870.0	973.2	1,153.5
Water from foods, g/1,000 kcal	569.9	635.4	682.8	730.9	813.1	466.3	546.6	599.8	669.1	769.5
Water from beverages, g/1,000 kcal	109.4	224.0	281.6	340.3	460.8	96.9	200.0	267.2	340.3	471.0
Protein,%Energy	12	14	14	15	17	12	13	14	16	18
Fat,%Energy	23	26	29	30	34	23	27	30	33	37
Carbohydrate,%Energy	50	53	56	58	63	45	50	53	57	63
Magnesium, mg/1,000 kcal	100.0	112.3	120.9	130.0	143.7	95.9	112.1	122.6	133.1	151.0
Iron, mg/1,000 kcal	3.0	3.5	3.8	4.2	4.6	2.8	3.3	3.7	4.1	4.8
Zinc, mg/1,000 kcal	4.0	4.2	4.4	4.6	5.0	3.7	4.1	4.4	4.7	5.2
Rice, g/1,000 kcal	102.1	127.9	159.5	187.6	234.0	80.1	122.5	160.7	206.2	265.8
Bread, g/1,000 kcal	13.7	19.9	26.2	33.9	44.4	4.6	13.2	21.5	29.9	43.4
Noodles, g/1,000 kcal	18.2	24.2	28.8	35.4	52.2	9.9	17.1	23.3	30.4	50.0
Confectionaries, g/1,000 kcal	13.6	26.3	36.4	51.1	73.2	16.1	28.7	43.3	61.0	89.2
Pulses, g/1,000 kcal	15.8	24.3	31.4	39.6	53.0	5.4	12.4	20.4	29.6	46.2
Vegetables, g/1,000 kcal	83.9	111.1	131.5	153.5	191.6	42.8	71.6	91.6	118.6	165.2
Fruits, g/1,000 kcal	13.3	22.7	32.2	50.4	80.1	4.4	11.0	19.3	32.7	61.1
Green tea, g/1,000 kcal	53.7	176.5	218.2	272.5	359.1	32.5	129.8	203.0	264.0	361.4
Sweetened beverages, g/1,000 kcal	0.0	12.5	33.0	52.2	111.4	0.0	9.3	28.4	53.2	129.4
Dairy products, g/1,000 kcal	103.7	135.5	159.5	188.4	236.9	49.5	101.4	146.0	204.0	301.0
Meat, g/1,000 kcal	24.8	32.2	37.3	43.1	53.4	19.0	27.7	34.6	43.2	58.3
Fish, g/1,000 kcal	16.0	21.7	26.3	32.7	44.6	12.1	20.4	27.5	36.6	54.0

Figures are medians in each category of Q1–Q5 from the lowest to the highest intake subgroups.

Table 3. Prevalence of functional constipation among nutrient intake subgroups based on the quintiles.

	Q1	Q2	Q3	Q4	Q5	p_{trend}
Total dietary fiber	37/437	32/440	29/440	27/439	20/438	
	1	0.85 (0.52, 1.39)	0.78 (0.47, 1.29)	0.73 (0.43, 1.23)	0.54 (0.30, 0.95)	0.030
Insoluble dietary fiber	37/437	33/439	25/441	24/439	26/438	
	1	0.87 (0.53, 1.43)	0.65 (0.38, 1.11)	0.64 (0.37, 1.09)	0.70 (0.41, 1.19)	0.084
Water-soluble dietary fiber	30/437	36/439	30/441	23/439	26/438	
	1	1.24 (0.74, 2.06)	1.02 (0.6, 1.73)	0.76 (0.43, 1.35)	0.91 (0.53, 1.59)	0.292
Water	28/437	33/439	27/441	19/439	38/438	
	1	1.31 (0.77, 2.22)	1.05 (0.6, 1.82)	0.71 (0.39, 1.30)	1.47 (0.88, 2.46)	0.629
Water from foods	49/437	23/439	20/441	20/439	33/438	
	1	0.46 (0.27, 0.78)	0.39 (0.23, 0.67)	0.40 (0.23, 0.69)	0.68 (0.43, 1.09)	0.057
Water from beverages	25/437	26/439	28/441	33/439	33/438	
	1	1.07 (0.61, 1.89)	1.20 (0.68, 2.10)	1.40 (0.81, 2.42)	1.34 (0.78, 2.30)	0.173
Protein	34/437	33/439	33/441	21/439	24/438	
	1	1.04 (0.63, 1.72)	1.00 (0.60, 1.65)	0.65 (0.37, 1.15)	0.73 (0.42, 1.26)	0.090
Fat	32/437	31/439	29/441	22/439	31/438	
	1	1.15 (0.71, 1.87)	0.73 (0.43, 1.24)	0.68 (0.40, 1.19)	0.71 (0.41, 1.22)	0.579
Carbohydrate	35/437	16/439	24/441	34/439	36/438	
	1	0.42 (0.23, 0.77)	0.66 (0.38, 1.13)	0.95 (0.58, 1.56)	0.97 (0.59, 1.59)	0.290
Magnesium	33/437	34/439	29/441	29/439	20/438	
	1	1.07 (0.65, 1.78)	0.86 (0.51, 1.46)	0.91 (0.54, 1.55)	0.63 (0.35, 1.13)	0.109
Iron	33/437	33/439	22/441	32/439	25/438	
	1	1.02 (0.61, 1.69)	0.67 (0.38, 1.18)	1.00 (0.60, 1.67)	0.78 (0.45, 1.35)	0.414
Zinc	32/437	34/439	27/441	28/439	24/438	
	1	1.07 (0.64, 1.77)	0.87 (0.51, 1.48)	0.93 (0.55, 1.59)	0.78 (0.45, 1.35)	0.313

Figures in upper rows are counts of functional constipation/subgroup from the lowest Q1 to the highest Q5. Figures in lower rows are odds ratios (95% confidence intervals). Odds ratios were adjusted for grade, sex, BMI, sexual maturation, number of siblings, single parent status, exercise frequency, TV watching, and wake-up time.

Table 4. Prevalence of functional constipation among food intake subgroups based on the quintiles.

	Q1	Q2	Q3	Q4	Q5	p_{trend}
Rice	33/437	25/439	22/441	26/439	39/438	
	1	0.70 (0.41, 1.21)	0.64 (0.36, 1.11)	0.77 (0.45, 1.32)	1.16 (0.71, 1.90)	0.443
Bread	27/437	27/439	31/441	31/439	29/438	
	1	1.01 (0.58, 1.77)	1.12 (0.65, 1.93)	1.16 (0.68, 1.98)	1.01 (0.58, 1.75)	0.817
Noodles	25/437	28/439	39/441	27/439	26/438	
	1	1.11 (0.63, 1.94)	1.52 (0.9, 2.57)	0.98 (0.56, 1.73)	0.93 (0.52, 1.65)	0.650
Confectionaries	30/437	29/439	31/441	30/439	25/438	
	1	0.96 (0.57, 1.64)	1.02 (0.6, 1.72)	1.02 (0.60, 1.73)	0.82 (0.47, 1.43)	0.599
Pulses	32/437	35/439	35/441	20/439	23/438	
	1	1.15 (0.69, 1.90)	1.1 (0.66, 1.82)	0.65 (0.36, 1.16)	0.76 (0.43, 1.32)	0.087
Vegetables	35/437	42/439	27/441	18/439	23/438	
	1	1.23 (0.76, 1.98)	0.79 (0.47, 1.34)	0.53 (0.29, 0.95)	0.68 (0.39, 1.17)	0.010
Fruits	42/437	27/439	31/441	25/439	20/438	
	1	0.63 (0.38, 1.04)	0.74 (0.45, 1.2)	0.60 (0.36, 1.01)	0.48 (0.28, 0.84)	0.014
Green tea	27/437	29/439	33/441	23/439	33/438	
	1	1.14 (0.66, 1.97)	1.32 (0.77, 2.24)	0.90 (0.50, 1.60)	1.26 (0.74, 2.14)	0.684
Sweetened beverages	29/437	27/439	26/441	31/439	32/438	
	1	0.93 (0.54, 1.61)	0.87 (0.5, 1.5)	1.07 (0.63, 1.82)	1.11 (0.65, 1.89)	0.575
Dairy products	27/437	32/439	26/441	29/439	31/438	
	1	1.24 (0.72, 2.11)	1 (0.57, 1.76)	1.12 (0.65, 1.94)	1.24 (0.72, 2.14)	0.586
Meat	35/437	28/439	25/441	32/439	25/438	
	1	0.80 (0.47, 1.34)	0.71 (0.41, 1.21)	0.92 (0.56, 1.53)	0.72 (0.42, 1.22)	0.386
Fish	34/437	30/439	22/441	31/439	28/438	
	1	0.89 (0.53, 1.49)	0.63 (0.36, 1.1)	0.91 (0.55, 1.52)	0.81 (0.48, 1.37)	0.495

Figures in upper rows are counts of functional constipation/subgroup from the lowest Q1 to the highest Q5. Figures in lower rows are odds ratios (95% confidence intervals). Odds ratios were adjusted for grade, sex, BMI, sexual maturation, number of siblings, single parent status, exercise frequency, TV watching, and wake-up time.

adjustment for total dietary fiber that had significant odds ratios (ORs) in the subject with the highest intake, and significant p_{trend}. For sensitivity analysis, the data were analyzed separately on the basis of grade or sex. Considering modification by soocial environment, we analyzed models without TV watching and awakening time, without single parent status and number of siblings and with bread intake. SAS 9.4 (SAS Institute Japan Ltd., Tokyo, Japan) was used for statistical analyses and a p value <0.05 was considered significant.

RESULTS

The characteristics of the subjects (5th graders aged 10.6±0.3 y, and 8th graders aged 13.6±0.3 y) are shown in Table 1. The most prevalent symptom was pain or hard stools (13.9% to 23.8%), followed by retentive posturing (5.8% to 8.9%). Defecation frequency was reported as being less than three times per week in 2.8% to 8.3% of the subjects. The prevalence of functional constipation in the subjects was 6.5% and 7.9% in 5th grade boys and girls, respectively, and 3.7% and 8.3% in 8th grade boys and girls.

Median energy intake of 5th and 8th graders was 1,772 and 2,229 kcal/d, respectively. When dietary intake amounts were described as energy density, the daily intake of nutrients and foods was higher in 5th graders than in 8th graders (Table 2). Median intake of total dietary fiber was 6.1 g/1,000 kcal in 5th graders, and 5.2 g/1,000 kcal in 8th graders, corresponding to 10.7 and 11.9 g/d in 5th and 8th graders, respectively. Median intake of water was 962.9 g/1,000 kcal and 870.0 g/1,000 kcal in 5th and 8th graders, respectively, 69–71% of which of derived from foods.

Q2 to Q5 of total dietary fiber, insoluble dietary fiber, and water from foods had odds ratios less than 1; odds ratios of Q5 of total dietary fiber, and odds ratios of Q2 to Q4 of water from foods were significant (95% confidence interval ranges<1; Table 3). Prevalence of functional constipation was lower as total dietary fiber intake increased (8.5%, 37/437 to 4.6%, 20/438; $p_{trend}=0.030$). The dose-dependent association for insoluble dietary fiber, and water from foods were nearly significant ($p_{trend}=0.084$, and 0.057, respectively).

Students with higher intake of vegetables and fruits had lower prevalence of functional constipation than lower intake groups ($p_{trend}=0.010$ and 0.014, respectively; Table 4). After additional adjustment for total dietary fiber in the models, significant associations with vegetable and fruit intake disappeared ($p_{trend}=0.074$ and 0.150, respectively; Model 1 in Table S1, Supplemental Online Material).

Fifth graders with higher fruit intake had lower prevalence of functional constipation than lower intake groups ($p_{trend}=0.012$; Table S2, Supplemental Online Material). Odds ratios of 2nd to 5th quintiles of intake in total and insoluble dietary fiber and in water from foods (0.32–0.91) were less than 1, but dose-dependent relationships were insignificant ($p_{trend}=0.296$–0.579).

For 8th graders, significant negative associations emerged between increased functional constipation and lower intake of several nutrients or foods including total dietary fiber, water from foods, total and animal protein, magnesium, zinc, and vegetables (Table S3, Supplemental Online Material). The highest intake groups in terms of total dietary fiber, water from foods, protein, and zinc had significant negative ORs (0.31–0.45) compared to the lowest intake groups. In contrast, the students who ate more bread had higher rates of functional constipation (p_{trend}=0.020).

When boys' and girls' data were analyzed separately, intakes of total dietary fiber and of fruits showed significant association only in girls (p_{trend}=0.029 or 0.005, respectively). For models without TV watching and awakening time, or without single parent status and number of siblings, these social environments scarcely affected the associations of total dietary fiber, vegetables, and fruits. Significant associations of water intake from foods appeared (p_{trend}=0.035 and 0.048, respectively). Additional adjustment for bread intake did not change the results.

DISCUSSION

The prevalence of functional constipation in the subjects of this study ranged from 3.7% to 8.3%. The prevalence of functional constipation in the current study is less than what has been found in previous reports (*6*). However, high frequency complaints of pain and hard stools and retention were similar to other reports (*19*). Defecation frequency has often been used as a functional definition of constipation in studies examining the association between lifestyle factors and constipation (*12*, *14*, *20*). Although the prevalence of infrequent defecation was similar to that of functional constipation, when infrequent defecation was used as an objective variable instead of functional constipation, more nutrients and foods showed significant associations (from 3 to 13 items; Model 2 in Table S1, Supplemental Online Material). More research will need to be conducted to examine which measure is more helpful and appropriate.

Dietary fiber has been studied in adults and increased intake is related to lower rates of constipation (*32*, *33*), and it can lead to improvement for those suffering from constipation (*34*). Children with clinically diagnosed constipation tend to have lower dietary fiber intakes than the non-constipated (*35*, *36*). In studies using defecation frequency as the measure of constipation, dietary fiber has desirable effects among infants (*18*, *20*). Previous studies of school-age children did not show significant negative associations between dietary fiber and constipation (*11*, *12*), but these associations have been found in college students (*17*). This is the first report that shows the significant association between functional constipation and dietary fiber intake among primary and secondary school students. The highest intake groups, who consumed 14.2 g/d and 13.4 g/d of total dietary fiber for 5th grade boys and girls (10–11 y old), respectively, and 15.8 g/d and 14.8 g/d for 8th grade boys and girls (13–14 y old), respectively, had lower prevalence of constipation than the lowest intake group (9.3, 9.0, 8.2, and 7.4 g/d, respectively). These intake amounts are slightly higher than the recommended value for both 10–11 y old boys and girls (13 g/d), and are less than the value for 12–14 y old boys and girls (17 g/d and 16 g/d, respectively) (*37*).

The results of this study revealed that 8th grade students who reported greater intake of total dietary fiber, vegetables, and fruits had lower rates of functional constipation. In 5th graders, odds ratios for total and water-soluble dietary fiber, water from foods, and fruits were less than 1, but only fruit intake showed a dose-dependent association (lower prevalence of functional constipation for higher intake). The reason why we found few significant relationships in 5th graders may be their early-stage developmental facility to recognize symptoms and habits; for example, low correlations between gold standard and estimates from questionnaires were found in physical dietary intake and physical activity of 5th graders (*28*, *38*). These measuring errors and possible biases could take results of the subpopulation in unexpected directions.

The main source of dietary fiber in Japan is vegetables (37.3% of total dietary fiber), followed by grains (21.1%), and other foods (<1.0%: fruits, potatoes, or pulses) (*39*). Vegetable intake was negatively associated with functional constipation in this study and this aligns with many previous studies (*14*, *15*, *20*), even though some studies found conflicting evidence (*16*, *40*).

The results of previous studies about the effect of water intake have been inconsistent (*12–14*, *18*, *19*). In 8th graders in the present study, water intake from foods had a beneficial effect on functional constipation defined based on Rome III, and this is similar to past findings (*19*). A previous study of Japanese preschool children showed that the association attenuated after adjustment for dietary fiber (*20*), and Anti et al. reported that water intake enhanced the effect of dietary fiber intake on stool frequency (*41*). It is difficult to discriminate the effects among vegetables, dietary fiber, and water in the observational study.

Magnesium salts, such as magnesium sulfate, modulate water transfer in the intestinal tract (*42*) and accelerate intestine transit time (*43*), and therefore they are expected as a constipation remedy. The association between increased magnesium intake and reduced constipation was shown in the 8th grade population of this study, which was similar to findings in other age groups like infants (aged 3–5 y) (*40*) and adult women (aged 18–20 y) (*16*). In the combined population of 5th and 8th grades, however, the dose-dependent association was not significant, even though the odds ratios of Q3–Q5 were less than 1.

Some existing studies have examined the association between increased bread intake and increased constipation (*16*, *20*, *44*), and only one study found a significant association. In the present study, we found that increased bread intake is related to higher prevalence of functional constipation in 8th graders. Some reasons for this association may be due to the gluten from wheat, which produces allergic reactions, and constipation, in

some people (*45*). While celiac disease is rare in Japanese (0.05%; *46*), increase of bowel symptoms in Canadian immigrant children at a younger age suggests that diet habitual change affects child symptoms (*47*). Additionally, families eating bread as the main staple food may be especially busy in the mornings and this may affect toileting habits (*48*).

This study has many strengths, including a relatively large sample size and statistical control of possible confounding variables, but there are several limitations. First, variables used in this study were obtained using self-reported questionnaires. Although the Brief-Type Self-Reported Diet History Questionnaire used for assessing dietary intake was validated in the population from the same areas, correlations of estimated nutrition intake with biomarkers were lower in 5th graders than in 8th graders (*28*). The Rome III Diagnostic Questionnaire for Pediatric Functional Gastrointestinal (GI) Disorders has reasonable test-retest reliability, but only fair validity when using physician diagnosis (*49*). Second, the cross-sectional design of this study could incompletely explain causality between dietary intake and functional constipation. Intake of dietary fiber and fluid is a first-line treatment in clinical settings, and a recommendation to prevent constipation at the community level. Knowledge about preferable foods is likely to make students with constipation eat more vegetables and fluids, but this might decrease the observational effects in comparison to the true effects. We did not ask the students about habitual use of laxatives, which might attenuate the effect. Third, the participants in this study were 5th and 8th graders in Shunan City. Generalizability of the obtained results to all Japanese school-age children is unknown. In addition to this, we cannot explain the relationship between intake of protein or zinc and the prevalence of functional constipation, although this result for protein is supported by previous studies among preschool children aged 5–6 y (*20*) and adults (*44*), and that for zinc is reported in a study of children aged 7–10 y (*12*).

In conclusion, functional constipation may distress Japanese school-age children and adolescents, and at the same time, dietary habits could reduce the prevalence of functional constipation. Diets rich in fiber, water, and vegetables and fruits have the potential to improve functional constipation, especially in 8th graders. Social environment that influences dietary intake of children may be a target for public health intervention to mitigate children's functional constipation.

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Supporting Information

Supplemental Online Material is available on J-STAGE.

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