Original Article

Dietary diversity score correlates with nutrient intake and monetary diet cost among Japanese adults

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Background and Objectives: Dietary diversity is an indicator of diet quality. Dietary diversity has been suggested to result in good nutrient intake, but it can affect dietary cost. We examined whether dietary diversity correlates with nutrient intake and monetary diet cost. **Methods and Study Design:** We used data for 3985 individuals (age range: 20–64 years) from the 2014 Japan National Health and Nutrition Survey (NHNS). Dietary diversity was assessed using the food variety score (FVS; the number of foods) and dietary diversity score (DDS; the number of food groups, range: 1–14). Mean energy and nutrient intake from NHNS, and diet cost from the National Retail Price Survey were compared among FVS quartiles using the Kruskal-Wallis test, and between 2 groups with median DDS using the Mann-Whitney U test. **Results:** Mean (SD) FVS and DDS per day were 22.3 (7.2) and 9.8 (2.0), respectively. For most nutrients, intake per 4184 kJ was relatively high when FVS was high (p<0.001); however, carbohydrate intake was relatively high in the low-FVS group (p<0.001). For all nutrients with significant differences, intake was higher in the group with high DDS (≥10). Monetary diet cost was higher in the high-FVS and DDS groups compared with the low groups (p<0.001). **Conclusions:** Intake of a variety of food and food groups resulted in higher intake of various nutrients as well as higher monetary diet cost. Additionally, care should be taken to avoid excessive intake of nutrients such as sodium and SFA that may result from diverse diets.

Key Words: food variety, dietary diversity, nutrient intake, monetary diet cost, Japanese adults

INTRODUCTION

Dietary diversity, defined as the number of different foods or food groups consumed over a given reference period,[1] is one of the indicators of diet quality. Many dietary guidelines for healthy eating recommend choosing a variety of nutrient-dense foods.[2,3] Previous studies have shown that increased food diversity contributes to improved nutrient intake, particularly in developing countries.[4-7] In Mali, dietary diversity was found to be useful as an indicator of nutrient adequacy.[4] In Iran, a study conducted among adolescents showed a correlation between dietary diversity and intake of nutrients such as saturated fatty acids (SFA) and dietary fiber.[5] Dietary diversity was also positively and significantly correlated with micronutrient adequacy and fruit and vegetable intake among Mexican men.[6] In a study conducted among women in 5 diverse resource-poor settings, dietary diversity indicators were useful to estimate the proportion of women who met nutrient adequacy. However, these indicators and cutoff points differed by study,[7] because different standards of dietary diversity were used.

The Dietary Guidelines for Japanese[8] recommend to "combine various foods" in the section entitled "Eat well-balanced meals with staple food, as well as main and side dishes." However, these guidelines do not specifically indicate the number of foods recommended. Also, data are lacking regarding the relationship between dietary diversity and nutrient intake in Japan.

In recent years, the relationship between socioeconomic status (SES) and nutrient intake has been examined.[9,10] It has been reported that high-income Japanese adults have high intake of vitamins and dietary fiber,[11] that household income is positively associated with fat intake and inversely associated with carbohydrate intake,[12] and that low-income individuals consume more cereals and less vegetables, fruits, and fish.[13] It was also shown that monetary diet cost was low in the low-income group, resulting in decreased food quality and nutrient intake; that is, monetary diet cost was negatively associated with carbohydrate intake and positively associated with intake of other nutrients (such as vitamins and minerals).[14,15] Jones et al. showed that diets meeting the UK recommendations for key nutrient and food groups were more ex-

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Manuscript received 01 December 2019. Initial review completed 20 January 2020. Revision accepted 29 March 2020.
doi: 10.6133/apjcn.202007_29(2).0021

pensive, especially with regard to fruits and vegetables and oily fat, and suggested that food costs may limit the adoption of dietary recommendations in the UK.[16] In addition, it has been shown that dietary diversity is associated with SES.[4] However, the relationship between dietary diversity-including the number of different foods and food groups eaten- and monetary diet cost has not been examined.

In this study, we used data from the Japanese National Health and Nutrition Survey (NHNS) to examine the relationship between nutrient intake and dietary diversity as assessed by number of different food items and food groups consumed. At the same time, we investigated whether there is a relationship between food diversity and monetary diet cost.

METHODS

Data source and procedure

The NHNS is a national nutrition survey that has been conducted by the Ministry of Health, Labour and Welfare every November since 1945 in accordance with the Health Promotion Law. Details of the NHNS have been published elsewhere.[17,18] The present study used data from the 2014 NHNS, with permission. The 2014 NHNS subjects were household members aged 1 year or older from 5432 households in 300 unit blocks randomly selected by stratification from approximately 11000 unit blocks established for the Comprehensive Survey of Living Conditions, 2014.[19] The following households and individuals were excluded from the survey: households headed by foreigners, individuals who did not have a self-selected diet (e.g., those living in dormitories), individuals who consumed only liquid foods or drugs because of disease, and those who were absent from the household. Of 5432 households, 3648 participated (67.2%), including a total of 8047 individuals. Of these, the following were excluded from our analysis: individuals under 20 years or over 65 years of age, pregnant or nursing women, and individuals with energy intake of this survey over 20920 kJ (5000 kcal). Finally, data from 3985 individuals were used.

The NHNS was conducted in accordance with the guidelines set out in the Declaration of Helsinki, with oral informed consent from each participant. The Ministry of Health, Labour and Welfare anonymized the person-level data collected from the NHNS under the Statistics Act, and provided the dataset for this study to the authors. On the basis of the Ethical Guidelines for Epidemiological Studies established by the Ministry of Education, Culture, Sports, Science and Technology and the Ministry of Health, Labour and Welfare, the analyses conducted for the present study did not require approval by an Institutional Review Board.

Dietary assessment

Dietary intake was investigated using a one-day, semi-weighed household dietary record conducted on a designated day in November, excluding Sundays and national holidays. Details of the dietary intake survey have been published elsewhere.[17,18] Before the survey, trained investigators such as registered dietitians visited the individual who was usually responsible for food preparation in each household (the main record-keeper) and gave written and verbal instructions for how to measure food and beverage quantities and complete the dietary record. The record-keeper weighed and recorded every food and beverage item consumed by household members. Food waste, leftovers, and foods eaten away from home were also recorded. If household members shared food items from the same dish, the proportion of food eaten by each household member was recorded to estimate the dietary intake of each individual. When it was not possible to weigh food items (e.g., when food was eaten away from home), the record-keeper recorded the food ingredients and estimated portion size in as much detail as possible. Dietary records were collected by the trained investigators, who reviewed them for completeness and corrected any missing information or errors.

The trained investigators then converted the estimated portion sizes into weights for each food ingredient and recorded the dietary intake data using software specially developed for this survey. The amounts of food and beverage items consumed and the energy and nutrient intake were calculated for each household member on the basis of the Standard Tables of Food Composition in Japan.[20]

Monetary diet cost

Monetary diet cost was calculated as described previously,[14,15] using retail food prices primarily based on the National Retail Price Survey 2013.[21] This survey is carried out annually in 167 cities, towns, and villages by the Statistics Bureau, the Ministry of Internal Affairs and Communications, and shows the average retail price for a 100-g portion of various major food items. Retail prices were applied to each food and beverage item appearing in the NHNS dietary intake data. The retail prices used were calculated as annual averages for all study areas weighted by population size. For foods to which prices could not be directly applied, prices for similar foods were used. For items with no comparable foods, prices found on the websites of major Japanese online supermarkets (Seiyu or Rakuten) were used.

The price of each food item per amount of food was calculated and the monetary cost of dietary intake per day was determined by linking to individual dietary records from the NHNS. This study used the price of purchased food ingredients that were eaten at home; added costs, such as those for food preparation and service outside the home, were not considered.

Assessment of dietary diversity

Dietary diversity was assessed using two methods: the food variety score (FVS) and the dietary diversity score (DDS). FVS was calculated using a simple count of the individual food items consumed per day or in each meal (breakfast, lunch, dinner, and snacks).[1,4,22] Foods that were consumed multiple times in a day were counted as one food item. Food items were divided into 18 groups based on the Standard Tables of Food Composition in Japan;[20] items not described in the food composition table were classified with similar foods. Food items that had similar nutrient components were counted as identical food items (e.g., raw potatoes and steamed potatoes; pork loin and pork ham). The following food groups were excluded from the count: sugar and sweeteners, beverages, seasonings and spices, and cooked and processed foods.

DDS was calculated by summing the number of food groups consumed per day; consumption of any quantity of food from a particular food group at least once per day or per meal was counted as 1 point.[1,4,22] Fourteen food groups were included in the calculation, giving a range of 1 to 14 points: cereals; potatoes and starches; pulses; nuts and seeds; vegetables; fruits; mushrooms; algae; fish, mollusks, and crustaceans; meat; eggs; milk and milk products; fats and oils; and confectionery. The four food groups excluded from the FVS calculation were also excluded from DDS. Both FVS and DDS scores were counted without considering a minimum intake for each food item or food group.

Statistical analysis

Median energy and nutrient intake, and monetary diet cost were compared among FVS quartiles using the Kruskal-Wallis test and Dunn's multiple comparison test, and between individuals with DDS above or below the median using the Mann-Whitney U test. Nutrient intake and monetary diet cost were adjusted using the density method.

Analyses were conducted using IBM SPSS Statistics 25.0 for Windows (IBM Japan Ltd.). p-values were two-tailed, and $p<0.05$ was considered to be statistically significant.

RESULTS

FVS and DDS per day and by meal

FVS and DDS are shown in Table 1. Mean (standard deviation; SD) FVS and DDS per day were 22.3 (7.2) and 9.8 (2.0), respectively. Median (interquartile range; IQR) FVS and DDS were 22 (17–27) and 10 (8–11), respectively. Median values of FVS and DDS were similar to their respective means. FVS for breakfast and snacks was higher among women, and FVS for lunch was higher among men ($p<0.001$ for all). There were no significant differences in FVS for dinner or per day. DDS was also higher among women for snacks ($p<0.001$). Mean DDS was higher among men for lunch, but median values were the same. Additionally, there was a high positive correlation between FVS and DDS ($r=0.775$, $p<0.001$; Spearman's rank-correlation coefficient).

Energy and nutrient intake by FVS quartile

Table 2-1 shows the comparison of energy intake and adjusted nutrient intake (per 4184 kJ) for all subjects by FVS quartile. FVS ranged from 1-17 for Q1 (n=1027), 18-22 for Q2 (n=1094), 23-27 for Q3 (n=1005), and ≥28 for Q4 (n=859). There were differences among the quartiles for all nutrients. For most nutrients, intake per 4184 kJ was relatively high when FVS was high ($p < 0.001$); however, for carbohydrates, intake was relatively high in the lowest FVS quartile ($p<0.001$).

Results by sex are shown in Table 2-2. Energy and nutrient intake varied by FVS quartile for all nutrients except sodium among men. Similarly, intake of all nutrients except carbohydrates was relatively higher in the highest FVS quartile.

Energy and nutrient intake by DDS category

Table 3-1 and 3-2 show the comparison of energy intake and adjusted nutrient intake (per 4184 kJ) by DDS category (above vs. below the median). The DDS range was 1–9 for the low group (n=1742) and 10–14 for the high group (n=2243). With the exceptions of carbohydrates, energy and nutrient intake was relatively high in the group with high DDS. Similarly, energy and nutrient intake varied by DDS category for all nutrients except carbohydrates, sodium, SFA, and monounsaturated fatty acids among men and carbohydrates, and sodium among women. For all nutrients with significant differences, intake was higher in the high-DDS group.

Monetary diet cost by FVS and DDS category

Table 4 shows a comparison of monetary diet cost by FVS quartile. Median (IQR) monetary diet cost was 745 (566–987) Japanese yen for Q1 (n=1027), 920 (735–1164) Japanese yen for Q2 (n=1094), 1040 (851–1287) Japanese yen for Q3 (n=1005), and 1219 (1004–1467) Japanese yen for Q4 (n=859). Monetary diet cost was relatively higher in the high-FVS group with higher FVS ($p<0.001$).

Table 5 shows a comparison of monetary diet cost by DDS category. Median (IQR) monetary diet cost was 840 (637–1100) Japanese yen for the low-DDS group (n=1742) and 1073 (855–1338) Japanese yen for the high-DDS group (n=2243). Here as well, monetary diet cost was higher in the group with high DDS ($p<0.001$).

DISCUSSION

This study examined the relationship between FVS and DDS and energy and nutrient intake using representative data from Japanese adults. Intake of a larger number of foods and food groups resulted in higher intake of many nutrients. In addition, monetary diet cost increased as food diversity increased.

Mean FVS per day in the 2013 NHNS[23] was 22.3 points; a similar result was found using data from the 2014 NHNS. Both FVS and DDS were low at breakfast, which may have been explained in part by some people skipping that meal. In the 2014 NHNS,[24] the prevalence of skipping breakfast was 14.3% for men and 10.5% for women. It also suggested that some people simply eat breakfast with a small number of food items.

For most nutrients, higher FVS or DDS was related to higher nutrient intake. However, for carbohydrates, nutrient intake decreased as FVS increased. This result is similar to those of previous studies.[5,25] In developing countries, diets based on starchy foods have been found to lack dietary diversity and nutrient intake quality.[1] In Japan as well, diets with a high proportion of carbohydrate-rich staple foods may result in inadequate nutrient intake. Therefore, an increase in FVS or DDS may be correlated with an increase in the intake of food items or food groups with high nutrient density (e.g., vegetables, fruits, meat, and fish), and it may cause nutrient intake quality to improve. Some previous studies have shown that dietary diversity is positively and significantly correlated with intake of fruits and vegetables.[4,7,25] This cannot be concluded from our study, which did not examine food group

Table 1. Food variety and dietary diversity scores

Variable	All (n=3985)			Men (n=1866)			Women (n=2119)			*p*-value§
	Mean	SD	Median (IQR)	Mean	SD	Median (IQR)	Mean	SD	Median (IQR)	
FVS, points†										
Total	22.3	7.2	22 (17–27)	22.2	7.1	22 (17–27)	22.4	7.4	22 (17–27)	0.691
Breakfast	5.5	4.0	5 (2–8)	5.2	4.1	5 (2–8)	5.8	3.9	5 (3–8)	<0.001
Lunch	9.0	5.2	9 (5–12)	9.4	5.1	9 (6–13)	8.6	5.3	8 (5–12)	<0.001
Dinner	11.2	4.5	11 (8–14)	11.3	4.6	11 (8–14)	11.1	4.4	11 (8–14)	0.131
Snacks	1.2	1.8	0 (0–2)	0.9	1.7	0 (0–1)	1.4	1.8	1 (0–2)	<0.001
DDS, points‡										
Total	9.8	2.0	10 (8–11)	9.6	2.0	10 (8–11)	9.9	2.0	10 (9–11)	<0.001
Breakfast	4.0	2.4	4 (2–6)	3.8	2.5	4 (2–6)	4.2	2.3	4 (3–6)	<0.001
Lunch	5.6	2.4	6 (4–7)	5.7	2.4	6 (4–7)	5.4	2.4	6 (4–7)	<0.001
Dinner	6.3	1.9	6 (5–8)	6.3	1.9	6 (5–8)	6.3	1.9	6 (5–8)	0.615
Snacks	0.9	1.3	0 (0–2)	0.7	1.2	0 (0–1)	1.1	1.3	1 (0–2)	<0.001

DDS: dietary diversity score; FVS: food variety score; SD: standard deviation; IQR: interquartile range.
†FVS was calculated as a simple count of the number of different food items consumed.
‡DDS was calculated by summing the number of different food groups consumed.
§For men vs. women, based on the Mann-Whitney U test.

Table 2-1. Nutrient intake by food variety score quartile, all subjects

Nutrient	Q1 (n=1027)	Q2 (n=1094)	Q3 (n=1005)	Q4 (n=859)	p-value†
	1–17	18–22	23–27	≥28	
	Median (IQR)				
Energy (kJ/day)	6540 (5196–8089) BCD	7486 (6238–8947) ACD	8131 (6808–9508) ABD	8734 (7490–10354) ABC	<0.001
Protein (g/4184 kJ)	34.7 (29.4–40.4) BCD	35.6 (31.0–40.6) AD	36.0 (32.0–40.7) AD	37.1 (33.2–42.0) ABC	<0.001
Fat (g/4184 kJ)	28.4 (21.7–35.2) BCD	29.9 (24.5–35.2) AD	30.5 (25.8–36.1) A	31.6 (26.1–36.7) AB	<0.001
Carbohydrate (g/4184 kJ)	139 (123–156) CD	137 (122–152) D	135 (121–148) A	133 (119–149) AB	<0.001
Sodium (mg/4184 kJ)	1954 (1492–2472) D	1938 (1549–2447) D	1980 (1636–2467)	2060 (1675–2459) AB	0.001
Potassium (mg/4184 kJ)	944 (755–1184) BCD	1063 (867–1304) ACD	1141 (950–1382) ABD	1255 (1053–1517) ABC	<0.001
Calcium (mg/4184 kJ)	181 (126–264) BCD	213 (156–299) ACD	239 (177–321) ABD	271 (208–349) ABC	<0.001
Magnesium (mg/4184 kJ)	107 (89–132) BCD	117 (98–139) ACD	124 (105–146) ABD	134 (226–158) ABC	<0.001
Iron (mg/4184 kJ)	3.4 (2.8–4.3) BCD	3.7 (3.0–4.5) ACD	3.9 (3.2–4.7) ABD	4.2 (3.5–5.0) ABC	<0.001
Zinc (mg/4184 kJ)	4.0 (3.4–4.6) BCD	4.1 (3.7–4.7) AD	4.2 (3.7–4.8) A	4.3 (3.8–4.8) AB	<0.001
Vitamin A (μg/4184 kJ)	152 (95–261) BCD	198 (127–295) ACD	219 (146–325) ABD	244 (181–354) ABC	<0.001
Vitamin D (μg/4184 kJ)	1.3 (0.6–4.6) BCD	1.7 (0.8–4.4) ACD	2.1 (1.0–5.3) AB	2.6 (1.2–5.2) AB	<0.001
Vitamin E (mg/4184 kJ)	2.7 (2.0–3.7) BCD	3.1 (2.4–4.1) ACD	3.3 (2.6–4.2) ABD	3.7 (3.0–4.6) ABC	<0.001
Vitamin K (μg/4184 kJ)	77 (39–144) BCD	93 (57–156) ACD	101 (65–170) ABD	115 (78–187) ABC	<0.001
Thiamin (mg/4184 kJ)	0.39 (0.29–0.53) BCD	0.41 (0.33–0.54) AD	0.42 (0.35–0.52) AD	0.45 (0.37–0.53) ABC	<0.001
Riboflavin (mg/4184 kJ)	0.51 (0.39–0.67) CD	0.52 (0.42–0.66) CD	0.55 (0.45–0.68) ABD	0.59 (0.49–0.71) ABC	<0.001
Vitamin C (mg/4184 kJ)	25 (15–44) BCD	35 (22–55) ACD	42 (26–65) ABD	48 (32–70) ABC	<0.001
SFA (g/4184 kJ)	7.33 (5.27–9.90) CD	7.66 (5.79–9.65) D	7.95 (6.06–9.97) AD	8.09 (6.31–10.0) AB	<0.001
MUFA (g/4184 kJ)	9.79 (7.19–12.8) BCD	10.5 (8.10–13.0) A	10.6 (8.42–12.9) A	10.8 (8.63–13.2) A	<0.001
PUFA (g/4184 kJ)	5.63 (4.29–7.42) BCD	6.16 (4.80–7.73) AD	6.39 (5.02–8.12) A	6.67 (5.45–8.29) AB	<0.001
Cholesterol (mg/4184 kJ)	139 (76–216) BCD	156 (93–215) AD	164 (111–218) A	164 (116–218) AB	<0.001
Dietary fiber (g/4184 kJ)	5.9 (4.5–8.2) BCD	6.8 (5.3–8.7) ACD	7.3 (5.7–9.3) ABD	8.0 (6.4–10.0) ABC	<0.001

SFA: saturated fatty acid; MUFA: monounsaturated fatty acid; PUFA: polyunsaturated fatty acid; Q: quartile; IQR: interquartile range.

†Comparison among food variety score quartiles, based on the Kruskal-Wallis test.

A Significant difference vs Q1 ($p<0.05$) by Multiple comparison test by Dunn's method after Kruskal-Wallis test.

B Significant difference vs Q2 ($p<0.05$) by Multiple comparison test by Dunn's method after Kruskal-Wallis test.

C Significant difference vs Q3 ($p<0.05$) by Multiple comparison test by Dunn's method after Kruskal-Wallis test.

D Significant difference vs Q4 ($p<0.05$) by Multiple comparison test by Dunn's method after Kruskal-Wallis test.

Table 2-2. Nutrient intake by food variety score quartile and sex

	Men (n=1866)				
FVS score	Q1 (n= 488)	Q2 (n= 509)	Q3 (n= 473)	Q4 (n= 396)	p-value†
	1–17	18–22	23–27	≥28	
Nutrient	Median (IQR)				
Energy (kJ/day)	7532 (6033–9307)^{BCD}	8566 (7319–10178)^{ACD}	9207 (8039–10676)^{ABD}	10086 (8591–11652)^{ABC}	<0.001
Protein (g/4184 kJ)	33.7 (29.1–39.7)^{CD}	34.7 (29.9–39.7)^{D}	35.3 (31.3–39.8)^{A}	36.3 (32.3–40.3)^{AB}	<0.001
Fat (g/4184 kJ)	27.5 (20.5–33.9)^{BCD}	29.1 (23.3–34.5)^{A}	29.0 (24.0–34.5)^{A}	30.4 (25.2–35.1)^{A}	<0.001
Carbohydrate (g/4184 kJ)	138 (123–156)^{CD}	136 (121–151)^{D}	134 (120–148)^{A}	131 (116–149)^{AB}	<0.001
Sodium (mg/4184 kJ)	1904 (1456–2405)	1875 (1479–2362)	1909 (1544–2386)	1977 (1630–2296)	0.211
Potassium (mg/4184 kJ)	876 (689–1084)^{BCD}	965 (817–1169)^{ACD}	1053 (855–1259)^{ABD}	1163 (975–1352)^{ABC}	<0.001
Calcium (mg/4184 kJ)	159 (114–230)^{BCD}	185 (133–260)^{ACD}	214 (159–283)^{ABD}	240 (186–312)^{ABC}	<0.001
Magnesium (mg/4184 kJ)	102 (85–124)^{BCD}	108 (92–133)^{ACD}	115 (99–135)^{ABD}	126 (109–151)^{ABC}	<0.001
Iron (mg/4184 kJ)	3.2 (2.6–3.9)^{BCD}	3.5 (2.8–4.2)^{AD}	3.6 (3.0–4.3)^{AD}	3.9 (3.3–4.6)^{ABC}	<0.001
Zinc (mg/4184 kJ)	3.9 (3.4–4.5)^{BCD}	4.1 (3.5–4.7)^{A}	4.2 (3.6–4.8)^{A}	4.2 (3.7–4.7)^{A}	<0.001
Vitamin A (µg/4184 kJ)	137 (79–247)^{BCD}	165 (107–257)^{ACD}	184 (129–278)^{ABD}	226 (161–315)^{ABC}	<0.001
Vitamin D (µg/4184 kJ)	1.2 (0.6–4.1)^{CD}	1.6 (0.7–4.1)^{CD}	2.1 (1.0–5.2)^{AB}	2.6 (1.1–5.2)^{AB}	<0.001
Vitamin E (mg/4184 kJ)	2.5 (1.8–3.4)^{BCD}	2.9 (2.1–3.8)^{AD}	3.1 (2.3–3.8)^{AD}	3.5 (2.8–4.2)^{ABC}	<0.001
Vitamin K (µg/4184 kJ)	65 (37–123)^{BCD}	85 (53–148)^{AD}	88 (58–138)^{AD}	106 (73–167)^{ABC}	<0.001
Thiamin (mg/4184 kJ)	0.38 (0.29–0.53)^{D}	0.39 (0.31–0.50)^{D}	0.41 (0.33–0.51)	0.43 (0.35–0.52)^{AB}	0.001
Riboflavin (mg/4184 kJ)	0.47 (0.37–0.62)^{CD}	0.48 (0.39–0.60)^{CD}	0.52 (0.42–0.64)^{ABD}	0.55 (0.45–0.67)^{ABC}	<0.001
Vitamin C (mg/4184 kJ)	22 (13–35)^{BCD}	30 (19–45)^{ACD}	35 (23–53)^{ABD}	39 (27–58)^{ABC}	<0.001
SFA (g/4184 kJ)	6.99 (5.00–9.32)^{D}	7.17 (5.52–9.26)^{D}	7.26 (5.72–9.05)	7.62 (5.98–9.61)^{AB}	0.002
MUFA (g/4184 kJ)	9.71 (6.97–12.7)^{BD}	10.3 (7.96–13.0)^{AD}	10.2 (8.09–12.3)	10.5 (8.46–12.7)^{A}	0.008
PUFA (g/4184 kJ)	5.58 (4.22–7.18)^{BCD}	6.14 (4.80–7.71)^{A}	6.14 (4.90–7.80)^{A}	6.51 (5.37–7.96)^{A}	<0.001
Cholesterol (mg/4184 kJ)	138 (74–212)^{CD}	145 (89–202)^{D}	157 (110–202)^{A}	155 (116–213)^{AB}	<0.001
Dietary fiber (g/4184 kJ)	5.3 (3.9–7.0)^{BCD}	5.9 (4.8–7.5)^{ACD}	6.5 (5.2–8.1)^{ABD}	7.2 (5.8–8.8)^{ABC}	<0.001

SFA: saturated fatty acid; MUFA: monounsaturated fatty acid; PUFA: polyunsaturated fatty acid; Q: quartile; IQR: interquartile range.
†Comparison among food variety score quartiles, based on the Kruskal-Wallis test.
^{A} Significant difference vs Q1 (p<0.05) by Multiple comparison test by Dunn's method after Kruskal-Wallis test.
^{B} Significant difference vs Q2 (p<0.05) by Multiple comparison test by Dunn's method after Kruskal-Wallis test.
^{C} Significant difference vs Q3 (p<0.05) by Multiple comparison test by Dunn's method after Kruskal-Wallis test.
^{D} Significant difference vs Q4 (p<0.05) by Multiple comparison test by Dunn's method after Kruskal-Wallis test.

Table 2-2. Nutrient intake by food variety score quartile and sex (cont.)

	Women (n=2119)				
FVS score	Q1 (n= 539)	Q2 (n= 585)	Q3 (n= 532)	Q4 (n= 463)	*p* -value†
	1–17	18–22	23–27	≥28	
Nutrient	Median (IQR)				
Energy (kJ/day)	5811 (4580–7013)[BCD]	6741 (5765–7767)[ACD]	7260 (6310–8445)[ABD]	7880 (6938–8968)[ABC]	<0.001
Protein (g/4184 kJ)	35.5 (29.8–40.9)[BCD]	36.0 (32.1–41.7)[AD]	36.8 (32.8–41.2)[AD]	37.9 (34.0–42.5)[ABC]	<0.001
Fat (g/4184 kJ)	29.3 (22.4–36.2)[CD]	30.5 (25.4–35.7)[CD]	32.3 (27.4–37.1)[AB]	32.5 (27.2–37.7)[AB]	<0.001
Carbohydrate (g/4184 kJ)	139 (122–156)[CD]	137 (123–152)	135 (122–147)[A]	134 (121–149)[A]	0.001
Sodium (mg/4184 kJ)	2001 (1532–2584)[D]	2008 (1611–2492)[D]	2072 (1716–2518)	2133 (1721–2563)[AB]	0.007
Potassium (mg/4184 kJ)	1016 (827–1291)[BCD]	1154 (928–1427)[ACD]	1222 (1028–1472)[ABD]	1372 (1138–1597)[ABC]	<0.001
Calcium (mg/4184 kJ)	209 (146–286)[BCD]	237 (174–329)[ACD]	271 (197–340)[ABD]	298 (235–371)[ABC]	<0.001
Magnesium (mg/4184 kJ)	114 (94–143)[BCD]	124 (105–145)[ACD]	131 (110–153)[ABD]	143 (122–167)[ABC]	<0.001
Iron (mg/4184 kJ)	3.6 (3.0–4.5)[CD]	3.8 (3.1–4.7)[CD]	4.2 (3.5–5.0)[ABD]	4.5 (3.7–5.2)[ABC]	<0.001
Zinc (mg/4184 kJ)	4.1 (3.4–4.6)[BCD]	4.2 (3.7–4.7)[AD]	4.2 (3.7–4.8)[AD]	4.4 (3.9–4.9)[ABC]	<0.001
Vitamin A (μg/4184 kJ)	162 (107–277)[BCD]	225 (150–330)[ACD]	239 (171–360)[AB]	260 (196–380)[AB]	<0.001
Vitamin D (μg/4184 kJ)	1.4 (0.7–5.0)[CD]	1.7 (0.9–4.9)[D]	2.1 (1.1–5.3)[A]	2.5 (1.2–5.3)[AB]	<0.001
Vitamin E (mg/4184 kJ)	2.9 (2.1–3.9)[BCD]	3.4 (2.6–4.4)[ACD]	3.6 (2.9–4.6)[ABD]	4.0 (3.2–4.9)[ABC]	<0.001
Vitamin K (μg/4184 kJ)	84 (42–164)[BCD]	101 (64–173)[ACD]	112 (73–188)[AB]	125 (82–203)[AB]	<0.001
Thiamin (mg/4184 kJ)	0.40 (0.30–0.53)[BCD]	0.44 (0.35–0.56)[AD]	0.43 (0.37–0.53)[A]	0.47 (0.38–0.55)[AB]	<0.001
Riboflavin (mg/4184 kJ)	0.55 (0.42–0.70)[CD]	0.56 (0.45–0.72)[D]	0.59 (0.48–0.74)[AD]	0.62 (0.53–0.75)[ABC]	<0.001
Vitamin C (mg/4184 kJ)	29 (16–52)[BCD]	40 (25–67)[ACD]	49 (31–75)[ABD]	57 (38–79)[ABC]	<0.001
SFA (g/4184 kJ)	7.55 (5.38–10.3)[CD]	7.99 (6.07–10.0)	8.31 (6.49–10.5)[A]	8.55 (6.69–10.5)[A]	<0.001
MUFA (g/4184 kJ)	9.86 (7.29–13.0)[BCD]	10.6 (8.24–13.0)[A]	11.1 (8.78–13.3)[A]	11.1 (8.82–13.5)[A]	<0.001
PUFA (g/4184 kJ)	5.68 (4.38–7.75)[CD]	6.22 (4.80–7.74)[CD]	6.72 (5.22–8.46)[AB]	6.90 (5.50–8.41)[AB]	<0.001
Cholesterol (mg/4184 kJ)	140 (78–221)[BCD]	164 (100–228)[AD]	171 (112–227)[A]	171 (117–222)[A]	<0.001
Dietary fiber (g/4184 kJ)	6.8 (5.0–9.1)[BCD]	7.4 (5.8–9.3)[ACD]	8.2 (6.5–10.1)[ABD]	8.9 (7.3–11.1)[ABC]	<0.001

SFA: saturated fatty acid; MUFA: monounsaturated fatty acid; PUFA: polyunsaturated fatty acid; Q: quartile; IQR: interquartile range.

†Comparison among food variety score quartiles, based on the Kruskal-Wallis test.

[A] Significant difference vs Q1 (p<0.05) by Multiple comparison test by Dunn's method after Kruskal-Wallis test.

[B] Significant difference vs Q2 (p<0.05) by Multiple comparison test by Dunn's method after Kruskal-Wallis test.

[C] Significant difference vs Q3 (p<0.05) by Multiple comparison test by Dunn's method after Kruskal-Wallis test.

[D] Significant difference vs Q4 (p<0.05) by Multiple comparison test by Dunn's method after Kruskal-Wallis test.

Table 3-1. Nutrient intake by dietary diversity score category, all subjects

Nutrient	All (n= 3985) Low (n=1742) 1–9	High (n=2243) 10–14	p-value†
	Median (IQR)		
Energy (kJ/day)	7051 (5648–8600)	8219 (6858–9768)	<0.001
Protein (g/4184 kJ)	35.1 (30.2–40.7)	36.4 (32.2–40.9)	<0.001
Fat (g/4184 kJ)	29.3 (23.1–35.3)	30.6 (25.4–36.1)	<0.001
Carbohydrate (g/4184 kJ)	136 (121–152)	136 (121–150)	0.251
Sodium (mg/4184 kJ)	1973 (1519–2486)	1990 (1637–2446)	0.040
Potassium (mg/4184 kJ)	977 (802–1244)	1178 (976–1435)	<0.001
Calcium (mg/4184 kJ)	190 (134–270)	250 (188–330)	<0.001
Magnesium (mg/4184 kJ)	109 (90–134)	128 (108–152)	<0.001
Iron (mg/4184 kJ)	3.5 (2.8–4.3)	3.9 (3.3–4.8)	<0.001
Zinc (mg/4184 kJ)	4.1 (3.5–4.6)	4.2 (3.7–4.8)	<0.001
Vitamin A (µg/4184 kJ)	173 (108–281)	225 (153–327)	<0.001
Vitamin D (µg/4184 kJ)	1.4 (0.7–4.6)	2.2 (1.1–5.1)	<0.001
Vitamin E (mg/4184 kJ)	3.0 (2.2–3.9)	3.4 (2.7–4.3)	<0.001
Vitamin K (µg/4184 kJ)	80 (46–144)	107 (70–177)	<0.001
Thiamin (mg/4184 kJ)	0.41 (0.31–0.54)	0.43 (0.35–0.53)	<0.001
Riboflavin (mg/4184 kJ)	0.51 (0.40–0.65)	0.57 (0.46–0.70)	<0.001
Vitamin C (mg/4184 kJ)	29 (17–50)	42 (27–66)	<0.001
SFA (g/4184 kJ)	7.49 (5.56–9.87)	7.97 (6.07–9.90)	<0.001
MUFA (g/4184 kJ)	10.2 (7.70–13.1)	10.6 (8.33–12.9)	0.012
PUFA (g/4184 kJ)	5.87 (4.46–7.66)	6.46 (5.10–8.12)	<0.001
Cholesterol (mg/4184 kJ)	143 (82–211)	164 (113–221)	<0.001
Dietary fiber (g/4184 kJ)	6.2 (4.7–8.3)	7.6 (5.9–9.5)	<0.001

SFA: saturated fatty acid; MUFA: monounsaturated fatty acid; PUFA: polyunsaturated fatty acid; IQR: interquartile range.
†Comparison of high vs low dietary diversity score, based on the Mann-Whitney U test.

Table 3-2. Nutrient intake by dietary diversity score category and sex

Nutrient	Men (n=1866) Low (n=863) 1–9	Men High (n=1003) 10–14	Men p-value†	Women (n=2119) Low (n=879) 1–9	Women High (n=1240) 10–14	Women p-value†
	Median (IQR)	Median (IQR)		Median (IQR)	Median (IQR)	
Energy (kJ/day)	8085 (6519–9927)	9441 (8135–11103)	<0.001	6238 (5012–7419)	7369 (6368–8529)	<0.001
Protein (g/4184 kJ)	34.0 (29.6–39.8)	35.8 (31.4–39.9)	<0.001	35.9 (30.8–41.6)	37.0 (33.0–41.6)	0.002
Fat (g/4184 kJ)	28.4 (22.4–34.4)	29.3 (24.2–34.7)	0.014	30.4 (24.3–36.2)	31.8 (26.6–37.0)	<0.001
Carbohydrate (g/4184 kJ)	135 (120–153)	135 (120–150)	0.374	137 (122–151)	136 (122–150)	0.395
Sodium (mg/4184 kJ)	1907 (1478–2382)	1925 (1562–2354)	0.313	2042 (1581–2605)	2060 (1689–2514)	0.176
Potassium (mg/4184 kJ)	913 (735–1115)	1082 (894–1297)	<0.001	1081 (867–1364)	1267 (1053–1517)	<0.001
Calcium (mg/4184 kJ)	169 (117–239)	221 (165–298)	<0.001	215 (155–297)	280 (210–356)	<0.001
Magnesium (mg/4184 kJ)	104 (85–127)	119 (102–142)	<0.001	116 (96–141)	135 (115–157)	<0.001
Iron (mg/4184 kJ)	3.2 (2.6–4.0)	3.7 (3.1–4.4)	<0.001	3.7 (3.0–4.6)	4.2 (3.5–5.1)	<0.001
Zinc (mg/4184 kJ)	4.0 (3.4–4.6)	4.2 (3.7–4.8)	<0.001	4.1 (3.5–4.7)	4.3 (3.8–4.8)	<0.001
Vitamin A (µg/4184 kJ)	152 (96–249)	200 (135–293)	<0.001	193 (125–314)	241 (173–351)	<0.001
Vitamin D (µg/4184 kJ)	1.2 (0.6–4.0)	2.3 (1.1–5.2)	<0.001	1.5 (0.7–5.1)	2.1 (1.1–5.1)	<0.001
Vitamin E (mg/4184 kJ)	2.8 (2.0–3.7)	3.2 (2.4–3.9)	<0.001	3.2 (2.4–4.2)	3.7 (2.9–4.7)	<0.001
Vitamin K (µg/4184 kJ)	73 (43–130)	96 (64–155)	<0.001	89 (50–156)	119 (76–193)	<0.001
Thiamin (mg/4184 kJ)	0.39 (0.30–0.53)	0.41 (0.33–0.51)	0.014	0.42 (0.33–0.56)	0.44 (0.37–0.54)	0.025
Riboflavin (mg/4184 kJ)	0.47 (0.37–0.60)	0.53 (0.44–0.65)	<0.001	0.55 (0.43–0.70)	0.61 (0.50–0.74)	<0.001
Vitamin C (mg/4184 kJ)	25 (16–40)	37 (24–55)	<0.001	35 (20–63)	49 (31–73)	<0.001
SFA (g/4184 kJ)	7.13 (5.32–9.38)	7.40 (5.74–9.29)	0.054	7.80 (5.73–10.2)	8.31 (6.46–10.3)	<0.001
MUFA (g/4184 kJ)	10.1 (7.59–13.0)	10.2 (8.02–12.6)	0.684	10.4 (7.78–13.2)	10.9 (8.57–13.2)	0.005
PUFA (g/4184 kJ)	5.86 (4.44–7.49)	6.29 (5.03–7.79)	<0.001	5.95 (4.51–7.78)	6.65 (5.22–8.32)	<0.001
Cholesterol (mg/4184 kJ)	142 (82–201)	156 (110–211)	<0.001	145 (83–221)	172 (118–227)	<0.001
Dietary fiber (g/4184 kJ)	5.6 (4.3–7.3)	6.7 (5.4–8.4)	<0.001	7.0 (5.3–9.3)	8.3 (6.6–10.3)	<0.001

SFA: saturated fatty acid; MUFA: monounsaturated fatty acid; PUFA: polyunsaturated fatty acid; IQR: interquartile range.
†Comparison of high vs low dietary diversity score, based on the Mann-Whitney U test.

Table 4. Monetary diet cost by food variety score quartile

Nutrient intake	Q1 1–17		Q2 18–22		Q3 23–27		Q4 ≥ 28		p value†
	n	Median (IQR)	n	Median (IQR)	n	Median (IQR)	n	Median (IQR)	
Monetary diet cost (Japanese yen)									
All (n=3985)	1027	745 (566–987) BCD	1094	920 (735–1164) ACD	1005	1040 (851–1287) ABD	859	1219 (1004–1467) ABC	<0.001
Men (n=1866)	488	844 (635–1102) BCD	509	1016 (793–1289) ACD	473	1148 (919–1430) ABD	396	1358 (1131–1618) ABC	<0.001
Women (n=2119)	539	672 (514–876) BCD	585	855 (703–1046) ACD	532	949 (795–1138) ABD	463	1125 (936–1347) ABC	<0.001
Monetary diet cost (Japanese yen /4184 kJ)									
All (n=3985)	1027	475 (389–583) BCD	1094	506 (432–610) ACD	1005	537 (458–631) ABD	859	578 (496–667) ABC	<0.001
Men (n=1866)	488	456 (369–559) BCD	509	484 (410–577) ACD	473	521 (447–615) ABD	396	563 (475–642) ABC	<0.001
Women (n=2119)	539	487 (407–598) BCD	585	530 (447–631) AD	532	551 (473–644) AD	463	590 (516–679) ABC	<0.001

Q: quartile; IQR: interquartile range.
† Comparison among food variety score quartiles, based on the Kruskal-Wallis test.
A Significant difference vsQ1 ($p<0.05$) by Multiple comparison test by Dunn's method after Kruskal-Wallis test.
B Significant difference vs Q2 ($p<0.05$) by Multiple comparison test by Dunn's method after Kruskal-Wallis test.
C Significant difference vs Q3 ($p<0.05$) by Multiple comparison test by Dunn's method after Kruskal-Wallis test.
D Significant difference vs Q4 ($p<0.05$) by Multiple comparison test by Dunn's method after Kruskal-Wallis test.

Table 5. Monetary diet cost by dietary diversity score category

Nutrient intake	Low 1–9		High 10–14		p-value†
	n	Median (IQR)	n	Median (IQR)	
Monetary diet cost (Japanese yen)					
All (n=3985)	1742	840 (637–1100)	2243	1073 (855–1338)	<0.001
Men (n=1866)	863	933 (710–1230)	1003	1190 (957–1461)	<0.001
Women (n=2119)	879	753 (588–969)	1240	993 (808–1213)	<0.001
Monetary diet cost (Japanese yen /4184 kJ)					
All (n=3985)	1742	496 (413–599)	2243	546 (463–637)	<0.001
Men (n=1866)	863	479 (396–580)	1003	522 (444–619)	<0.001
Women (n=2119)	879	513 (427–620)	1240	562 (480–655)	<0.001

IQR, interquartile range.
†Comparison of high vs low dietary diversity score, based on the Mann-Whitney U test.

intake; however, our results suggest a similar possibility.

Our findings also suggest consideration of cutoff points for FVS and DDS. By comparing the reference values from the Dietary Reference Intakes for Japanese (2015),[26] (adjusted using the density method, based on the Estimated Energy Requirement of the medium activity level) with the actual nutrient intakes for men and women, we found that recommendations for many minerals and vitamins were not met in the highest FVS quartile (≥28 points) or in the high-DDS group (10-14 points). For example, median calcium intakes in FVS Q4 (240 mg/4184 kJ for men; 298 mg/4184 kJ for women) did not meet recommended values (302 [20–29 years], 245 [30–49 years], 286 [50–64 years] mg/4184 kJ/day for men; 333 [20–29 years], 325 [30–49 years], 342 [50–64 years] mg/4184 kJ/day for women). Similarly, median thiamine intakes in FVS Q4 (0.43 g/4184 kJ for men; 0.47 mg/4184 kJ for women) were lower than the recommended values (0.53 [all age categories] mg/4184 kJ/day for men; 0.56 [20–29 years], 0.55 [30–49 years], 0.53 [50–64 years] mg/4184 kJ/day for women). For dietary fiber, median intakes in FVS Q4 (7.2 g/4184 kJ for men; 8.9 g/4184 kJ for women) were close to the recommended values (8.0 g/4184 kJ/day for men [all age categories]; 9.0 g/4184 kJ/day for women [all age categories]).

Recommendations of at least 28 points for FVS and at least 10 points for DDS have been suggested. The study conducted previously in Mali showed that an FVS of at least 20 points and DDS of at least 5 points on an 8-point scale were necessary for an overall nutrient adequacy ratio of 0.75 of the recommended daily allowance.[27] Another study showed that FVS of at least 21 points and DDS of at least 8 points on a 12-point scale were required for adequate nutrient intake among women in Vietnam.[25] A study comparing these two dietary diversity indicators showed that DDS is a stronger determinant of nutrient adequacy than FVS, because increasing the number of food groups consumed has a greater impact on dietary quality than increasing the number of individual foods in the diet.[1] Further investigation of the DDS cutoff value is necessary. Because the present study analyzed only two DDS categories, an appropriate DDS cutoff value cannot be determined from our data.

Our findings also indicated overconsumption of some nutrients such as sodium and SFA, even in the groups with low dietary diversity. Recommended intake of sodium is under 1413 [20–29 years], 1378 [30–49 years], 1451 [50–64 years] mg/4184kJ/day for women, however even median intake in FVS Q1 was above reference values. Among women, sodium intake further increased as the number of foods increased. Similar results were obtained in the low-DDS group. As a consequence of increased the dietary diversity, increased nutrient intake can lead to overconsumption of nutrients, which may then require restriction of intake. Although it has been suggested that dietary diversity may lead to overconsumption of energy and nutrients, consistent results have not been obtained regarding the relationship between dietary diversity and obesity.[28,29] Therefore, it is necessary to examine how to increase dietary diversity without leading to overconsumption of nutrients. In the future, it will be necessary to examine this relationship using finer score divisions, or by assessing the relationship of indicators such as body mass index and SES with dietary diversity.

Intake of higher numbers of foods and food groups was related to higher nutrient intake, but also to higher monetary diet cost. This study used data from the 2013 Retail Price Survey, which may have resulted in underreporting of dietary costs, however, this has negligible impact on our findings concerning trends between FVS/DDS groups. Okubo et al. showed that mean monetary diet cost was 1022 Japanese yen/day,[14] similar to the present finding. They also showed that monetary diet cost was positively associated with intake of protein, dietary fiber, and vitamins and minerals, and negatively associated with carbohydrate intake. Higher diet cost was related to higher intake of pulses, vegetables, fruits, fish, and meat, and lower intake of grains, eggs, and fats and oils.[14] Together, these findings suggest that intake of high–nutrient density foods and increased food diversity require higher dietary cost than a low–nutrient density diet. In addition, previous studies have shown that dietary diversity is associated with SES[4] and that intake of recommended food groups may be limited by food costs.[16] In order to improve diet quality, it may therefore be necessary to secure food expenses.

Limitations

This study has some limitations that should be mentioned. First, although this study examined representative data from Japan, the household response rate was 67.2%. Also, because surveys were completed by household, the response rate of individuals within each household is unknown. Second, dietary intake was investigated using a one-day, semi-weighed household dietary record. The validity of intake estimates from family dietary records has been confirmed for young women,[30] but has not been examined for women of other age groups or for men. Also, because dietary assessment was conducted on only one arbitrarily selected day of November, the possibility of bias, such as seasonal variation, cannot be excluded. Third, because monetary diet cost was estimated from the survey[21] and from websites, it may differ from actual cost. In addition, other costs (e.g., for eating out or ready-made meals) were not considered, nor were any price differences between organic or non-organic and domestic or imported products. However, our methods were similar to those used in previous studies.[14,15]

Conclusion

This study showed that intake of larger variety of food and food groups resulted in higher intake of various nutrients. However, care should be taken to avoid excessive intake of nutrients such as sodium and SFA that may result from diverse diets. In addition, monetary diet cost increased with increasing food diversity. These findings suggest that in order to improve food quality, it may be necessary to secure a certain amount of dietary cost.

ACKNOWLEDGEMENTS

The authors wish to acknowledge Dr Hitomi Okubo, Department of Health Promotion, National Institute of Public Health, for her help in providing food and retail price correspondence table data.

AUTHOR DISCLOSURES
The authors declare no conflict of interest.

This research was funded by a Health and Labour Sciences Research Grant (No. H29- jyunkankitou-ippan-006) from the Ministry of Health, Labour and Welfare, Japan. The Ministry of Health, Labour and Welfare had no role in the study design, data analysis, or writing of this article.

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