

AGE-RELATED 12-YEAR CHANGES IN DIETARY DIVERSITY AND FOOD INTAKES AMONG COMMUNITY-DWELLING JAPANESE AGED 40 TO 79 YEARS

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Abstract: *Objectives:* This study describes trends in dietary diversity and food intake over 12 years according to age at first participation in the study. *Design:* Prospective cohort study. *Setting:* The National Institute for Longevity Sciences - Longitudinal Study of Aging, a community-based study. *Participants:* Participants included 922 men and 879 women who participated in the first study-wave (age, 40-79 years) and also participated in at least one study-wave from the second to seventh study-wave. Study-waves were conducted biennially. *Measurements:* Dietary intake was calculated from 3-day dietary records with photographs. Dietary diversity was determined using the Quantitative Index for Dietary Diversity based on food intake. A mixed-effects model was used to estimate linear changes in dietary diversity and food intake over 12 years according to age at first study-wave. *Results:* Mean (standard deviation (SD)) follow-up time and number of study-wave visits were 9.5 (3.7) years and 5.4 (1.8), respectively. Mean (SD, range) dietary diversity score was 0.86 (0.06, 0.52-0.96) in men and 0.88 (0.04, 0.66-0.96) in women, respectively. Fixed effects for interactions of age and time with dietary diversity score were statistically significant ($p < 0.05$). The slope of dietary diversity among men aged 40 to 55 years increased (40-year-old slope = 0.00093/year, $p < 0.01$; 55-year-old slope = 0.00035/year, $p = 0.04$), with a decreasing trend started at 65 years old, although this trend was not significant (65-year-old slope = -0.00003/year, $p = 0.88$; 79-year-old slope = -0.00057/year, $p = 0.21$). The slope of dietary diversity among women aged 40 to 44 years increased (40-year-old slope = 0.00053/year, $p = 0.02$; 44-year-old slope = 0.00038/year, $p = 0.04$), whereas the slope of dietary diversity among women aged 63 to 79 years decreased (63-year-old slope = -0.00033/year, $p = 0.03$; 79-year-old slope = -0.00092/year, $p < 0.001$). Fruit, milk and dairy intake decreased in men around their 60s; milk and dairy intake decreased in women around their 50s; and beans and fruit intake decreased in women from their 70s. *Conclusion:* Twelve-year longitudinal data showed dietary diversity declined in women in their 60s. In terms of food intake, fruit, milk and dairy intake decreased in both sexes in their 50s and 60s; such declines would lower dietary diversity.

Key words: Dietary diversity, food intake, longitudinal study, Japanese.

Introduction

Several dietary guidelines suggest that eating a variety of foods is healthy (1, 2), and previous epidemiologic studies have indicated that dietary diversity is closely associated with decreased mortality and better nutritional status, cognitive function, and functional capacity (3-5).

Compared with younger subjects, elderly show a higher risk of being nutritionally vulnerable due to eating alone, loss of appetite, or economic considerations (6, 7). Eating alone and lower chewing ability have been shown to be associated with lower dietary diversity (8, 9). Food intake is easily changeable and is affected by various factors associated with aging (10, 11). Older adults have decreased energy intake (12) and might eat a small variety of foods. However, age-related changes in dietary diversity remain unclear.

This study attempted to identify trends in changes to dietary diversity over 12 years in non-institutionalized, community-dwelling, middle-aged and elderly Japanese participants to

clarify age-related changes in dietary diversity. In addition, we also investigated age-related changes in food intake, to understand what kinds of foods that comprise dietary diversity increase and decrease with aging.

Methods

Participants

Data for this survey were collected as part of the National Institute for Longevity Sciences - Longitudinal Study of Aging (NILS-LSA), a community-based study. In this project, the normal aging process has been assessed using detailed questionnaires and medical checkups, anthropometrical measurements, physical fitness tests, and nutritional examinations over time. Details of the NILS-LSA have been reported elsewhere (13). The initial survey of the NILS-LSA involved 2,267 men and women aged between 40 and 79 years, including approximately 300 men and 300 women for each decade of life. Participants included were sex- and decade of

age-stratified randomly sampled individuals living in Obu-shi and Higashiura-cho, Aichi Prefecture, Japan. These subjects had been followed-up every 2 years from the first study-wave (November 1997 - April 2000) to the second study-wave (April 2000 - May 2002), third study-wave (May 2002 - May 2004), fourth study-wave (June 2004 - July 2006), fifth study-wave (July 2006 - July 2008), sixth study-wave (July 2008 - July 2010), and seventh study-wave (July 2010 - July 2012). Study-waves were conducted biennially; the total interval from first through seventh study-waves was 15 years.

When participants could not be followed-up (e.g., moved to another area, dropped out for personal reasons, or died), new age decade- and sex-matched participants were randomly recruited. All study-waves included approximately 1200 men and 1200 women. For this study, we selected participants who had participated in both the first study-wave ($n=2,267$; age range, 40-79 years) and at least one study-wave from the second to seventh study-wave ($n=1,919$), as variables could be followed up at least once after the first study-wave. Individuals who did not complete nutritional assessments in any study-wave ($n=118$) were excluded. Thus, a total of 1,801 Japanese individuals (922 men, 879 women) between 40 and 79 years in the first study-wave of the NILS-LSA were available for analysis. To simplify the analysis, age at first participation was used in all analyses.

Written informed consent was obtained from all participants. The Ethics Committee of the National Center for Geriatrics and Gerontology approved all procedures of the NILS-LSA.

Nutritional assessments

Nutritional intake was assessed using a 3-day dietary record in all study-wave surveys. The dietary record was completed over 3 continuous days (2 weekdays and 1 weekend day) (14), and most participants completed records at home and returned them within 1 month. Food was weighed separately on a scale (1-kg kitchen scales; Sekisui Jushi, Tokyo, Japan) before being cooked, or portion sizes were estimated. Participants used a disposable camera (27 shots; Fuji Film, Tokyo, Japan) to take photos of meals before and after eating. Dietitians used these photos to complete missing data and telephoned participants to resolve any discrepancies or obtain further information as necessary. Averages for 3-day food and nutrient intake (including alcohol intake) were calculated according to the Standard Tables of Foods Composition in Japan 2010 and other sources (14, 15).

Dietary diversity was determined using the Quantitative Index for Dietary Diversity (QUANTIDD) (16). QUANTIDD is calculated using the proportion of foods that contribute to total energy, or the amount of foods and the number of food groups. The index ranges from 0 to 1, with lower scores indicating an unbalanced diet, and higher scores indicating a more equal distribution of each food group. We calculated the score based on the amount of 13 food groups (cereals, potatoes, beans, nuts and seeds, non-green yellow vegetables, green yellow

vegetables, fruit, mushrooms, seaweed, fish and shellfish, meats, eggs, and milk and dairy products), excluding beverages and seasonings according to the Japanese food composition table (15).

Other measurements

Weight and height were measured under a fasting state (around 9-10 am) to the nearest 0.1 kg and 0.1 cm, respectively, with participants wearing light clothing and no shoes. Body mass index (BMI) was calculated as the body weight in kilograms divided by the square of the height in meters. Education (years of school), and smoking status (yes/no) were collected using self-reported questionnaires. These measurements were assessed in the first study-wave. Follow-up time (years) was calculated by the length of time (days) that has elapsed since the day each participant entered the first study-wave.

Statistical analyses

All statistical analyses were conducted using SAS version 9.3 software (SAS Institute, Cary, NC) and were performed separately by sex. The mixed-effects model (Proc Mixed) was used for analyses of repeated measures of dietary diversity or each food intake. This method is a generalized form of linear regression analysis that allows for repeated measures of each participant while accounting for the considerable variation across participants in overall average dietary diversity or intake of each food. Analytical models included the fixed effects of baseline age, follow-up time from baseline, and the interaction of age and time, which showed the mean-level intercept and slope of dietary diversity or each food intake. Models also included the random effects of intercept and time, which account for subject-specific deviation from the mean-level intercept and slope. In addition, mixed-effects model can handle missing data, so we were able to use all variable data during follow-up. Linear changes in dietary diversity or food intake for 12 years by baseline age (4-year separations) were estimated using the coefficients in the models. To exclude the effect of energy intake on dietary diversity or food intake, we further adjusted energy intake in the mixed-effects model.

All reported p values were two-sided. Values of $p < 0.05$ were considered statistically significant.

Results

Mean (standard deviation (SD), range) follow-up time and number of study-wave visits in participants were 9.5 (3.7, 1.9-13.6) years and 5.4 (1.8, 2-7), respectively.

Characteristics and nutrient intake at first participation are shown in Table 1. Mean age of study participants was 58.6 (10.5) years for men and 57.8 (10.5) years for women. Average energy intake and dietary diversity score were 2346.6 (408.1) kcal/day and 0.86 (0.06) in men and 1913.2 (318.3) kcal/day and 0.88 (0.04) in women, respectively.

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Table 1
Characteristics and nutrient intakes at first participation

	Men (n=922)	Women (n=879)
	Mean ± SD	Mean ± SD
Age (years)	58.6 ± 10.5	57.8 ± 10.5
Body mass index (kg/m ²)	23.1 ± 2.8	22.9 ± 3.2
Education (years)	12.2 ± 2.5	11.5 ± 2.1
Dietary diversity score ^a	0.86 ± 0.06	0.88 ± 0.04
Food intakes (g/day)		
Cereals	531.5 ± 146.4	392.5 ± 103.8
Potatoes	53.4 ± 40.9	49.8 ± 37.1
Beans	75.1 ± 54.8	61.4 ± 46.7
Nuts and seeds	3.9 ± 7.6	4.6 ± 8.6
Non-green yellow vegetables	191.5 ± 91.8	167.4 ± 69.8
Green yellow vegetables	114.3 ± 72.3	114.6 ± 66.9
Fruits	139.4 ± 120.6	160.5 ± 117.6
Mushrooms	12.7 ± 13.4	12.5 ± 13.6
Seaweed	10.1 ± 11.2	9.1 ± 16.4
Fish and shellfish	111.1 ± 54.0	87.5 ± 46.0
Meats	71.8 ± 41.7	54.6 ± 32.0
Eggs	52.2 ± 28.3	43.1 ± 24.9
Milk and dairy products	145.5 ± 131.7	172.1 ± 130.3
Nutrient intakes		
Energy (kcal/day)	2346.6 ± 408.1	1913.2 ± 318.3
Protein (g/day)	88.2 ± 17.1	74.4 ± 14.8
Fat (g/day)	60.9 ± 17.3	54.1 ± 15.3
Carbohydrate (g/day)	325.8 ± 66.2	274.4 ± 51.3
Alcohol (g/day)	16.6 ± 19.2	2.9 ± 5.9
Smoking status, n (%)		
Current	332 (36.0)	61 (7.0)
Former	381 (41.3)	26 (2.9)
Never	209 (22.7)	792 (91.1)

SD, standard deviation; a. Dietary diversity scores range from 0 to 1. Higher scores represent greater dietary diversity.

The mixed-effects models estimates for dietary diversity score and food intakes for 12 years in men and in women are shown in Tables 2 and 3, respectively. In both men and women, fixed effects of the interaction of age and time with dietary diversity score were statistically significant ($p < 0.05$). Therefore, the slope of dietary diversity score was different by age at baseline. When we estimated the slope of dietary diversity score according to age at baseline, the slope of dietary diversity among men aged 40 to 55 years increased (40-year-old slope = 0.00093/year, $p < 0.01$; 55-year-old slope = 0.00035/year, $p = 0.04$), and a decreasing trend started at 65 years old, although this trend was not significant (65-year-old slope = -0.00003/year, $p = 0.88$; 79-year-old slope = -0.00057/year, $p = 0.21$).

Figure 1

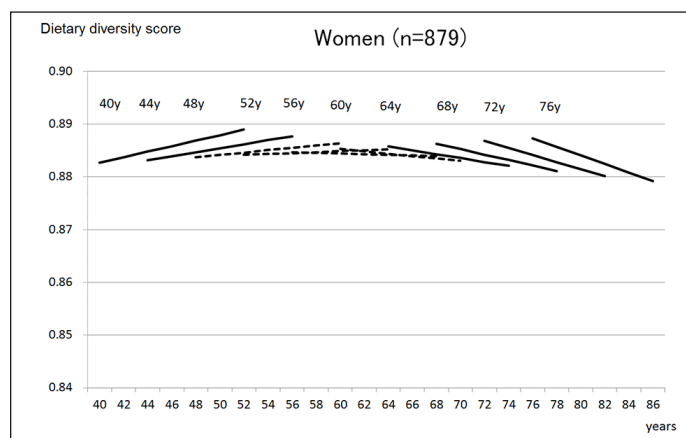
Estimated linear changes in dietary diversity score^a for 12 years^b by 4-year age groups at baseline in men



Solid line represents a significant slope ($p < 0.05$); Dashed line represents a non-significant slope ($p \geq 0.05$); a. Dietary diversity scores range from 0 to 1. Higher scores represent greater dietary diversity. b. The entire follow-up period in individuals was 12 years from the first to seventh study-waves.

Figure 2

Estimated linear changes in dietary diversity score^a for 12 years^b by 4-year age groups at baseline in women



Solid line represents a significant slope ($p < 0.05$); Dashed line represents a non-significant slope ($p \geq 0.05$); a. Dietary diversity scores range from 0 to 1. Higher scores represent greater dietary diversity. b. The entire follow-up period in individuals was 12 years from the first to seventh study-waves.

On the other hand, the slope of dietary diversity among women aged 40 to 44 years increased (40-year-old slope = 0.00053/year, $p = 0.02$; 44-year-old slope = 0.00038/year, $p = 0.04$), whereas the slope of dietary diversity among women aged 63 to 79 years decreased (63-year-old slope = -0.00033/year, $p = 0.03$; 79-year-old slope = -0.00092/year, $p < 0.001$). To simplify these findings, Figures 1 and 2 show estimated linear changes in dietary diversity score for 12 years using 4-year age groups at baseline (40, 44, 48, 52, 56, 60, 64, 68, 72, and 76 years old) in men and women, respectively.

In terms of the food intake items used to determine dietary

Table 2
Mixed-effects model estimates for dietary diversity score and food intakes for 12 years^a in men (n = 922)

	Fixed effects							
	Age ^b		Time ^c		Age ^b *Time		Energy intake ^d	
	$\beta \pm SE$	p	$\beta \pm SE$	p	$\beta \pm SE$	p	$\beta \pm SE$	p
Dietary diversity score ^e	0.00077 ± 0.00017	<.0001	0.00247 ± 0.00104	0.0178	-0.00004 ± 0.000018	0.0354	-	
Food intakes (g/day)								
Cereals	-1.128 ± 0.414	0.006	-2.283 ± 2.509	0.363	-0.041 ± 0.044	0.355	-	
Potatoes	0.132 ± 0.100	0.188	-1.053 ± 0.852	0.216	0.005 ± 0.015	0.721	-	
Beans	0.489 ± 0.144	0.001	0.706 ± 1.068	0.509	-0.016 ± 0.019	0.399	-	
Nuts and seeds	0.029 ± 0.018	0.103	0.129 ± 0.153	0.401	-0.003 ± 0.003	0.219	-	
Non-green yellow vegetables	0.141 ± 0.255	0.579	4.877 ± 2.069	0.019	-0.059 ± 0.036	0.103	-	
Green yellow vegetables	1.331 ± 0.195	<.0001	2.713 ± 1.558	0.082	-0.041 ± 0.027	0.133	-	
Fruits	2.743 ± 0.334	<.0001	7.684 ± 2.351	0.001	-0.142 ± 0.041	0.001	-	
Mushrooms	-0.018 ± 0.036	0.630	-0.149 ± 0.286	0.603	0.000 ± 0.005	0.963	-	
Seaweed	0.119 ± 0.042	0.004	-0.058 ± 0.411	0.888	0.014 ± 0.007	0.046	-	
Fish and shellfish	0.053 ± 0.148	0.720	-0.367 ± 1.060	0.729	-0.013 ± 0.019	0.494	-	
Meats	-1.320 ± 0.103	<.0001	1.270 ± 0.848	0.135	-0.022 ± 0.015	0.132	-	
Eggs	-0.127 ± 0.076	0.093	-0.761 ± 0.561	0.175	0.001 ± 0.010	0.892	-	
Milk and dairy products	1.545 ± 0.387	<.0001	4.234 ± 2.486	0.089	-0.086 ± 0.044	0.047	-	
Dietary diversity score ^{e,f}	0.00081 ± 0.00017	<.0001	0.00249 ± 0.00104	0.017	-0.00004 ± 0.00002	0.034	0.000006 ± 0.000004	0.161
Food intakes (g/day) ^{e,f}								
Cereals	-0.256 ± 0.377	0.498	-1.835 ± 2.521	0.467	-0.05001 ± 0.044	0.257	0.109 ± 0.008	<.0001
Potatoes	0.221 ± 0.100	0.026	-0.942 ± 0.853	0.270	0.003 ± 0.015	0.835	0.011 ± 0.002	<.0001
Beans	0.624 ± 0.144	<.0001	0.807 ± 1.067	0.450	-0.018 ± 0.019	0.341	0.017 ± 0.003	<.0001
Nuts and seeds	0.040 ± 0.018	0.028	0.144 ± 0.153	0.348	-0.004 ± 0.003	0.180	0.001 ± 0.0003	<.0001
Non-green yellow vegetables	0.495 ± 0.250	0.048	5.066 ± 2.071	0.015	-0.063 ± 0.036	0.083	0.044 ± 0.005	<.0001
Green yellow vegetables	1.514 ± 0.194	<.0001	2.862 ± 1.560	0.067	-0.044 ± 0.027	0.107	0.023 ± 0.004	<.0001
Fruits	3.059 ± 0.334	<.0001	7.845 ± 2.352	0.001	-0.146 ± 0.041	0.0004	0.040 ± 0.008	<.0001
Mushrooms	-0.002 ± 0.037	0.951	-0.133 ± 0.286	0.642	-0.001 ± 0.005	0.912	0.002 ± 0.001	0.009
Seaweed	0.143 ± 0.042	0.001	-0.038 ± 0.411	0.926	0.014 ± 0.007	0.052	0.003 ± 0.001	0.001
Fish and shellfish	0.246 ± 0.146	0.092	-0.235 ± 1.059	0.825	-0.015 ± 0.019	0.408	0.024 ± 0.003	<.0001
Meats	-1.190 ± 0.100	<.0001	1.396 ± 0.851	0.101	-0.025 ± 0.015	0.095	0.016 ± 0.002	<.0001
Eggs	-0.072 ± 0.076	0.342	-0.706 ± 0.561	0.209	0.0002 ± 0.010	0.981	0.007 ± 0.001	<.0001
Milk and dairy products	1.899 ± 0.387	<.0001	4.379 ± 2.489	0.079	-0.089 ± 0.044	0.040	0.044 ± 0.009	<.0001

SE, standard error; a. The entire follow-up period in individuals was 12 years from the first to seventh study-waves; b. Age (year) at first participation; c. Time (year) from baseline; d. Energy intake (kcal/day) at first participation; e. Dietary diversity scores range from 0 to 1. Higher scores represent greater dietary diversity; f. Adjusted for energy intake

diversity score, significant findings (p<0.05) were seen for the fixed effect of the interaction of age and time with fruit, seaweed, and milk and dairy products in men, and for beans, fruit, and eggs in women. After adjusting for energy intake, the slope for fruit among men aged 40 to 46 years increased, whereas the slope decreased for men aged 60 to 79 years. The slope for milk and dairy products among men aged 59 to 79 years decreased. For women, when we adjusted for energy intake, the slope for beans among women aged 40 to 54 years increased, whereas the slope for women aged 73 to 79 years decreased. The slope for fruit among women aged 40 to 42 years increased, whereas that for women aged 72 to 79 years

decreased. The slope for milk and dairy products among women aged 49 to 79 years decreased.

Discussion

Twelve-year longitudinal data showed that dietary diversity increased in both men and women until middle age (55 years in men, 44 years in women), and declined in women aged 63-79 years. When we focused on declined intakes of specific foods, we found that fruit and milk and dairy products intake decreased in men around their 60s; milk and dairy products

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Table 3
Mixed-effects model estimates for dietary diversity score and food intakes for 12 years^a in women (n=879)

	Fixed effects							
	Age ^b		Time ^c		Age*Time		Energy intake ^d	
	$\beta \pm SE$	p	$\beta \pm SE$	p	$\beta \pm SE$	p	$\beta \pm SE$	p
Dietary diversity score ^e	0.00013 ± 0.00012	0.2941	0.00202 ± 0.00072	0.0052	-0.00004 ± 0.000013	0.004	-	
Food intakes (g/day)								
Cereals	0.167 ± 0.297	0.574	-1.642 ± 1.720	0.340	-0.008 ± 0.031	0.783	-	
Potatoes	0.294 ± 0.092	0.001	0.335 ± 0.768	0.663	-0.018 ± 0.014	0.194	-	
Beans	0.578 ± 0.129	<.0001	3.916 ± 1.148	0.001	-0.065 ± 0.020	0.002	-	
Nuts and seeds	0.030 ± 0.020	0.141	0.109 ± 0.155	0.482	-0.003 ± 0.003	0.210	-	
Non-green yellow vegetables	0.182 ± 0.202	0.367	4.221 ± 1.694	0.013	-0.044 ± 0.030	0.151	-	
Green yellow vegetables	1.231 ± 0.186	<.0001	2.256 ± 1.502	0.133	-0.032 ± 0.027	0.224	-	
Fruits	1.727 ± 0.343	<.0001	5.241 ± 2.301	0.023	-0.093 ± 0.041	0.023	-	
Mushrooms	0.030 ± 0.038	0.426	0.306 ± 0.291	0.295	-0.008 ± 0.005	0.112	-	
Seaweed	0.156 ± 0.044	0.0004	1.024 ± 0.416	0.014	-0.007 ± 0.007	0.370	-	
Fish and shellfish	-0.031 ± 0.123	0.799	-0.614 ± 0.865	0.478	-0.006 ± 0.015	0.705	-	
Meats	-0.773 ± 0.085	<.0001	0.034 ± 0.665	0.959	-0.002 ± 0.012	0.866	-	
Eggs	-0.235 ± 0.069	0.001	-2.247 ± 0.496	<.0001	0.032 ± 0.009	0.0002	-	
Milk and dairy products	0.438 ± 0.371	0.238	1.600 ± 2.333	0.493	-0.053 ± 0.042	0.205	-	
Dietary diversity score ^{e,f}	0.00019 ± 0.00013	0.125	0.00203 ± 0.00072	0.005	-0.00004 ± 0.00001	0.004	0.000012 ± 0.000004	0.002
Food intakes (g/day) ^{e,f}								
Cereals	0.660 ± 0.275	0.017	-1.569 ± 1.721	0.362	-0.011 ± 0.031	0.732	0.093 ± 0.008	<.0001
Potatoes	0.351 ± 0.092	0.0001	0.366 ± 0.766	0.633	-0.019 ± 0.014	0.174	0.011 ± 0.002	<.0001
Beans	0.651 ± 0.129	<.0001	3.958 ± 1.149	0.001	-0.066 ± 0.021	0.001	0.014 ± 0.003	0.0001
Nuts and seeds	0.043 ± 0.020	0.030	0.113 ± 0.156	0.467	-0.004 ± 0.003	0.194	0.003 ± 0.0005	<.0001
Non-green yellow vegetables	0.381 ± 0.200	0.057	4.283 ± 1.691	0.012	-0.045 ± 0.030	0.137	0.037 ± 0.006	<.0001
Green yellow vegetables	1.421 ± 0.182	<.0001	2.330 ± 1.500	0.121	-0.034 ± 0.027	0.200	0.035 ± 0.005	<.0001
Fruits	2.187 ± 0.331	<.0001	5.367 ± 2.299	0.020	-0.096 ± 0.041	0.019	0.086 ± 0.009	<.0001
Mushrooms	0.039 ± 0.038	0.301	0.310 ± 0.291	0.288	-0.008 ± 0.005	0.107	0.002 ± 0.001	0.069
Seaweed	0.173 ± 0.044	<.0001	1.032 ± 0.416	0.013	-0.007 ± 0.007	0.357	0.003 ± 0.001	0.0101
Fish and shellfish	0.076 ± 0.121	0.531	-0.574 ± 0.866	0.508	-0.007 ± 0.015	0.654	0.020 ± 0.003	<.0001
Meats	-0.703 ± 0.084	<.0001	0.069 ± 0.666	0.959	-0.003 ± 0.012	0.814	0.013 ± 0.002	<.0001
Eggs	-0.189 ± 0.069	0.006	-2.228 ± 0.497	<.0001	0.032 ± 0.009	0.0003	0.009 ± 0.002	<.0001
Milk and dairy products	0.875 ± 0.360	0.015	1.732 ± 2.335	0.459	-0.086 ± 0.044	0.047	-0.056 ± 0.042	0.178

SE, standard error; a. The entire follow-up period in individuals was 12 years from the first to seventh study-waves; b. Age (year) at first participation; c. Time (year) from baseline; d. Energy intake (kcal/day) at first participation; e. Dietary diversity scores range from 0 to 1. Higher scores represent greater dietary diversity; f. Adjusted for energy intake

intake decreased in women around their 50s; and beans and fruit intake decreased in women from their 70s.

Dietary diversity increased until middle age in both sexes. In Japan, nationwide health checkups are done in middle-aged workers or community dwellers (aged 40 and older), and some nutritional guidance is provided to those with risk factors for metabolic syndrome or lifestyle-related diseases. Therefore, increases in diet- or food-consciousness among middle-aged people may affect food intake, and dietary diversity might increase with age.

However, this study showed a decreased trend of

dietary diversity starting at age 65 years in men, although these findings were not statistically significant. In women, a statistically negative association was shown among those aged 63 to 79 years. Higher dietary variety is associated with better nutritional status among the elderly (17), and we have previously reported lower dietary diversity and lower dairy product intake as risk factors for declines in cognitive or functional level among community-dwelling individuals (4, 5, 18). Dietary diversity has been associated with sociodemographic factors such as age, marital status, or education in Americans (19). Among elderly Japanese

living alone, higher dietary diversity was associated with higher income or educational level (20). In general, raw fruit, vegetables, or milk and dairy products need to be fresh to provide the most nutritional value, and fruit, and milk and dairy products are difficult to grow in homes or the community. On the other hand, several kinds of vegetable are easily grown in a community. In addition, these foods are heavy, and it may be difficult for the elderly to carry them home from a store, which may contribute to them eating less of them. Therefore, the financial ability to buy fresh fruit and dairy products, or an increased access to foods (21) might confound the association between the dietary diversity and aging.

Soy-based foods or beans that contain high levels of flavonoids and plant proteins have been recognized as healthy foods (22), particularly for elderly women after menopause. In this study, bean intake decreased among women from their 70s. Among elderly nursing home residents (75% women) in Belgium, more than 60% showed a protein intake below the recommended level (23). To prevent declines in food variety and achieve sufficient protein intake, the best approach may be for health professionals, the government, and dietary guidelines to encourage consumption of more fruit and dairy products for elderly men and women, and eating more beans for elderly women when intake of these food groups is low. In fact, nutritional interventions such as videoconferencing for elderly community-dwelling individuals has been reported as a well-accepted and feasible method for providing nutritional advice in Finland (24). Energy, protein and nutrient intakes in these individuals increased via home-based interventions.

Interestingly, dietary diversity was higher in women than in men at all ages (data not shown). This better nutritional status in the former group might contribute to the longer life expectancy of women.

The main strengths of the present study were as follows. First, trends in dietary diversity and food intakes were assessed longitudinally. Second, trends in these variables were analyzed by age at first participation. Food consumption among Japanese has changed during the past few decades (25, 26). In addition, differences in diet by age and birth cohort have been reported (25, 27). Therefore, examination of data separated by age (birth cohort) is essential to understand trends in food intake among Japanese participants. To the best of our knowledge, no previous studies have longitudinally assessed dietary diversity according to birth cohort group. Third, a Swedish study identified large individual differences in energy intake among elderly individuals (28), but we considered such individual differences as random effects in our mixed-effects model. Finally, the average dietary intake for participants younger than 70 years in the present study was similar to that reported in the National Nutrition Survey in Japan (29). The present results may thus be more applicable in non-institutionalized, community-dwelling, middle-aged and elderly participants.

Our study had several limitations. First, we assessed nutritional intake using 3-day dietary records with photographs.

Three-day dietary records offer one of the best methods to assess individual food intake (14), but might be difficult for men or the elderly in Japan to complete. However, more than half of the male or elderly participants in this study asked a spouse, child, or daughter-in-law who usually cooked to record their dietary intake. Therefore, the reliability of dietary records might be maintained even in men or the elderly.

Second, 3-day dietary records might be too short a period to assess dietary diversity. Indices for evaluating diversity in different studies have used a range of evaluation methods, including indices based on the number of different items consumed (3, 30), qualitative evaluations such as the extent to which national nutritional guidelines are met (19, 31), and, in the present study, diversity from the variation between food groups (32). Differences between these indices need to be investigated, and the reproducibility of results where different indices have been used must be confirmed.

Third, we used the mixed-effects model to evaluate dietary diversity and food intakes. This method is a generalized form of linear regression analysis, but non-linear analyses (for example, a two-dimensional model) would be better to assess age-related changes in these factors.

Conclusions

Twelve-year longitudinal data showed that dietary diversity declined in women in their 60s. To prevent this decline in diversity, dietary guidelines should encourage elderly men and women to consume more fruit and milk and dairy products, and elderly women to eat more beans, when intake of these food groups is low.

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Conflicts of interest: All authors declare no conflict of interest.

Ethics Statement: The NILS-LSA followed the principles of the Declaration of Helsinki and the Ethical Guidelines for Epidemiological Research in Japan. The study was approved by the Ethics Committee of the National Center for Geriatrics and Gerontology (No. 644-2). Written informed consent was obtained from all participants.

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