Original Article

Food and nutrient intakes and overall survival of elderly Japanese

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As part of the International Union of Nutritional Sciences (IUNS) Food Habits in Later Life Project, a group of 89 free-living Japanese aged 70 years and over (43 men and 46 women) residing in semiurban Okazaki, located in the middle of Honshu Island in Japan, were studied. They were followed up in order to determine whether nutrition plays a role in Japanese longevity. Information on food and nutrient intake was collected at study entry. During 55 months follow-up, eight men and five women died. The consumption of various food groups, after adjustment for energy intake to 10.5 MJ for men and 8.4 MJ for women, was similar for survivors and deceased, but there was a greater consumption of mushrooms and fats and oils among the survivors ($P < 0.05$). Furthermore, survivors had a higher intake of total n-3 fatty acids, especially alpha-linolenic acid, compared with the deceased ($P < 0.05$). Subjects who were not chronically energy deficient (BMI ≥ 18.5 kg/m^2) showed a better survival probability with a higher intake of total n-3 fatty acids (≥ 2.1 g/day, 25th percentile). A similar result for total n-3 fatty acids and alpha-linolenic acid was found using Cox proportional hazards analyses adjusted for age, gender and smoking status ($P < 0.05$). After adjustment for bodyweight, the conditionally essential amino acid tyrosine was higher in women who survived ($P < 0.05$). These findings suggest that the intake of n-3 fatty acids and of certain amino acids might be particularly important in elderly people for living longer.

Key words: elderly, Japanese, Okazaki, mortality, n-3 fatty acids, alpha-linolenic acid, food intake, nutrient intake, amino acid, tyrosine.

Introduction

Japanese people are known to have one of the longest life expectancies in the world. The life expectancy at birth for Japanese by the year 2050 is projected to be 81.3 years for men and 88.7 years for women.[1] Additionally, by the year 2020 it is predicted that nearly 25% of the entire population in Japan will be aged 65 years and over.[2] Japanese are therefore one of the best populations for the study of human longevity.[3] Their diet may play a key role in promoting longevity,[2–6] in addition to other factors such as social network, social activity, physical activity and environmental factors.[4–6]

There are limited studies describing the food intake of the Japanese in Japan in relation to survival.[7,8] Studies of food intake of elderly Japanese in relation to longevity have the advantage of mortality rates high enough for smaller sample sizes. Thus, Japanese food patterns, which include high intakes of putatively protective foods such as fish, pulses, mushrooms, seaweed and possibly soybean oil, which are sources of alpha-linolenic acid, along with other nutrients, can be evaluated more readily.[9]

As a background to studies of food habits and survival among the aged, it is instructive to consider specific causes of mortality that might be amenable to minimization by food and inform the food inquiry in any study of total survival.[10,11]

There are a number of studies showing the beneficial effect of the intake of n-3 fatty acids, either from fish or plants, on mortality.[12–15] However, limited data are available on the n-3 fatty acid consumption by people in their later years and how this influences longevity.

There is emerging evidence that certain amino acids, namely excessive homocysteine in peripheral blood and inadequate intakes of arginine (as a precursor to the vasodilator nitric oxide) and lysine (for adequate protein synthesis), may be contributing to the development of macrovascular disease. More studies are needed in order to determine the effect of amino acid composition, including their relationships with each other, on longevity in the elderly.

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We have conducted an observational study from 1991 to 1996 with baseline food intake data and cumulative (55 months follow-up) mortality data. In this paper we report the food and nutrient intakes of 89 Japanese men and women aged 70 years and over. We were particularly interested in the effects of n-3 fatty acids and amino acids on the overall survival of elderly Japanese.

Subjects and methods

Subjects

In September 1991, a group of 43 men and 46 women aged 70 years and over were recruited for the Food Habits in Later Life Project (FHILL).[10] The FHILL project was approved by the Monash University Ethics Committee and Nagoya City University Human Ethics Committee. Subjects were randomly selected from the City Hall Population Register for residents living in semiurban Okazaki-Shi (Okazaki City), located in the prefecture of Aichi in Honshu Island, Japan. None of the subjects were hospitalized or institutionalized. There were 21 (10 men and 11 women) who lived alone, 27 (15 men and 12 women) who lived with their spouse and 41 (18 men and 23 women) who lived with some other family member. One subject did not participate in the follow-up. The subjects were representative of their community, but were not necessarily representative of the entire country. Details of subjects and methods have been reported elsewhere.[10]

Food and nutrient intakes

A 24-h weighed-food record was used to obtain information on food and nutrient intake for three consecutive days. Each subject was asked to weigh the foods they ate, using portable scales provided by the research team. This was done prior to the interview about all dishes and foods consumed.

The intakes of food and nutrients including amino acids and fatty acids were assessed using two commercially available software programs: NUTAS 4 (Software Developing Co. Ltd, Tokyo, Japan), and HEALTH MAKE WIN Version 1.0 (Health Make Institute, Yokohama, Japan) based on the 1982, 1986 and 1989 standard tables of food composition in Japan.[16–18] Dietary fibre intakes were calculated using software from Lotus 123 based on composition tables for dietary fibre.[19] Food items were grouped into three food groups, namely plant-derived food, animal-derived food and other foods. Plant-derived food included cereals, vegetables, nuts and seeds, pulses, fruits, mushrooms, other fungi and algae (seaweed). Animal-derived food consisted of fish and shellfish, meat and meat products, eggs, milk and dairy products. Sugar and sweeteners, confectionery, fats and oils, beverages, seasonings and spices, and pre-prepared foods were included as 'other foods'.

Data on food and nutrient intake, except amino acids, were adjusted to energy intake, 10 500 kJ for men and 8400 kJ for women. This adjustment was consistent with methods being used for comparative purposes for the IUNS study.[11] Recommended protein intakes are ordinarily expressed according to gender and bodyweight; therefore, the consumption of amino acids in milligrams was adjusted to bodyweight (kilograms) and reported separately for men and women. The 'Standard Tables of Food Composition 1997' in Japan list 18 amino acids, namely, the essential amino acids, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, valine, and the remaining amino acids, cystine, tyrosine, histidine, arginine, alanine, aspartic acid, glutamic acid, glycine, proline and serine.

Statistical analysis

Statistical analyses were performed using the Statistical Analysis System (SAS Institute, Cary, NC, USA).[20] A non-parametric Wilcoxon rank sum test was used to compare variables of interest between the survivors and deceased groups. The significance level was set at 5%.

In order to determine whether total n-3 fatty acids intake at study entry could be used as a predictor of all-cause mortality for this population, subjects were classified as having a low or high n-3 fatty acid intake using the 25th percentile (2.1 mg/day) as the cut-off point. A χ^2 test was performed and a Kaplan Meier curve was also plotted in order to demonstrate the difference in the survival probability between these two groups. A Cox proportional hazard analysis was used to calculate the risk of death for subjects with high and low intakes of n-3 fatty acid after adjusting for age at enrolment, gender and smoking status. In this survival analysis, those with chronic energy deficiency (BMI < 18.5 kg/m^2) were not included.

Table 1. Subject characteristics at enrolment in 1991 for men and women

	Men (n = 43)	Women (n = 46)
Age (years)[a]	77.6 ± 6.4	76.8 ± 4.9
Body mass index (kg/m^2)[a]	21.9 ± 3.6	22.0 ± 3.4
Smokers[b]	20/37	4/41
Drinkers of alcohol[c]	20/38	11/43
Living arrangement		
Living alone[d]	10 (23.3%)	11 (23.9%)
Living with spouse[d]	15 (34.9%)	12 (26.1%)
Living with family member[d]	18 (41.9%)	23 (50%)

[a]Mean ± standard deviation; [b]*n*/total. Smoking status was unavailable for six men and five women; [c]*n*/total. Drinking status was unavailable for five men and three women; [d]*n* (%).

Table 2. Ages and causes of death of men and women who died during the follow-up period (1991–1996)

Subject	Gender	Age at enrolment (years)	Age at death (years)	Cause of death
1	M	71	74	Liver cancer
2	M	74	77	Cardiovascular disease
3	M	83	87	Colorectal cancer
4	M	81	85	Cerebrovascular disease
5	M	83	86	Liver cancer
6	M	86	90	Senescence
7	M	72	73	Kidney failure
8	M	77	81	Cardiovascular disease
9	F	85	89	Senescence
10	F	82	85	Liver cancer
11	F	87	90	Senescence
12	F	85	90	Senescence
13	F	71	75	Cerebrovascular disease

Table 3. Energy adjusted food intakes (g/day)

	Survivors (n = 76) Mean ± SD	Deceased (n = 13) Mean ± SD
Total intake[a]	1473 ± 402.3	1523 ± 315.7
Plant-derived food[b]	1120 ± 338.8	1175 ± 331.2
Cereals	302.8 ± 86.3	330.9 ± 87.9
Vegetables	418.1 ± 224.8	455.9 ± 262.9
Mushrooms[c]	4.3 ± 7.5	1.8 ± 4.6 *
Other fungi	160.9 ± 97.9	181.3 ± 99.5
Algae (seaweed)[d]	5.2 ± 6.6	5.2 ± 4.6
Pulses[e]	88.1 ± 71.7	63.4 ± 38.6
Nuts and seeds	5.3 ± 21.3	3.3 ± 11.7
Fruits	134.9 ± 99.6	133.4 ± 107.3
Animal-derived food[f]	353.9 ± 181.9	347.6 ± 130.8
Fish and shellfish	105 ± 71.8	86.9 ± 51.5
Meat and meat products	42.6 ± 37.5	44.4 ± 41.6
Eggs	42.2 ± 40.3	46.8 ± 43.6
Milk and dairy products	164.1 ± 152.2	169.6 ± 144.1
Plant : animal ratio	4.3 ± 3	3.9 ± 1.8
Other foods		
Fats and oils[g]	10.1 ± 8.7	6.3 ± 9.8 *
Sugar and sweeteners	16 ± 16.9	10.1 ± 6.2
Confectioneries	43.5 ± 46.8	45.2 ± 60.0
Seasonings and spices	48.2 ± 30.9	45.2 ± 31.2
Beverages[h]	658.8 ± 609.5	559.5 ± 504.7
Pre-prepared foods[i]	2.7 ± 16.8	4.9 ± 17.5

*P < 0.05 using Wilcoxon rank sum test adjusted to 10.5 MJ for men and 8.4 MJ for women. [a]Total intake = daily intake of plant + animal foods; [b]plant-derived food includes cereals, vegetables, nuts and seeds, pulses, fruits, fungi, other fungi and algae; [c]mushrooms include shiitake, enokidake and shimejidake; [d]algae include laver (nori), kombu, hijiki and wakame; [e]pulses include soybeans, tofu, natto, miso, peas, and kidney beans; [f]animal-derived food includes fish and shellfish, meat and meat products, eggs, milk and other dairy products; [g]fats and oils include soybean oil, corn oil and lard; [h]beverages include tea, carbonated drinks, cocoa and coffee but exclude alcoholic drinks; [i]pre-prepared foods include frozen meals.

Table 4. Differences in nutrient intakes between deceased and survivors[a]

	Survivors (n = 76) Mean ± SD	Deceased (n = 13) Mean ± SD
Energy (MJ/day)	6.7 ± 1.6	6.6 ± 2.5
Protein (g/day)	83.3 ± 17.2	86.1 ± 13.8
Carbohydrate (g/day)	341 ± 125	410 ± 162
Fat (g/day)	53.8 ± 16.6	51.1 ± 15.6
Dietary fibre (g/day)	14.1 ± 4.6	14.7 ± 4.5
Vitamin A (IU)	2473 ± 2057	2947 ± 1912
Vitamin E (mg)	7.9 ± 2.5	7.6 ± 2.0
Vitamin B1 (mg)	1.2 ± 0.3	1.2 ± 0.2
Vitamin B2 (mg)	1.5 ± 0.6	1.5 ± 0.3
Vitamin C (mg)	98.4 ± 50.6	103.5 ± 48.1
Niacin (mg)	18.2 ± 5.8	16.2 ± 4.9
Sodium (mg)	6140 ± 1784	6071 ± 2503
Potassium (mg)	3059 ± 777.4	3259 ± 961.9
Calcium (mg)	612.2 ± 260.9	671.6 ± 235.5
Phosphorus (mg)	1327 ± 300.5	1428 ± 255.4
Potassium/sodium ratio (mg/mg)	0.5 ± 0.2	0.6 ± 0.3
Calcium/phosphorus ratio (mg/mg)	0.5 ± 0.1	0.5 ± 0.1
Iron (mg)	12.5 ± 3.6	12.7 ± 4.7
Salt (g)	14.8 ± 4.5	14.9 ± 6.5

[a]Nutrient intakes have been adjusted to 10.5 MJ for men and 8.4 MJ for women

Results

The age range at study entry for men (n = 43) was 70–91 years, whilst for women (n = 46) it was 70–87 years. Subject characteristics for each gender, at baseline, are listed in Table 1. During 55 months, 13 subjects (eight men and five women) died. The causes of death and age at death are shown in Table 2.

The mean values of food and nutrient intakes after adjustment for energy intake are shown in Tables 3 and 4, respectively. While subjects in the survivor group consumed significantly higher amounts of mushrooms and fats and oils than those in the deceased group (P < 0.05), for macronutrient and available micronutrient intakes there were no significant differences (Table 4).

Table 5 shows energy-adjusted fatty acid intakes. Total n-3 fatty acids included alpha-linolenic acid (ALA; C18 : 3 n-3), eicosatetraenoic acid (C20 : 4 n-3), eicosapentaenoic acid (EPA; C20 : 5 n-3), docosapentaenoic acid (C22 : 5 n-3), and docosahexaenoic acid (DHA; C22 : 6 n-3). Total n-3 fatty acid intake was significantly higher in survivors than in the deceased (P < 0.05). However, when individual n-3 fatty acids were compared, a significant difference was found only in alpha-linolenic acid (P < 0.05). Interestingly, the ratio of vitamin E to total n-3 fatty acids in the survivor group was significantly lower (P < 0.05). The n-3 to n-6 ratio was sig-

Table 5. Energy adjusted fatty acid intakes (mg/day)[a]

	Survivors (n = 76) Mean ± SD	Deceased (n = 13) Mean ± SD
Total fatty acids	45.9 ± 14.8	42.4 ± 17.5
Saturated fatty acids	13.6 ± 5	13.6 ± 4.6
Monounsaturated fatty acids	17.6 ± 6.3	16.5 ± 8.2
Polyunsaturated fatty acids	14.7 ± 5	12.3 ± 5.8
P/S ratio	1.2 ± 0.4	1.8 ± 0.8
Total n-3 fatty acids	3024 ± 1326	2214 ± 1078 *
Total n-6 fatty acids	11047 ± 4067	9732 ± 4484
N-3/n-6 ratio	0.3 ± 0.1	0.2 ± 0.04
Vitamin E/PUFA ratio	0.7 ± 0.2	1.3 ± 0.7
Vitamin E/n-3 ratio	0.003 ± 0.001	0.004 ± 0.002 *
Vitamin E/n-6 ratio	0.0008 ± 0.0002	0.0009 ± 0.0003
C18	2768 ± 1097	2881 ± 1006
C18 : 1 n-9	14651 ± 5402	14413 ± 6867
C18 : 2 n-6	10916 ± 4052	9614 ± 4460
C18 : 3 n-3	1901 ± 865.2	1368 ± 874.6 *
C18 : 4	88.4 ± 120.8	35.6 ± 50.3
C20	196.4 ± 108.2	185.1 ± 105.4
C20 : 1	545.9 ± 491	339.5 ± 229
C20 : 2 n-6	25.3 ± 18.2	18.1 ± 12.5
C20 : 3 n-6	23.7 ± 11.9	26.6 ± 10.6
C20 : 4 n-3	99.1 ± 69.5	97.6 ± 65.2
C20 : 4 n-6	79.7 ± 48.3	70.4 ± 35.5
C20 : 5 n-3	333.3 ± 372.4	220.4 ± 257.3
C22	77 ± 44.1	101.1 ± 171.5
C22 : 1 n-9	346.6 ± 506.4	116.6 ± 106.2
C22 : 5 n-3	94 ± 105.6	77.7 ± 83.8
C22 : 5 n-6	3 ± 6.8	3.4 ± 8.4
C22 : 6 n-3	588.3 ± 510	450.5 ± 311.8
C24	14.4 ± 13.4	39.6 ± 97.8
C24 : 1	59.3 ± 61.6	37.8 ± 31.6

*P < 0.05 using Wilcoxon rank sum test; [a]adjusted to 10.5 MJ for men and 8.4 MJ for women; PUFA, polyunsaturated fatty acids.

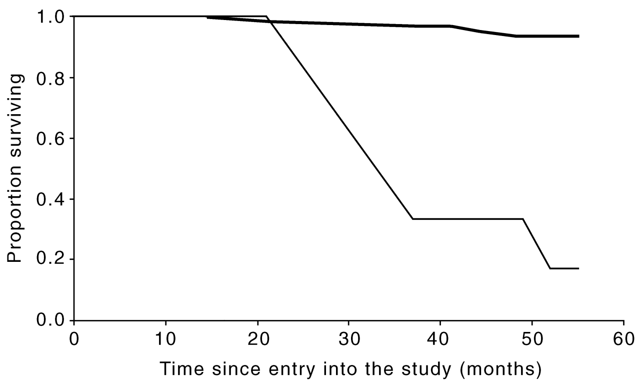

Figure 1. Kaplan–Meier plot of survival probability for Japanese elderly (n = 69) (P < 0.05, χ^2 test) in relation to n-3 fatty acid intake. (—) High n-3 fatty acids; (—) low n-3 fatty acids.

nificantly lower in the deceased when the parametric analysis of variance (ANOVA) was applied.

Using a Kaplan–Meier plot, total n-3 fatty acid intakes at baseline showed similar survival probability for all subjects over 55 months. However, for subjects with body mass index (BMI) at or above 18.5 kg/m^2 (used to identify chronic energy deficiency according to WHO criteria) (n = 69), those with a higher intake of n-3 fatty acids (≥ 2.1 g/day, 25th percentile) had a better survival probability (P < 0.05) (Fig. 1). Cox proportional hazards analyses showed similar results for both total n-3 fatty acids and alpha-linolenic acid (ALA), after adjustment for age, gender and smoking status (Table 6).

The intakes of protein, after adjustment for bodyweight or energy intake, and total amino acids were similar among the survivors and deceased. However, in women tyrosine intake was significantly higher for those who survived compared with those who died (P < 0.05) (Table 7).

Table 6. Cox proportional hazard for n-3 fatty acid intakes

Subjects	Risk ratio	95% Confidence interval	P value
All	0.41	0.12–1.38	0.15
BMI < 18.5	0.37	0.02–6.39	0.50
BMI ≥ 18.5	0.21	0.04–0.97	<0.05
BMI ≥ 18.5 for ALA	0.18	0.04–0.88	<0.05*

Model includes age at enrolment, gender and smoking. *P < 0.05.

Table 7. Weight adjusted amino acid intakes (mg/day)[a]

	Survivors Mean ± SD	Deceased Mean ± SD
	Men	
	n = 76	n = 13
Total amino acid	991.5 ± 313.7	904.3 ± 243.5
Essential amino acid	379.2 ± 125.6	349.2 ± 98.9
Tyrosine[b]	35.7 ± 10.4	32.8 ± 8.3
	Women	
	n = 41	n = 5
Total amino acid	1042 ± 265.5	1047 ± 493.1
Essential amino acid	388.1 ± 99.2	404.5 ± 193.7
Tyrosine	74.1 ± 29.7	37.2 ± 18.2 **

**P < 0.01 using Wilcoxon rank sum test. [a]Adjusted to kilogram body weight; [b]n = 34 in the survivors group.

Discussion

Food intake and longevity

The Japanese diet is believed to be one of the most ideal diets in the world.[21,22] Based on three epidemiological studies in elderly Japanese (age 65 years–centenarian), Shibata *et al.* reported that animal protein might have a favourable effect on life expectancy.[7] They also reported that 10-year survivorship was associated with a higher intake of animal foods such as eggs, milk, fish and meat. The present study did not confirm this although a larger sample, as in the Shibata *et al.* meta-analysis, may have done so.

While overall fungi consumption was similar for the deceased and survivors, the consumption of shiitake, enokidake and shimejidake mushrooms was significantly greater in the survivors (P < 0.05). These three types of mushroom typify a Japanese food pattern, through their use in dishes such as hotpot (*nabemono*). There are limited data on the composition of mushrooms, but what is available suggests the possibility that they may confer health benefits through various components, such as dietary fibre, oligosaccharides, n-3 fatty acids, amino acids and trace elements.[23–25]

Fats and oils, which are used principally for cooking, were mainly soybean oil, corn oil and lard. The higher consumption of fats and oils in survivors may have partly contributed to the higher intakes of n-3 fatty acids, as shown in Table 5, and also reduced risk of chronic energy deficiency (CED), which is known to increase mortality (Fig. 1).[26]

Nutrient intake and longevity

The higher ratio of vitamin E to n-3 fatty acids in the deceased, compared with the survivors, may reflect on the lower consumption of total n-3 fatty acids by the deceased and similar vitamin E intake in the two groups. It is possible that, given the profile of vitamin E isomers in the Japanese diet and peripheral blood compared with Caucasians,[27] with relatively more gamma- and delta-tocopherol in the Japanese, the functional relationship of antioxidant vitamin E to polyunsaturated fatty acids (PUFA) is different in Japanese to what might be expected in Caucasians, for whom it is presumed that a higher vitamin E to PUFA ratio is a biological advantage.

A protective effect of n-3 fatty acid intake from plant and marine sources has been documented.[12–15,28] de Deckere *et al.* concluded that n-3 fatty acids might reduce the risk of coronary heart disease and also alleviate the symptoms of rheumatoid arthritis.[28] From the Lyon Diet Heart Study, de Lorgeril *et al.* hypothesized that n-3 fatty acids, especially from an alpha-linolenic acid-rich diet, might have specific cardioprotective effects and reduce total mortality.[14,29] The US Multiple Risk Factor Intervention Trial (MRFIT) of more than 10 000 people showed that those with the highest omega-3 intakes (as alpha-linolenic acid) had the lowest overall death rates and the least deaths from cancer.[12] Recent findings from the Nurses Health Study supported the hypothesis that a protective effect against ischemic heart disease was seen with a higher intake of alpha-linolenic acid.[13] In our study, the intake of total n-3 fatty acids, which were obtained from either plant or marine sources or both, was also found to predict survivorship. The significantly higher intake of alpha-linolenic acid in survivors in the present study also suggests that alpha-linolenic acid might be protective against total mortality.

In subjects with a BMI ≥ 18.5 kg/m^2 and a higher intake of n-3 fatty acid, better survival probability was seen, using a Kaplan–Meier plot.[26] This provides further evidence of the role of n-3 fatty acids in Japanese longevity. A protective effect of n-3 fatty acids was not seen in the chronically energy-deficient Japanese, possibly because of sample size, but also possibly because, in this situation, energy deficiency becomes relatively more important for survivorship.

Protein and amino acid nutrition is also of interest in relation to survivorship among the elderly.[30] Essential amino acids are usually of greatest interest in this regard. More recently, specific amino acids have been receiving greater attention. For example, the importance of homocysteine is now recognized. Interestingly, women who survived had higher tyrosine intakes than did the deceased. This could be either because this conditionally essential amino acid,[31,32] at higher concentration, can overcome blockage if it is utilized with age (dependence on, for example, vitamin C is known) or because its formation from phenylalanine may be impaired and its conditional essentiality becomes more apparent in the aged.

Conclusion

In summary, this study suggests that a higher intake of n-3 polyunsaturated fatty acids, from both plant and marine sources, might have a beneficial effect on life expectancy in older Japanese, in particular for those who are not chronically energy deficient. Some plant foods such as mushrooms, which are characteristic of a Japanese food pattern, in combination with fish and other plant sources of n-3 fatty acids, possibly soybean oil and seaweed, might be important factors in determining longer life expectancy. The statistical power of this study has been limited by the small number of deaths. A 7-year follow-up study of the population is being carried out. Further research is needed in order to examine these results and to add more insights to the understanding of food and longevity in the Japanese.

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