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CARDIOVASCULAR DISEASE

Dietary patterns and cardiovascular disease mortality in Japan: a prospective cohort study

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Background Although ecological observations suggest that the Japanese diet may reduce the risk of cardiovascular disease (CVD), the impact of a Japanese dietary pattern upon mortality due to CVD is unclear.

Methods We prospectively assessed the association between dietary patterns among the Japanese and CVD mortality. Dietary information was collected from 40 547 Japanese men and women aged 40–79 years without a history of diabetes, stroke, myocardial infarction or cancer at the baseline in 1994.

Results During 7 years of follow-up, 801 participants died of CVD. Factor analysis (principal component) based on a validated food frequency questionnaire identified three dietary patterns: (i) a Japanese dietary pattern highly correlated with soybean products, fish, seaweeds, vegetables, fruits and green tea, (ii) an 'animal food' dietary pattern and (iii) a high-dairy, high-fruit-and-vegetable, low-alcohol (DFA) dietary pattern. The Japanese dietary pattern was related to high sodium intake and high prevalence of hypertension. After adjustment for potential confounders, the Japanese dietary pattern score was associated with a lower risk of CVD mortality (hazard ratio of the highest quartile vs the lowest, 0.73; 95% confidence interval: 0.59–0.90; P for trend = 0.003). The 'animal food' dietary pattern was associated with an increased risk of CVD, but the DFA dietary pattern was not.

Conclusion The Japanese dietary pattern was associated with a decreased risk of CVD mortality, despite its relation to sodium intake and hypertension.

Keywords Diet, factor analysis, statistical, cardiovascular diseases, mortality, prospective studies, Japan

The traditional Japanese diet has drawn considerable attention since the 1960s because of its association with an extremely low rate of coronary heart disease (CHD).[1,2] On the other hand, this diet used to be characterized by high consumption of salt[2] and low consumption of animal fat and protein,[3] which would increase the risk of stroke, especially intracerebral haemorrhage (ICH).[4]

Over the past 40 years, however, the Japanese diet has changed. Average consumption of fruits, dairy products, eggs and meat has increased, while the high consumption of vegetables, soy products and fish has been maintained.[5] In parallel with the change from a traditional Japanese diet, the stroke mortality rate has fallen dramatically,[6] and the CHD mortality rate is still lower than in Western countries.[7] The age-adjusted rate of mortality due to cardiovascular disease (CVD) is lower than in the UK (∼40%) and the US (∼30%).[7] Thus, the contemporary Japanese diet may have beneficial effects in terms of lower CVD mortality.

While several single food items in the Japanese diet such as fish[8–10] and soybean[10,11] have been studied for CVD association, the results have not always been consistent. As food variables

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are highly intercorrelated and possibly have biochemical interactions, it is difficult to examine their separate effects.[12] To address the difficulties of the single food approach, many studies have investigated the association between dietary patterns and CVD among Western populations.[13–19]

Among the Japanese, previous studies on the association with specific cancers[20–22] or all-cause mortality[23] have identified a dietary pattern correlated with distinctive Japanese foods by using factor analysis.[24] However, no study has investigated the contribution of 'Japanese' dietary patterns to lower CVD mortality.

Our study objectives were to identify contemporary dietary patterns among the Japanese by factor analysis and to investigate their impact upon CVD mortality in a large-scale population-based prospective cohort study.

Methods

Study population

The details of the Ohsaki National Health Insurance (NHI) Cohort study have been described previously.[25,26] Briefly, we delivered a self-administered questionnaire including items on dietary intake [40-item food frequency questionnaire (FFQ)], medical history, smoking status and physical health status, between October and December 1994 to all NHI beneficiaries aged 40–79 years living in the catchment area of Ohsaki Public Health Center, Miyagi Prefecture, northeast Japan. Ohsaki Public Health Center, a local government agency, provides preventive health services for residents of 14 municipalities in Miyagi Prefecture. Of 54 996 eligible individuals, 52 029 (95.0%) responded.

From January 1, 1995, we started prospective collection of data on the date of death and withdrawal from the NHI, by obtaining NHI withdrawal history files from the local NHI Association. We excluded 774 participants because they had withdrawn from the NHI before collection of the NHI withdrawal history files. Thus, 51 255 participants formed the study cohort. The study protocol was reviewed and approved by the Ethics Committee of Tohoku University School of Medicine. We considered the return of self-administered questionnaires signed by the study participants to imply their consent to participate.

For current analysis, we excluded participants who died before collection of NHI withdrawal history files ($n = 37$), who left blank more than 24 of the 40 food items on the FFQ ($n = 3941$) and who reported daily energy intakes at the extreme 0.5% upper or lower ends of the range (sex-specific cut-off points were used: 1759 kJ, 14 884 kJ for men and 1256 kJ, 9609 kJ for women, respectively) ($n = 478$). We followed the exclusion criteria for the number of blanks on the FFQ reported in previous studies[17,18] of dietary patterns. We also excluded participants who reported a history of cancer ($n = 1533$), myocardial infarction ($n = 1325$), stroke ($n = 1040$) or diabetes mellitus at the baseline ($n = 3092$), because these diseases could have changed their diet and lifestyle. Consequently, our analysis included 40 547 participants.

Dietary assessment

The 40-item FFQ asked about the average frequency of consumption of each food. Regarding the foods that showed different patterns of consumption between seasons, the FFQ asked about the frequency in the season when these foods were consumed most frequently within a year. However, the FFQ did not refer a specific time frame. Five frequency categories were used for the majority of food items (almost never, 1–2 days/month, 1–2 days/week, 3–4 days/week and almost every day). For rice and miso (fermented soybean paste) soup, the number of bowls consumed daily was asked. For current drinkers, the frequency of alcohol consumption was asked using four frequency categories (once or less/week, 1–2 days/week, 3–4 days/week, almost every day) and the usual amount was asked using six categories. For consumption of four non-alcohol beverages (green tea, black tea coffee and Chinese tea), five categories were used (almost never, sometimes, 1–2 cups/day, 3–4 cups/day, 5 or more cups/day).

We had previously conducted a validation study of the FFQ.[27] In brief, 113 participants (55 men and 58 women), who were a subsample of the cohort, provided four 3-day diet records (DRs) within a 1-year period and subsequently responded to the FFQ. We computed the Spearman correlation coefficients between the amounts consumed according to the DRs and the amounts consumed according to the FFQ. For 40 food items, medians (range) of the age and total energy-adjusted correlation coefficients were 0.35 (−0.30–0.72) in men and 0.34 (−0.06–0.75) in women. Medians (range) of the age and total energy-adjusted correlation coefficients of the two FFQs administered 1 year apart were 0.43 (0.14–0.76) in men and 0.45 (0.06–0.74) in women for the 40 food items.

We examined the daily consumption of 40 food items, total energy and nutrients from the FFQ by converting the selected frequency category for each food to a daily intake, using portion sizes based on the median values observed in the DRs. To calculate nutrients, we developed a food composition table that corresponded to the food items listed in the FFQ. Using the Standard Tables of Food Composition published by the Science and Technology Agency of Japan,[28] we calculated nutrients from the DRs and grouped the food codes to form food categories that best corresponded to the listing of the FFQ. We assigned relative weights to the food codes grouped into a single category based on the DR data.

Dietary pattern derivation

To derive dietary patterns, factor analysis (principal component analysis) was conducted by using the daily consumption (weight in grams) of 40 food items from the FFQ. If the reported frequency was blank, we assumed that the item was never consumed. We used the PROC FACTOR procedure in SAS version 9.1[29] to perform the analyses. To determine the number of factors to retain, we considered eigenvalue, Scree test and factor interpretability.[24] Because 10 factors satisfied the criteria for eigenvalues greater than one, and the Scree plot indicated five factors that were retained, we selected solutions ranging from 2 to 5 for rotation. To achieve a simpler structure with greater interpretability, the factors were rotated by an orthogonal transformation (varimax rotation function in SAS).

With regard to factor interpretability, a three-factor solution appeared to describe most meaningfully the distinctive dietary patterns of the study population. We named them (i) a Japanese pattern, (ii) an 'animal food' pattern and (iii) a high-dairy, high-fruit-and-vegetable, and low-alcohol (DFA) pattern, according to the food items showing high factor loading (absolute value) with respect to each dietary pattern. These dietary patterns were consistent with those reported previously in Japanese men.[20] For each pattern and each participant, we calculated a factor score by summing the consumption from each food item weighted by its factor loading.[24]

We conducted additional sensitivity analysis of dietary pattern derivation. When we also performed factor analyses for six subgroups stratified by sex and three age groups (aged 40–59, 60–69 and 70–79 years), the derived patterns appeared similar. Thus, in our analyses, we used a factor solution including both men and women, and all age groups. Among the participants who left no blanks for food items ($n = 17\,010$), the derived dietary patterns closely resembled those derived from the total participants. As an additional analysis with stricter cut-off points of total energy intake for inclusion, we excluded participants who reported of daily energy intakes at the extreme 2.5% upper or lower ends of the range. The derived dietary patterns were similar to those of the main analysis.

Additional analyses using the maximum likelihood method instead of the principal component method as the initial factor-extracting method, and oblique rotation (promax rotation function in SAS) as a factor rotation method made the factor loadings for the three dietary patterns similar. The same criteria as the main analysis indicated three factors that were retained, and each factor was correlated to with (i) vegetables, fruits, seaweeds, soy products, and fish, (ii) meat and fat and (iii) rice (negatively), miso soup (negatively) and dairy products, respectively.

Follow-up

The primary endpoint was CVD mortality. Secondarily, we conducted analyses of CHD and stroke mortality. We investigated cause of death by reviewing the death certificates filed at Ohsaki Public Health Center. Cause of death was coded by trained physicians according to the International Statistical Classification of Diseases and Related Health Problems, Tenth Revision (ICD-10).[30] We identified deaths from CVD (codes I00-I99), CHD (codes I20-I25), total stroke (codes I60-I69), cerebral infarction (code I63) and ICH (code I61).

Statistical analyses

From January 1, 1995 to December 31, 2001, we prospectively counted the number of person-years of follow-up for each participant from the beginning of follow-up until the date of death, withdrawal from the NHI or the end of the follow-up, whichever occurred first.

Cox proportional hazards regression analysis was used to calculate the hazard ratio (HR) and 95% confidence interval (CI) of CVD mortality according to quartiles of the dietary pattern score and to adjust for potentially confounding variables, using SAS.[29] For all models, the proportional hazards assumptions were tested and met using time-dependent covariates.[31] Dummy variables were created for the quartiles of each dietary pattern score. The lowest quartile of a dietary pattern score was used as a reference category. The P-values for analysis of linear trends were calculated by scoring the quartiles of a dietary pattern score, from one for the lowest quartile to four for the highest, entering the number as a continuous term in the regression model. Interaction between sex and quartiles of each dietary pattern score was tested by addition of cross-product terms to the multivariate model. The association between each dietary pattern and CVD mortality did not vary by sex (P for interaction $n = 0.55$). All reported P-values are two-tailed.

Multivariate models were adjusted for the following variables: age (in years), sex, smoking status (never, former, currently smoking <20 cigarettes per day and currently smoking $\geqslant$20 cigarettes per day), walking duration (<1 hour per day and $\geqslant$1 hour per day), total energy intake (as a continuous variable), body mass index (<18.5 kg/m^2, 18.5–24.9 kg/m^2 and $\geqslant$25.0 kg/m^2) and history of hypertension (yes or no). Two multivariate models not including and including body mass index and history of hypertension were used, since these two factors could be regarded as intermediate in the causal pathway between dietary pattern and CVD mortality. Walking duration was used as a parameter of physical activity because it is the most common type of physical activity among middle-aged and older individuals in rural Japan. The validity and reproducibility of the question on walking time has been reported elsewhere.[32]

All analyses were repeated after exclusion of participants who had died in the first 3 years of follow-up. To minimize any possible bias caused by physically inactive participants, we performed additional analysis that was restricted to participants who were able to perform vigorous activity [Medical Outcome Study (MOS) Short Form General Health Survey[33] score of 5–6] and with a well self-perceived health status. As an additional analysis, dietary pattern scores were adjusted for total energy by using the residual method.[34]

Results

Table 1 shows factor loadings, which are equivalent to simple correlations between the food items and dietary patterns. A positive loading indicates that a food item is positively associated with the dietary pattern, and a negative loading indicates an inverse association with the dietary pattern. That is, food items highly loaded within a dietary pattern are highly correlated with each other.

The Japanese dietary pattern was loaded heavily on soybean products, fish, seaweeds, vegetables, fruits and green tea, whereas the 'animal food' pattern was loaded heavily on various animal-derived foods (beef, pork, ham, sausage, chicken, liver and butter), coffee and alcoholic beverages. The DFA dietary pattern was heavily loaded on dairy products (milk and yoghurt), margarine, fruits and vegetables (carrot, pumpkin and tomato), and negatively loaded on rice, miso soup and alcoholic beverages. These three dietary patterns explained 26.2% of the variance.

Table 2 compares the characteristics of participants according to the quartiles of each dietary pattern score. Participants

Table 1 Factor-loading matrix for the major dietary pattern identified by factor analysis

	Japanese pattern	'Animal food' pattern	DFA[a] pattern
Rice			−0.59
Miso soup	0.25		−0.39
Beef		0.48	
Pork (excluding ham, sausage)		0.55	
Ham, sausage		0.56	
Chicken		0.49	
Liver		0.43	
Egg	0.34	0.32	
Milk	0.26		0.28
Yoghurt			0.50
Cheeses		0.44	
Butter		0.50	
Margarine		0.37	0.40
Deep fried-dishes, tempura	0.28	0.39	
Fried vegatable	0.43		
Raw fish, fish boiled with soy, roast fish	0.51		
Boiled fish paste	0.39	0.32	
Dried fish	0.37		
Green vegetables	0.64		
Carrot, pumpkin	0.59		0.36
Tomato	0.45		0.32
Cabbage, lettuce	0.59		
Chinese cabbage	0.62		
Wild plant	0.27		
Mushrooms (shiitake, enokitake)	0.42		
Potato	0.61		
Seaweeds	0.59		0.26
Pickles (radish, chinese cabbage)	0.41		
Food boiled with soy			
Boiled beans			
Soybean (tofu, fermented soybeans)	0.57		
Orange	0.50		0.42
Other fruits	0.49		0.47
Fresh juice			
Confectioneries	0.27		
Green tea	0.29		
Black tea			
Coffee		0.29	
Chinese tea			
Alcoholic beverages		0.27	−0.50
Variance explained (%)	15.1	6.4	4.8

[a] DFA means high-dairy, high-fruit-and-vegetable, low-alcohol.
Absolute values <0.25 were not listed for simplicity.

with a higher Japanese dietary pattern score tended to be older, were more likely to walk and have a history of hypertension, and less likely to be current drinkers and smokers. Participants with a higher 'animal food' dietary pattern score tended to be younger and male, were more likely to be current smokers and drinkers, and less likely to have a history of hypertension. Participants with a higher DFA dietary pattern score tended to be female, and were similar to those with a higher Japanese dietary pattern score except for walking duration, education and history of hypertension.

Table 3 shows total energy-adjusted daily nutrient and food intakes according to dietary pattern score quartiles. Although the fat and protein intakes in any given quintile of dietary patterns were almost equivalent, their sources varied among dietary patterns. Participants with a higher Japanese dietary pattern score consumed more fish and soybean, a higher 'animal food' dietary pattern score was associated with higher meat and fat intake, and a higher DFA dietary pattern was associated with a higher intake of dairy products. Although the Japanese and DFA dietary patterns were similar in terms of high vegetable and fruit intake, the Japanese dietary pattern differed from the DFA pattern in terms of high intakes of sodium, fish, soybean, seaweeds and green tea.

During 7 years of follow-up (252 647 person-years), we documented 801 deaths from CVD. These deaths included 181 CHDs, 432 total strokes (163 cerebral infarctions, 129 ICHs). Table 4 shows the association between the three dietary pattern score quartiles and CVD mortality. The Japanese dietary pattern was associated with a reduced risk of CVD mortality. On the other hand, the 'animal food' dietary pattern was associated with an increased risk of CVD mortality, and the DFA dietary pattern was not associated with CVD mortality.

After adjustment for age, sex, smoking status, walking duration, education and total energy intake, the multivariate HRs (95% CI) of CVD mortality across increasing quartiles of the Japanese dietary pattern score were 1.00, 0.76 (0.63–0.93), 0.71 (0.58–0.87) and 0.73 (0.59–0.90) (P for trend = 0.003), whereas for the 'animal food' dietary pattern, the corresponding multivariate HRs (95% CI) of CVD mortality were 1.00, 0.93 (0.76–1.13), 1.13 (0.92–1.38) and 1.22 (0.99–1.51) (P for trend = 0.03). With additional adjustment for body mass index and history of hypertension, the results were essentially unchanged. Furthermore, the results of analysis using body mass index as a continuous variable and history of hypertension remained similar.

As the Japanese and 'animal food' dietary patterns were associated with CVD mortality, their associations with CHD and stroke were further investigated (Table 5). After adjusting for potential confounders, the point estimate of the HR for CHD mortality of participants with the highest quartile of the Japanese dietary pattern score was 20% lower than the lowest, whereas those with the highest quartile of the 'animal food' dietary pattern score was 49% higher.

The multivariate HRs (95% CI) of CHD mortality across increasing quartiles of the Japanese dietary pattern score were 1.00, 0.84 (0.56–1.26), 0.70 (0.45–1.08) and 0.80 (0.51–1.25) (P for trend = 0.24), and the corresponding multivariate HRs (95% CI) of the 'animal food' dietary pattern score were 1.00,

Table 2 Baseline characteristics of the participants according to dietary pattern score quartiles

	Dietary pattern score quartiles			
Characteristic	1 (lowest)	2	3	4 (highest)
Age (years), mean (SD)				
Japanese pattern	57.7 (11.1)	59.3 (10.5)	60.6 (9.9)	61.9 (9.3)
'Animal food' pattern	63.8 (8.9)	60.6 (10.1)	58.2 (10.4)	57.0 (10.6)
DFA[a] pattern	58.5 (10.1)	60.5 (10.4)	60.5 (10.4)	60.1 (10.4)
Male (%)				
Japanese pattern	55.3	48.3	43.4	41.3
'Animal food' pattern	23.5	42.2	53.4	69.1
DFA[a] pattern	89.8	53.0	28.8	16.7
Body mass index (kg/m^2), mean (SD)				
Japanese pattern	23.4 (3.3)	23.5 (3.2)	23.5 (3.1)	23.6 (3.1)
'Animal food' pattern	23.8 (3.4)	23.6 (3.2)	23.5 (3.1)	23.3 (3.0)
DFA[a] pattern	23.5 (3.0)	23.5 (3.3)	23.7 (3.3)	23.5 (3.2)
Current smoker (%)				
Japanese pattern	44.8	35.1	28.6	24.4
'Animal food' pattern	18.1	30.0	36.1	46.9
DFA[a] pattern	58.0	35.7	21.3	14.8
Walking duration ⩾1 hour/day (%)				
Japanese pattern	41.2	45.0	47.7	52.1
'Animal food' pattern	43.9	44.8	47.7	49.5
DFA[a] pattern	54.8	47.3	44.0	40.0
Current drinker (%)				
Japanese pattern	55.6	51.1	46.9	43.5
'Animal food' pattern	29.6	45.9	54.6	64.8
DFA[a] pattern	80.0	49.6	34.4	29.8
Education until age ⩾19 years (%)				
Japanese pattern	8.3	7.7	7.6	7.8
'Animal food' pattern	5.8	7.3	8.9	9.4
DFA[a] pattern	4.4	5.8	7.8	13.4
History of hypertension (%)				
Japanese pattern	22.2	23.4	25.7	27.0
'Animal food' pattern	31.6	26.2	21.7	18.9
DFA[a] pattern	22.3	25.0	25.7	25.4

[a] DFA means high-dairy, high-fruit-and-vegetable, low-alcohol.
SD, standard deviation.

1.12 (0.73–1.72), 1.38 (0.89–2.15) and 1.49 (0.94–2.34) (P for trend = 0.06).

The Japanese dietary pattern was associated with a decreased risk of total stroke, cerebral infarction and ICH mortality. The multivariate HRs (95% CI) of total stroke mortality across increasing quartiles of the Japanese dietary pattern score were 1.00, 0.70 (0.54–0.92), 0.66 (0.50–0.87) and 0.64 (0.47–0.85) (P for trend = 0.003). The 'animal food' dietary pattern was not positively associated with the risk of total stroke.

We analysed the association between the Japanese dietary pattern derived from participants who left no blanks for food items ($n = 17\,010$) and CVD mortality, and the results were similar. The multivariate HR (95% CI) of CVD mortality for the highest quartile of the Japanese dietary pattern score vs the lowest was 0.74 (0.51–1.07) (P for trend = 0.04). After exclusion of participants who reported daily energy intakes at the extreme 2.5% instead of the extreme 0.5% of the upper or lower ends of the range, we analysed the association between the Japanese dietary pattern derived and CVD mortality ($n = 38\,937$), and the results were similar. The multivariate HR (95% CI) of CVD mortality for the highest quartile of the Japanese dietary pattern score vs the lowest was 0.75 (0.60–0.93) (P for trend = 0.005).

After excluding the 287 participants who died from CVD in the first 3 years of follow-up, the multivariate HR (95% CI) of CVD mortality for the highest quartile of the Japanese dietary pattern score vs the lowest was 0.70 (0.54–0.92)

Table 3 Daily nutrient and food intakes of the participants according to dietary pattern score quartiles

	Dietary pattern score quartiles			
Variable	1 (lowest)	2	3	4 (highest)
Daily nutrient and food intakes[a] (median)				
Energy (kJ)				
Japanese pattern	5046	5793	6227	6861
'Animal food' pattern	5128	5826	6430	7458
DFA[b] pattern	8346	5956	5537	5466
Fat (g)				
Japanese pattern	31	35	38	41
'Animal food' pattern	34	35	37	41
DFA[b] pattern	32	35	37	41
Protein (g)				
Japanese pattern	61	66	70	74
'Animal food' pattern	65	66	68	72
DFA[b] pattern	68	67	67	69
Sodium (mg)				
Japanese pattern	2418	2762	2925	3152
'Animal food' pattern	2909	2824	2768	2822
DFA[b] pattern	2684	2865	2897	2878
Rice (g)				
Japanese pattern	814	684	620	567
'Animal food' pattern	617	647	734	744
DFA[b] pattern	885	739	601	524
Total meats (g)				
Japanese pattern	20	21	22	22
'Animal food' pattern	14	19	24	34
DFA[b] pattern	21	21	21	22
Dairy products (g)				
Japanese pattern	127	191	217	223
'Animal food' pattern	192	198	201	206
DFA[b] pattern	86	142	226	268
Total Fish (g)				
Japanese pattern	50	64	73	96
'Animal food' pattern	68	67	66	69
DFA[b] pattern	69	67	66	68
Total vegetables (g)				
Japanese pattern	59	79	99	138
'Animal food' pattern	101	89	86	87
DFA[b] pattern	66	82	96	118
Soybean (g)				
Japanese pattern	64	82	98	101
'Animal food' pattern	95	88	85	87
DFA[b] pattern	87	86	89	92
Seaweeds (g)				
Japanese pattern	3	5	6	9
'Animal food' pattern	6	5	5	5
DFA[b] pattern	4	5	6	7
Total fruits (g)				
Japanese pattern	111	145	173	204
'Animal food' pattern	178	155	147	147
DFA[b] pattern	79	132	183	238
Green tea consumption ⩾5 cups/day (%)				
Japanese pattern	16	26	33	44
'Animal food' pattern	39	31	26	25
DFA[b] pattern	29	30	30	32

[a] Nutrient and food intakes presented in this table are adjusted for total energy intake.
[b] DFA means high-dairy, high-fruit-and-vegetable, low-alcohol.

(P for trend = 0.009). We performed additional analysis restricted to participants who performed vigorous activity and with a well self-perceived health status (n = 27 239, 312 deaths from CVD), and a similar result was obtained. The multivariate HR (95% CI) of CVD mortality for the highest quartile of the Japanese dietary pattern score vs the lowest was 0.71 (0.50–1.01) (P for trend = 0.07). When we used the model adjusted for total energy intake by the residual method, the multivariate HR (95% CI) of CVD mortality for the highest quartile of the Japanese dietary pattern score vs the lowest was 0.78 (0.64–0.96) (P for trend = 0.03).

The results of further analysis stratified by smoking status on the association between the Japanese dietary pattern and CVD mortality are shown in Table 6. Although the point estimates of the HR for CVD mortality were consistently below unity compared with the reference category, the inverse association was less pronounced among current smokers than among never or past smokers (P = 0.07 for interaction with smoking). No interaction between the other covariates and quartiles of the Japanese dietary pattern score was observed (data not shown).

Discussion

We identified three dietary patterns among the Japanese population: the Japanese, 'animal food' and DFA dietary patterns. The Japanese dietary pattern was associated with a decreased risk of CVD mortality. In contrast, the 'animal food' dietary pattern was associated with an increased risk of CVD mortality, and the DFA dietary pattern was not.

Three dietary patterns we identified were consistent with previously reported patterns observed among different Japanese populations.[20–23] Corresponding to the (i) Japanese, (ii) 'animal food' and (iii) DFA dietary patterns, the previous studies reported dietary patterns that were correlated with (i) vegetables, fruits, seaweeds, soy products and fish,[20–23] (ii) meat and fat[20–23] and (iii) rice (negatively), miso soup (negatively) or bread and dairy products.[20,22,23] Although our FFQ is short, it includes these key foods, especially Japanese foods.

Table 4 Age, sex-adjusted and multivariate-adjusted hazard ratio for cardiovascular disease mortality according to dietary pattern score quartiles

	Dietary pattern score quartiles				
Dietary pattern	1 (low)	2	3	4 (high)	***P* for Trend**
Japanese pattern					
No. of deaths	243	189	179	190	
Person-years	62 529	63 035	63 316	63 767	
Age, sex-adjusted HR (95% CI)	1	0.73 (0.60–0.88)	0.64 (0.53–0.78)	0.63 (0.52–0.77)	<0.001
Multivariate-adjusted HR1[a] (95% CI)	1	0.76 (0.63–0.93)	0.71 (0.58–0.87)	0.73 (0.59–0.90)	0.003
Multivariate-adjusted HR2[b] (95% CI)	1	0.77 (0.63–0.94)	0.71 (0.58–0.88)	0.74 (0.59–0.91)	0.004
'Animal food' pattern					
No. of deaths	244	188	184	185	
Person-years	63 113	63 396	63 143	62 996	
Age, sex-adjusted HR (95% CI)	1	0.90 (0.74–1.09)	1.04 (0.85–1.27)	1.07 (0.88–1.32)	0.31
Multivariate-adjusted HR1[a] (95% CI)	1	0.93 (0.76–1.13)	1.13 (0.92–1.38)	1.22 (0.99–1.51)	0.03
Multivariate-adjusted HR2[b] (95% CI)	1	0.93 (0.76–1.13)	1.14 (0.93–1.39)	1.24 (1.00–1.54)	0.02
DFA[c] pattern					
No. of deaths	180	251	211	159	
Person-years	63 303	62 878	62 848	63 618	
Age, sex-adjusted HR (95% CI)	1	1.27 (1.04–1.55)	1.17 (0.94–1.45)	0.94 (0.74–1.19)	0.38
Multivariate-adjusted HR1[a] (95% CI)	1	1.18 (0.96–1.45)	1.07 (0.85–1.35)	0.88 (0.68–1.13)	0.14
Multivariate-adjusted HR2[b] (95% CI)	1	1.18 (0.96–1.45)	1.10 (0.87–1.38)	0.89 (0.69–1.14)	0.19

[a] Multivariate-adjusted HR1 was adjusted for age (in years), sex, smoking status (never, former, currently smoking <20 cigarettes/day and currently smoking 20 cigarettes/day), walking duration (<1 hour/day and 1 hour/day), education (until age up to 15 years, until age 16–18 years, and until age 19 years) and total energy intake (continuous).

[b] Multivariate-adjusted HR2 was adjusted for the same as HR1, body mass index (<18.5 kg/m^2, 18.5–24.9 kg/m^2 and 25 kg/m^2), and history of hypertension (yes or no).

[c] DFA means high-dairy, high-fruit-and-vegetable, low-alcohol.

HR, hazard ratio; CI, confidence interval.

The Japanese dietary pattern has partly similar characteristics to 'healthy' dietary patterns reported previously among Western populations that were inversely associated with CVD mortality. High consumption of vegetables and fruits is a common component of 'healthy' dietary patterns in Western populations.[13–19] These components might partly explain the possible protective effect of the Japanese dietary pattern against CVD mortality including CHD and stroke, although we might have failed to detect associations with CHD mortality due to insufficient statistical power. However, compared with 'healthy' dietary patterns among Western populations, the Japanese dietary pattern also has unique characteristics.

The Japanese diet has so far been considered to increase the risk of CVD because it includes a large amount of salt.[35] In the present study, the Japanese dietary pattern was related to higher sodium consumption (Table 3) and higher prevalence of hypertension (Table 2). In spite of these risk factors, the Japanese dietary pattern was associated with lower CVD mortality. Although some components of the Japanese diet (i.e. salt) increase the risk of hypertension, other components may compensate for this, and decrease the risk of CVD. Components unique to the Japanese diet would include items such as soybeans, seaweeds and green tea. The effect of those foods upon CVD risk has yet to be clarified.

Factor analysis has both strengths and limitations. On the one hand, it can overcome multicollinearity of various dietary variables, because it is a statistical dimension-reduction technique that exploits the correlation of each variable. However, factor analysis requires several decisions about the methods used for extracting initial factors and rotation.[36] Even after multiple sensitivity analyses using these methods and various groupings by age and sex, the dietary patterns were essentially unchanged.

Our study also had other limitations. First, healthy behaviour in adhering to a Japanese dietary pattern could have confounded the association between dietary patterns and mortality. Although we adjusted our data using measured potential confounders including non-dietary variables, we could not completely exclude the effects of unmeasured confounders. Second, 12% of the participants were lost to follow-up. This proportion did not vary across the quartiles of each dietary pattern score (13%, 13%, 12% and 11% of participants from the lowest to highest Japanese dietary pattern score quartiles, respectively). Therefore, we consider it unlikely that the association between each dietary pattern and CVD mortality was substantially distorted by the effect of loss to follow-up.

Third, our FFQ did not ask about individual portion size, and preparation of foods including added oil. Some misclassification of food consumption could have arisen in deriving dietary pattern scores and estimating the effect of the patterns on

Table 5 Multivariate-adjusted hazard ratio for coronary heart disease and stroke mortality according to dietary pattern score quartiles

	Dietary pattern score quartiles				
Variable	1 (low)	2	3	4 (high)	***P* for Trend**
Coronary heart disease					
Japanese pattern					
No. of deaths	54	45	38	44	
Multivariate-adjusted HR1[a] (95% CI)	1	0.84 (0.56–1.26)	0.70 (0.45–1.08)	0.80 (0.51–1.25)	0.24
Multivariate-adjusted HR2[b] (95% CI)	1	0.86 (0.57–1.29)	0.71 (0.46–1.11)	0.82 (0.52–1.29)	0.29
'Animal food' pattern					
No. of deaths	42	44	46	49	
Multivariate-adjusted HR1[a] (95% CI)	1	1.12 (0.73–1.72)	1.38 (0.89–2.15)	1.49 (0.94–2.34)	0.06
Multivariate-adjusted HR2[b] (95% CI)	1	1.10 (0.72–1.70)	1.39 (0.89–2.16)	1.50 (0.95–2.37)	0.05
Total stroke					
Japanese pattern					
No. of deaths	138	100	97	97	
Multivariate-adjusted HR1[a] (95% CI)	1	0.70 (0.54–0.92)	0.66 (0.50–0.87)	0.64 (0.47–0.85)	0.003
Multivariate-adjusted HR2[b] (95% CI)	1	0.71 (0.54–0.92)	0.67 (0.51–0.88)	0.64 (0.48–0.86)	0.004
'Animal food' pattern					
No. of deaths	142	103	103	84	
Multivariate-adjusted HR1[a] (95% CI)	1	0.89 (0.68–1.15)	1.11 (0.84–1.43)	0.97 (0.72–1.31)	0.79
Multivariate-adjusted HR2[b] (95% CI)	1	0.89 (0.69–1.15)	1.11 (0.85–1.45)	1.00 (0.74–1.35)	0.66
Cerebral infarction					
Japanese pattern					
No. of deaths	48	44	38	33	
Multivariate-adjusted HR1[a] (95% CI)	1	0.89 (0.59–1.36)	0.73 (0.47–1.15)	0.60 (0.37–0.99)	0.03
Multivariate-adjusted HR2[b] (95% CI)	1	0.89 (0.59–1.36)	0.73 (0.47–1.15)	0.60 (0.37–0.99)	0.03
'Animal food' pattern					
No. of deaths	51	43	35	34	
Multivariate-adjusted HR1[a] (95% CI)	1	1.04 (0.68–1.57)	1.08 (0.69–1.70)	1.11 (0.69–1.78)	0.66
Multivariate-adjusted HR2[b] (95% CI)	1	1.03 (0.68–1.56)	1.09 (0.69–1.71)	1.14 (0.71–1.85)	0.57
Intracerebral hemorrhage					
Japanese pattern					
No. of deaths	45	29	25	30	0.04
Multivariate-adjusted HR1[a] (95% CI)	1	0.62 (0.38–1.00)	0.52 (0.31–0.87)	0.60 (0.35–1.01)	0.04
Multivariate-adjusted HR2[b] (95% CI)	1	0.63 (0.39–1.02)	0.52 (0.31–0.88)	0.60 (0.36–1.03)	
'Animal food' pattern					
No. of deaths	44	28	30	27	
Multivariate-adjusted HR1[a] (95% CI)	1	0.71 (0.44–1.15)	0.87 (0.53–1.43)	0.82 (0.48–1.41)	0.59
Multivariate-adjusted HR2[b] (95% CI)	1	0.71 (0.44–1.16)	0.89 (0.54–1.46)	0.86 (0.50–1.47)	0.71

[a] Multivariate-adjusted HR1 was adjusted for age (in years), sex, smoking status (never, former, currently smoking <20 cigarettes/day and currently smoking 20 cigarettes/day), walking duration (<1 hour/day and 1 hour/day), education (until age up to 15 years, until age 16–18 years, and until age 19 years), and total energy intake (continuous).

[b] Multivariate-adjusted HR2 was adjusted for the same as HR1, body mass index (<18.5 kg/m^2, 18.5–24.9 kg/m^2, and 25 kg/m^2) and history of hypertension (yes or no).

HR, hazard ratio; CI, confidence interval.

Table 6 Multivariate-adjusted hazard ratio for cardiovascular disease mortality according to the Japanese dietary pattern score quartiles stratified by smoking status

Variable	Dietary pattern score quartiles 1 (low)	2	3	4 (high)	P for Trend
Never smoker					
No. of deaths	82	71	76	73	
Multivariate-adjusted HR1[a] (95% CI)	1	0.70 (0.50–0.97)	0.68 (0.48–0.95)	0.54 (0.38–0.78)	0.002
Multivariate-adjusted HR2[b] (95% CI)	1	0.70 (0.50–0.97)	0.68 (0.48–0.95)	0.54 (0.37–0.78)	0.002
Past smoker					
No. of deaths	53	28	30	27	
Multivariate-adjusted HR1[a] (95% CI)	1	0.53 (0.33–0.85)	0.53 (0.33–0.85)	0.53 (0.32–0.89)	0.01
Multivariate-adjusted HR2[b] (95% CI)	1	0.53 (0.33–0.85)	0.53 (0.33–0.86)	0.53 (0.32–0.89)	0.01
Current smoker					
No. of deaths	87	62	45	61	
Multivariate-adjusted HR1[a] (95% CI)	1	0.79 (0.57–1.10)	0.66 (0.46–0.97)	0.92 (0.64–1.33)	0.41
Multivariate-adjusted HR2[b] (95% CI)	1	0.79 (0.57–1.11)	0.66 (0.46–0.97)	0.93 (0.65–1.34)	0.44

HR, hazard ratio; CI, confidence interval.

[a] Multivariate-adjusted HR1 was adjusted for age (in years), sex, walking duration (<1 hour/day and ⩾ 1 hour/day), education (until age up to 15 years, until age 16-18 years, and until age ⩾ 19 years), and total energy intake (continuous).

[b] Multivariate-adjusted HR2 was adjusted for the same as HR1, body mass index (<18.5kg/m2, 18.5-24.9kg/m^2, and ⩾ 25kg/m2), and history of hypertension (yes or no).

CVD mortality. However, this misclassification may be non-differential and would tend to result in underestimation of the impact of the dietary patterns.

In conclusion, we have found that the Japanese dietary pattern is associated with lower CVD mortality, despite the fact that the Japanese dietary pattern appeared to be related to higher sodium intake and high prevalence of hypertension.

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KEY MESSAGES

- Although ecological observations suggest that the Japanese diet may reduce the risk of cardiovascular disease, the impact of a Japanese dietary pattern upon mortality due to CVD is unclear.
- The association between dietary patterns among 40 547 Japanese aged 40–79 years and CVD mortality was examined in a 7-year prospective cohort study.
- The Japanese dietary pattern was associated with a lower risk of CVD mortality, despite its relation to sodium intake.

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