Japanese Diet: An Explanation for Japanese Paradox

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Abstract

The current life expectancy of the Japanese is the longest in the world [1]. The incidence and mortality from acute myocardial infarction (AMI) remain low in Japan despite major dietary changes and recent worsening of cardiovascular risk factors that should have resulted in a substantial increase in incidence and mortality from AMI [2]. This phenomenon has been defined by some authors as the “Japanese paradox” [3-5]. Their nutritional intake pattern is likely to contribute at least in part to the “Japanese paradox” and their longevity. Since Japan is an island nation, people eat much seafood. Meat-eating has been relatively rare. The beneficial aspects of the traditional Japanese diet have been attributed to its low intake of saturated fatty acids (SFA) and a high intake of polyunsaturated fatty acids (PUFA), especially from fish. Long-term benefits include lower mortality from coronary heart disease (CHD) and from some cancers [6,7]. A drawback of the Japanese diet is its high intake of salt and its association with a higher incidence and mortality from stroke and gastric cancer [8,9].

Recent interest in dietary patterns has spawned several studies of the associations between dietary patterns and longevity [10,11]. Among them, probably the Mediterranean food pattern has attracted most considerable interest; the number of publications on this subject has been increasing consistently ever since in 1985 [12]. Because the life expectancy of the Japanese is longer than that in the Mediterranean countries, it would be worth reviewing the studies on the Japanese dietary pattern.

Two general approaches have been used to define these summary variables [13]. In so-called ‘a posteriori’ approach, or analytic method, exploratory factor analysis is predominantly used. The other approach, the so-called ‘a priori’ approach, or empirical approach, focuses on the construction of pattern variables that reflect hypothesis-oriented patterns based on available scientific evidence for specific diseases. A priori pattern scores were, for example, constructed on the basis of dietary recommendations. First, we overview cross-sectional studies used analytical methods with factorial analysis to derive the Japanese dietary pattern. And examined the association of the obtained Japanese dietary pattern with impaired glucose tolerance. Second, we review prospective studies on the association of Japanese dietary patterns with risk of cancer. Third, we review prospective studies on the association of Japanese dietary patterns with risk of cardiovascular diseases (CVD). Forth, we will review the other method of developing the Japanese dietary score using more empirical approach, and then examined the association of the score with disease outcomes. Then finally we will review the Japanese dietary pattern in migration studies and multiethnic studies.

The Japanese Dietary Pattern and Glucose Tolerance Abnormalities—Cross-Sectional Studies

The surveys showed that age-specific prevalence of diabetes in Japanese population was slightly higher than that in European [14, 15]. The results are seemed paradoxical in light of the fact that obesity is not as prevalent in Japanese population as in Caucasian populations [16]. The reasons may be attributable either to a high genetic susceptibility to type 2 diabetes of Japanese individuals [17], and/or to the role of diets typically consumed by the Japanese. Mizoue et al. investigated dietary patterns in relation to glucose tolerance status, using data from pre-retirement health examinations of 2,377 male Self-Defense officials in Japan [18]. They identified three dietary patterns by factor analysis: (1) a high-dairy, high-fruit and -vegetable, high-starch, low-alcohol pattern; (2) an animal food pattern; and (3) a Japanese pattern. The Japanese dietary pattern was characterized by a higher intake of soybean products, seaweeds, pickles, green tea, vegetables, and fish; common to traditional Japanese food. Logistic regression analysis adjusted for potential confounding factors revealed a significant inverse association of the high-dairy, high-fruit and -vegetable, high-starch, low-alcohol pattern with glucose tolerance abnormality including impaired fasting glucose, impaired glucose tolerance, or type 2 diabetes, and that the Japanese dietary pattern was positively associated with impaired glucose tolerance. Nanri, et al. [19] in a cross-sectional study of community residents in Fukuoka comprised of 3,243 men and 4,667 women, identified four dietary patterns by principal component analysis (1) a healthy dietary pattern with frequent consumption of vegetables, fruit, soy products, fish, and yogurt; (2) a high-fat dietary pattern characterized by frequent consumption of fried food, meat, processed meat, mayonnaise, and egg; (3) a seafood dietary pattern characterized by frequent consumption of a variety of sea foods; (4) a Westernized breakfast pattern characterized by frequent consumption of bread, margarine, and coffee and infrequent consumption of rice and miso soup. Logistic regression analysis with adjustment for potential confounding variables found that the Westernized breakfast pattern was inversely related to hemoglobin...
AIC concentrations in both men and women, and the seafood dietary pattern was positively associated with hemoglobin A1C concentrations in men only. Thus, the both studies suggested that adherence to some traditional dietary patterns in Japanese featuring white rice or salty sea foods may be related to deterioration of glucose metabolism and may explain, at least in part, why Japanese have a high prevalence of type 2 diabetes despite their relatively lean body mass. A higher glycemic indices of traditional dietary pattern in Japanese is attributed to a higher association of impaired glucose metabolism with this dietary pattern [20]. In addition, a greater consumption of salt in traditional Japanese dietary patterns may be related to this association, because there is evidence in humans that diets high in salt deteriorate insulin metabolism [21].

The Japanese Dietary Pattern and Risk of Cancers

In Japan, gastric cancer was ranked as the most common cancer in the past, but from 1970s, mortality rate for gastric cancer showed a declining trend in the subsequent trend [22]. Mortality rate for colorectal cancer in Japan was relatively low, but it has been increasing since 1970s [22]. There have been some studies on dietary patterns and cancers in Japan. Mizoue et al investigated dietary patterns in relation to the risk of colorectal adenoma [23], a precursor of colorectal cancer [24,25], using data from preretirement check-up among male Self-Defense Forces officials in Japan, as in the other study [18]. They generated three dietary patterns by factor analysis: (1) a high-dairy, high-fruit and -vegetable, high-starch, low-alcohol pattern; (2) an animal food pattern; and (3) a Japanese pattern. Among 2,390 male Self-Defense Forces officials who underwent the examination, 2,370 (99 percent) agreed to participate in the study. There were 346 men who had adenoma (case group) and 995 men who were free from any colorectal polyp and cancer (referent group) were analyzed to assess the association between dietary patterns and colorectal adenomas. A significant inverse association was found for the high-dairy, high-fruit and -vegetable, high-starch, low-alcohol pattern; the odds ratios (OR) for the second, third, and fourth quartiles were 0.97 (95% confidence interval [CI], 0.70–1.36), 0.71 (95%CI, 0.50–1.01), and 0.62 (95%CI, 0.43–0.90), respectively, compared with the lowest (P trend = 0.003). The Japanese and “animal food” patterns were not clearly associated with colorectal adenomas.

Masaki et al. studied the dietary patterns and gastric cancer in a cohort of 5,644 middle-aged male workers in Tokyo [26]. During the 10 years of follow-up, there were 86 incident cases of gastric cancer. Principal component analysis identified four dietary patterns: “vegetable and fruit”, “Western breakfast”, “meat”, and “rice/snack” patterns. However, the authors did not find any significant association between dietary patterns and gastric cancer risk.

So far, we have not found any evidence for supporting the hypothesis that Japanese dietary patterns as explanation for Japanese paradox. Now we move on to prospective studies on the association of Japanese dietary patterns with risk of CVD.

Japanese Dietary Patterns and Risk of CVD

Shimazu et al. prospectively assessed the association between dietary patterns among the Japanese and CVD mortality [27]. Dietary information was collected from 40,547 Japanese men and women aged 40–79 years without a history of diabetes, stroke, AMI or cancer at the baseline in 1994. During 7 years of follow-up, 801 participants died of CVD. Factor analysis based on a food frequency questionnaire identified three dietary patterns: (1) a Japanese dietary pattern, which was heavily loaded on soybean products, fish, seaweeds, vegetables, fruits and green tea, (2) an ‘animal food’ dietary pattern, which was loaded heavily on various animal-derived foods (beef, pork, ham, sausage, chicken, liver and butter), coffee and alcoholic beverages, and (3) a high-dairy, high-fruit-and-vegetable, low-alcohol (DFA) dietary pattern, which 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. 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 [HR] of the highest quartile vs the lowest, 0.73; 95%CI, 0.59–0.90; P for trend = 0.003) (Figure 1). The ‘animal food’ dietary pattern was associated with an increased risk of CVD (Figure 1), but the DFA dietary pattern was not. They investigated further the associations of the Japanese and ‘animal food’ dietary patterns with CHD and stroke. After adjusting for potential confounders, the point estimate of the hazard ratio 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. Thus, they found that the Japanese dietary pattern was 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.

Figure 1a. Animal Food Dietary Pattern

Figure 1b. The Japanese Dietary Pattern

Age, sex-adjusted and multivariate-adjusted hazard ratio for CVD mortality according to dietary pattern score quartiles.

The figure 1a shows hazard ratio for CVD mortality according to “animal food” dietary pattern, and figure1b hazard ratio for CVD mortality according to “the Japanese” dietary pattern. After adjustment for potential confounders, the ‘animal food’ dietary pattern was associated with an increased risk of CVD, and the Japanese...
A major criticism of the a posteriori, analytic approach is that the dietary patterns extracted in one study population cannot be reproduced in other study populations [28,29]. Thus, nutritional studies using factor analysis reported quite different patterns [30-39]. Even though patterns have been successfully linked to disease risk [33,34,40] and mortality [39], study specific estimates of relative risks are consequently not reproducible and comparable. These short comings limit the significance of the a posteriori pattern analysis approach in epidemiological research.

On the other hand, the a priori, empirical approach offers the possibility of constructing pattern variables based on scientific evidence, replacing study-specificity by disease-specificity. The data to construct these patterns might come from observational studies of various dietary habits that appear to be associated with the specific diseases [13]. This concept of constructing an a priori pattern variable has been demonstrated to be successful in studying, for example, whether a diet score reflecting key elements of a Mediterranean diet [41] is related to mortality in another population [42]. Now we are going to review our study that applied this a priori empirical approach in constructing a Healthy Reduced-Salt Japanese Diet Score and examining the relationship between this score and all-cause and cause-specific mortality.

**A Healthy Reduced-Salt Japanese Diet Score and All-cause and Cause-specific Mortality An a priori empirical approach**

As stated before, a drawback of the Japanese diet is its high intake of salt and its association with a higher incidence and mortality from stroke and gastric cancer. If the Japanese diet is modified to emphasize the intake of foods that are low in salt, Japanese longevity could be increased further. Based on the previous studies, we comprehensively extracted the beneficial components of the Japanese diet and derived a healthy Reduced Salt Japanese Diet Score [43]. We analyzed the relationship between the diet score and all-cause and cause-specific mortality using the database of the National Integrated Project for Prospective Observations of Non-communicable Diseases and Its Trends in the Aged, 1980 (NIPPON DATA80). The database includes more than 10,000 participants from randomly selected regions in Japan who were followed for 19 years [44-46].

A total of 10,546 community-based participants aged 30 years and over in 300 randomly selected health districts throughout Japan participated in the survey, which consisted of history-taking, physical examinations, blood tests and a self-administered questionnaire on lifestyle, including an essential nutritional survey by the food-frequency method. Participants were followed to 1999 (NIPPON DATA 80, 1980-99). The participation rate was 76.6 % of the overall population in the participating health districts before exclusion because of co-morbidity and some missing data.

We reviewed the residence records of all the study participants for their vital status. In cases of deaths, the causes were examined. To clarify the cause of death, we used the National Vital Statistics records. Deaths were confirmed in each district by computer-matching of data from the Vital Statistics records using the district, sex, and dates of birth and death as key codes.

After exclusion of some participants, the final sample comprised 9,086 participants (4,018 men and 5,068 women). A lifestyle survey was carried out using a self-administered questionnaire which asked about the typical daily consumption of 31 food items [43].

Hypertension was defined as systolic blood pressure 140 mmHg or higher, diastolic blood pressure 90 mmHg or higher, use of antihypertensive agents or any combination of these. Diabetes was determined by medical history or defined as a serum glucose concentration ≥200 mg/dl.

We defined 7 components from the nutritional survey to measure a healthy Reduced Salt Japanese Diet. The components included egg intake ≤2 eggs/week, fish intake ≥ once in 2 days, meat intake ≤2 times/week, tsukemono intake ≥once per day, infrequent intake of soup with noodles, use of low salt soy products, and occasional drinking. The above cut-off values were determined based on previous studies on the intake of eggs, fish, and alcohol [45,49]. For meat and tsukemono, a near median was used as the cut-off. Although we could not define the salt content of the low salt diet, infrequent intake of soup with noodles and the use of low salt soy sauce were used as markers of salt restriction. Because data on amounts of alcohol consumed were not available, and the association between all-cause mortality and alcohol consumption is known to be J-shaped [49], we chose occasional drinking as a component of a healthy reduced salt Japanese diet. Moderate alcohol consumption was also a component of a Mediterranean diet [11]. If any single dietary component was part of a typical daily diet, it was scored as one and zero otherwise. Thus, the total score ranged from 0 to 7, with 0 being least healthy and 7 being most healthy. Participants were divided into approximate tertiles of dietary scores (0-2, 3 and 4-7 scores). To examine the association between the reduced salt Japanese diet score and all cause and cause-specific mortality, age- and sex-adjusted and multivariate-adjusted hazard ratios were calculated using a Cox proportional hazards model. For multivariate analyses, age, sex, BMI, and cigarette smoking (never and past smokers, current smokers <20 cigarettes/day, current smokers 20 to 40 cigarettes/day, and current smokers ≥41 cigarettes/day) were entered as covariates for model 1. For model 2, hyper tension, and diabetes were added. The dietary score group 0-2 served as a reference for comparison with the other tertiles.

During the 19 years of follow-up, there were 1,823 deaths. Among this group, 654 were from CVD, 299 were from stroke, 131 were from AMI, 551 were from cancer, and 119 were from non-cardiovascular, non-cancer inflammatory diseases [50]. As the score increased, risk of death from all-causes, from CVD, and from stroke declined significantly in all models (Figure 2.3). Mortality from AMI, cancer, and inflammatory diseases tended to decrease, but without statistical significance, a possible consequence of the relatively small number of such events.

**All-Cause Mortality**

<table>
<thead>
<tr>
<th>Hazard Ratio</th>
<th>Score 0-2</th>
<th>Score 3</th>
<th>Score 4-7</th>
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</thead>
<tbody>
<tr>
<td>0.70-0.78</td>
<td>1.0</td>
<td>0.89</td>
<td>0.88</td>
</tr>
<tr>
<td>0.80-0.92</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>0.94-1.2</td>
<td>1.0</td>
<td>1.0</td>
<td>1.2</td>
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</table>

**Figure 2: Hazard Ratio for All-cause Mortality According to Reduced-Salt Japanese Diet Score.**

Hazard ratio for all-cause mortality according to Reduced-Salt Japanese Diet Score is shown. As the score increased, risk of death from all-cause declined significantly.
Table 1: Variables Used for Propensity Score Matching --NIPPON DATA80, 1980-99.

<table>
<thead>
<tr>
<th>Before Matching</th>
<th>After Matching</th>
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<td>N</td>
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<tr>
<td>Age (years)</td>
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<tr>
<td>Men (%)</td>
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<td>BMI (kg/m2)</td>
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<td>Smokers (%)</td>
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<td>SBP (mmHg)</td>
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<tr>
<td>DBP (mmHg)</td>
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<td>Uric acid (mg/L)</td>
<td>Uric acid (mg/L)</td>
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<td>Creatinine (mg/L)</td>
<td>Creatinine (mg/L)</td>
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</tbody>
</table>

We defined 7 components from the nutritional survey to measure a healthy Reduced Salt Japanese Diet. The components included egg intake ≤ 2 eggs/week, fish intake ≥ once in 2 days, meat intake ≤ 2 times/week, tsukemono intake ≥ once per day, infrequent intake of soup with noodles, use of low salt soy products, and occasional drinking. If any single dietary component was part of a typical daily diet, it was scored as one and zero otherwise. Thus, the total score ranged from 0 to 7, with 0 being least healthy and 7 being most healthy.

Abbreviations: BMI=body mass index, SBP=systolic blood pressure, DBP=diastolic blood pressure, TCH=total cholesterol concentration.
Comparison of the survival curves was based on the log-rank test. The variables used in the calculation of the propensity score were also compared by t-test and chi-square test to determine if the propensity score matching was successful in mitigating risk factor differences.

The results from the propensity score matching are shown in Table 1. As can be seen, significant differences in the average propensity score and the variables used in its calculation before matching in the two groups disappeared after matching. In contrast, a significant difference between the matched survival curves remained as seen in Figure 4 (P=0.0003 by log-rank test).

![Kaplan-Meier Survival Curve after Propensity Score Matching](image)

**Figure 4: Kaplan-Meier Survival Curve after Propensity Score Matching.**

Significant differences in the average propensity score and the variables used in its calculation before matching in the two groups disappeared after matching. In contrast, a significant difference between the matched survival curves remained as seen in Figure 1 (P=0.0003 by log-rank test). Thick line indicates survival for the participants with the Reduced Salt Japanese Diet Score 4-7, and thin line with the Reduced Salt Japanese Diet Score 0-3. We defined 7 components from the nutritional survey to measure a healthy Reduced Salt Japanese Diet. The components included egg intake ≤ 2 eggs/week, fish intake ≥ once in 2 days, meat intake ≤ 2 times/week, tsukemono intake ≥ once per day; infrequent intake of soup with noodles, use of low salt soy products, and occasional drinking. If any single dietary component was part of a typical daily diet, it was scored as one and zero otherwise. Thus, the total score ranged from 0 to 7, with 0 being least healthy and 7 being most healthy (This figure was reused from Reference 43. The permission was obtained from Cambridge University Press).

Although frequent intake of tsukemono is also a characteristic feature of the traditional Japanese diet, it was unexpected to find that consuming tsukemono at least once a day was associated with a statistically significant lower risk of all-cause mortality. Many types of Japanese tsukemono are prepared in a traditional Japanese fashion with high reliance on salt. Kurosawa M et al. reported that frequent intake of tsukemono and tsukudani and that of mountain herbs were associated with risk of stomach cancer mortality [52]. In our cohort, we examined the association of our diet score with all cancer mortality, or stomach cancer mortality. We found that there was no indication that a higher score was associated with all cancer or stomach cancer mortality (all cancer mortality: fully adjusted model: HR=0.95, 95%CI, 0.77-1.17, P=0.61 for score 3; HR=0.85, 95%CI, 0.69-1.05, P=0.13 for score 4-7 vs score 1-2; stomach cancer mortality: HR=0.87, 95%CI, 0.58-1.33, P=0.53 for score 3; HR=0.71, 95%CI, 0.46-1.08, P=0.11 for score 4-7 vs score 1-2). The healthy nutritional value from eating unsalted tsukemono, even if it existed, may be modest and offer little prognostic significance. Rather, its association with lower mortality may be through a high likelihood of being associated with a traditional Japanese diet.

Those who eat tsukemono may consume meat less often and prefer foods that are commonly enjoyed with tsukemono, such as fish, vegetables, fruits and soybean products.

As stated earlier that Mizoue et al. reported their results of cross-sectional study indicating that traditional Japanese diet, rich in carbohydrate intake, was associated with increased risk of abnormal glucose tolerance and diabetes [18]. We examined in our cohort cross-sectionally using logistic analysis whether or not our diet score was associated with diabetes at baseline. However, there was no indication that a higher score was associated with risk of diabetes (OR=1.19, 95%CI, 0.94-1.51, P=0.16 for score 3; OR=1.12, 95%CI, 0.88-1.42, P=0.36 for score 4-7 vs score 1-2). Using NIPPON DATA80 dataset, we confirmed previously that glucose metabolism abnormality plays an important role in CVD mortality [53]. We also found that increases in non-fasting casual blood glucose concentration, even within higher normal range (5.22 to 7.77 mmol/L), predicted CVD mortality [54].

We did not measure waist circumference (WC). Although the measurement of WC is widely advocated as a simple anthropometric-marker of health risk, and several studies indicated the predictive power of WC on diabetes and other metabolic syndromes was better that BMI [55-57], we showed in a population based study that BMI and WC correlated very well in men and women, and that BMI predicted accumulation of cardiometabolic risk factors as accurate as WC did, and thus BMI could be used instead of WC in a study when the latter was not available [58].

The Japanese Dietary Pattern in Migration Studies and Multiethnic Studies.

The effects of changing dietary pattern on health outcome have been examined by previous migration studies. A large-scale epidemiological study, Ni-Hon-San Study, was begun in 1965 on males in Japan (Hiroshima and Nagasaki) and Japanese-American male residents in Hawaii and at San Francisco [59]. The incidence of MI in men in Japan was about half that in Japanese men in Hawaii [60]. The age-adjusted incidence of total stroke in men in Japan was about 3 times that in Hawaii [61]. Mean relative intakes of animal protein and SFA were higher, and mean complex carbohydrate intake was lower in men in Hawaii than in Japan. Conventional risk factors equally influenced the incidence of AMI in men in Japan and in Hawaii, however, mean total cholesterol, blood glucose, triglycerides were higher in men in Hawaii than in Japan in those days; mean alcohol consumption was lower in men in Hawaii than in Japan. These differences explained the difference in AMI incidence in the two regions. Conversely, relative intake of animal food and SFA were inversely related to total stroke incidence. Lower relative intake of animal food and SFA in Japanese men in Japan than those in Hawaii explained the difference in stroke incidence in the two regions.

Dietary patterns in Japanese migrants to Brazil and their descendants were examined by Cardoso et al. [62]. Intakes of red meat, chicken, coffee were higher in Brazil-born participants than in Japan-born participants; fish intake was less in Brazil-born participants than in Japan-born participants. Changes in dietary pattern might have been occurring even in first-generation Japanese migrants to Brazil judging from the results of a study by Tsugane et al. reporting that standardized mortality ratio (SMR) values for diabetes mellitus, AMI were higher, and that for stroke was lower in first-generation Japanese migrants to Brazil than SMR values in Japanese in Japan [63].
The relative influences of genetic susceptibility of dietary pattern on outcome of chronic diseases were investigated in some multiethnic studies. Sangita et al. studied the association between adherence to dietary guidelines for fruit and vegetable intake with CHD mortality among different ethnic groups of the U.S. Multiethnic Cohort Study (MEC) that included Japanese Americans [64]. They found that the protective effects of dietary intake of fruit and vegetables on CHD mortality did not vary by ethnicity [64]. In another study of MEC, Sharma et al. observed no significant variations for the associations between diet and stroke mortality among ethnic groups [65].

Conclusions

Although some cross-sectional studies suggested that adherence to traditional dietary patterns in Japanese featuring white rice or salty sea foods may be related to deterioration of glucose metabolism, cohort studies demonstrated adherence to a Japanese diet was associated with a lower rate of all-cause and cardiovascular mortality. While Japanese are exceptionally long-lived, placing greater emphasis on the intake of foods that are low in salt could increase longevity in Japan further.

References


