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Nutritional characteristics of the Japanese diet: A cross-sectional study of the correlation between Japanese Diet Index and nutrient intake among community-based elderly Japanese

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ABSTRACT

Objectives: To our knowledge, the overall nutritional quality of the Japanese diet has not been assessed previously. The aim of this study was to investigate the relationship between adhering to a Japanese diet and nutrient intake.

Methods: We conducted a cross-sectional study of 1129 Japanese persons ≥70 y of age. Dietary habits were assessed using a food frequency questionnaire. The primary outcome was nutrient intake (12 components of NRF9.3 index). The overall nutrient adequacy (ONA) score was applied for assessing the potential of nutrient density. Correlation analysis was performed to compare the Japanese Diet Index (JDI) and nutrient intake, and multiple regression analysis was used to simulate the modified JDI (MJDI).

Results: The JDI was positively correlated with all nine beneficial nutrients, and negatively correlated with two nutrients (saturated fat and sugar). The JDI was significantly correlated with the ONA score (Spearman's coefficient = 0.248). The MJDI, which was defined by the coefficients for seven food items, was significantly correlated with the ONA score (Spearman's coefficient = 0.515). However, the JDI and MJDI were correlated with higher sodium intake.

Conclusions: The present findings suggest that adhering to a Japanese diet defined by the JDI score is associated with better nutrient intake. However, this dietary pattern also appears to be associated with high sodium intake.

Introduction

The Japanese diet has been widely expected to have health benefits that have contributed to the longevity of the Japanese population [1–3] Previous studies have reported that the Japanese dietary pattern is associated with a lower risk for mortality or adverse health outcomes (e.g., disability, dementia, and depression) [4–9].

Nutritionally, ecological observations have suggested that the Japanese diet is characterized by a low fat content (particularly saturated fats) [2,3,10,11]. Although several reports have speculated that the Japanese diet has a balanced nutritional content [1], to our knowledge, its overall nutritional quality has not yet been investigated directly.

To understand the nutritional characteristics of the Japanese diet, examining the correlation between index of Japanese diet and nutrient density would be appropriate as a research approach [12]. The Japanese Diet Index (JDI), which is used to rate adherence to an ordinary Japanese dietary pattern, has already been adopted in previous epidemiologic studies [6,7]. In these previous epidemiologic studies, the JDI was defined by nine food items (rice, miso soup, fish, green and yellow vegetables, seaweeds, pickled vegetables, green tea, beef and pork, coffee), based on previous findings about traditional Japanese dietary patterns [13]. Therefore, examining the correlation between the JDI and nutrient density would be useful for understanding the nutritional basis of previous findings regarding the association between the JDI and adverse health outcomes [6,7].

However, because the JDI is an indicator for rating adherence to an "ordinary" Japanese dietary pattern (not necessarily the best, healthy combinations of Japanese-style food), it may include both recommended and non-recommended components [14]. For

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example, a high sodium content has been pointed out as one demerit of the Japanese diet [1,14]. Therefore, it may be necessary to modify the JDI so that it better represents overall nutrient intake.

The objective of the present study was to examine the relationship between adherence to a Japanese dietary pattern and major nutrient intake. To do this, we analyzed the association between the JDI score and nutrient intake. We also conducted analyses to simulate a modified JDI (MJDI) that would predict overall nutrient adequacy.

Materials and methods

Study design

The Tsurugaya Project was a community-based, comprehensive geriatric assessment conducted with elderly Japanese individuals living in Tsurugaya district, a suburban area of Sendai City in northern Japan, between July and October 2002 [15–19].

At the time of the study, 2730 persons ≥70 y of age were living in Tsurugaya. We sent letters to all of them, inviting them to participate in the health survey. Of those invited, 1176 participated in the survey and provided written informed consent for inclusion in the analysis. We excluded 47 individuals for whom data on any items of the JDI were missing, leaving 1129 participants for the present analyses.

For analysis of the relationship between the JDI and blood markers of oxidative stress and inflammation, we further excluded 26 individuals who did not consent to analysis of their blood samples, and therefore a final total of 1103 participants were analyzed.

Dietary assessment

Dietary habits were assessed using a food frequency questionnaire called the Brief Self-administered Diet History Questionnaire (BDHQ), which had been used previously in a validation study [20]. The BDHQ is a 58-item questionnaire that records the consumption frequency of selected foods, but not portion size, and is designed to estimate the dietary intake of 58 food and beverage items during the preceding month. The BDHQ consists of five sections:

1. Intake frequency of food and non-alcoholic beverage items
2. Daily intake of rice and miso soup
3. Frequency of drinking and amount per drink for alcoholic beverages
4. Usual cooking methods
5. General dietary behavior

We obtained estimates of the intake volume for food items, energy, and nutrients that were calculated using an ad hoc computer algorithm for the BDHQ [20,21].

Japanese Diet Index

Based on previous studies [6,7], for calculating the JDI score, we identified nine food items: rice, miso soup, fish and shellfish, green and yellow vegetables, seaweeds, pickled vegetables, green tea, beef and pork, and coffee (corresponding food items of the BDHQ are shown in Table 1).

For each of seven components (rice, miso soup, fish and shellfish, green and yellow vegetables, seaweeds, pickled vegetables, green tea) that were consumed habitually, participants received 1 point if their intake was more than or equal to the sex-specific median. For each of the two components (beef and pork, and coffee) that were not consumed habitually, participants received 1 point if their intake was below the sex-specific median. Thus, the JDI score ranged from 0 to 9, with higher scores indicating greater dietary conformity.

Nutrient intakes and nutrient adequacy score

The primary outcome was the intake of 12 components in the NRF9.3 index (a nutrient density indicator) [22,23]. The NRF9.3 index was based on nine beneficial nutrients (protein; fiber; vitamins A, C, and E; calcium; iron; potassium; and magnesium) and on three nutrients to limit (saturated fat, sodium, and sugar).

We applied the overall nutrient adequacy (ONA) score as an external criterion to compare the potential for nutrient density between the JDI score and the MJDI score, and as a theoretical value to define the MJDI. The ONA score was generated using data for energy and nutrient intake value by the BDHQ [22,24]. With reference to the NRF9.3 index, 11 nutritional components were selected and their corresponding reference values were set according to the recommended dietary allowance (RDA) values in the Dietary Reference Intake (DRI) for Japanese 2015 (shown in Table A.1). Although the NRF9.3 index is an index calculated from 12 components (nine nutrients that are encouraged and three that are limited) [23], we chose all of the nutrients except sugar (thus leaving nine that are encouraged and two that are restricted) because no reference value for sugar has been established in the DRI for Japanese [25]. When nutrient intakes were calculated, each (except for saturated fat) was standardized with the sex-stratified energy intake, considering that nutrient intake may differ in terms of food intake volume and associated energy (for details see Table A.1 in the appendix, footnote) [25]. The nutrient adequacy ratios (i.e., the ratios of standardized intakes to the reference values) of 11 nutritional components were calculated (Table 1). Finally, the ONA score was generated as an average value for all 11 nutrient adequacy ratios. Thus, a high ONA score represents a diet that has a high nutrient density.

Table 1
Nine Components of the Japanese Diet Index and corresponding food items in the BDHQ

Components of Japanese Diet Index	Corresponding food items of BDHQ
Adhering components (7 items)	
Rice	Rice
Miso soup	Miso for miso soup
Fish and shellfish	Squid, octopus, shrimp, and clam
	Small fish with bones
	Canned tuna
	Dried fish and salted fish*
	Oily fish†
	Non-oily fish‡
Green and yellow vegetables	Green leafy vegetables including broccoli
	Carrots and pumpkins
	Tomatoes, tomato ketchup, boiled tomatoes, and stewed tomatoes
Seaweeds	Seaweeds
Pickled vegetables	Salted green and yellow vegetable pickles
	Other salted vegetable pickles (excluding salted pickled plum)
Green tea	Green tea
Non-adhering components (2 items)	
Beef and pork	Pork and beef (including ground pork and beef)
	Ham, sausages, and bacon
Coffee	Coffee

BDHQ, Brief-type Self-administered Diet History Questionnaire
*Includes salted mackerel, salted salmon, and dried horse mackerel.
†Includes sardines, mackerel, saury, amberjack, herring, eel, and fatty tuna.
‡Includes salmon, trout, white meat fish, freshwater fish, and bonito.

Other outcomes (biomarkers)

In the present study, 8-iso-prostaglandin (PG) F2 α was adopted as a marker of oxidative stress, and C-reactive protein (CRP) was adopted as an inflammatory marker.

Plasma total 8-iso-PGF2 α concentration was assayed using a specific enzyme immunoassay kit (Cayman Chemical: Ann Arbor, MI, USA) [16].

The serum CRP concentration was assayed using an immunotechnique employing a Behring BN II analyzer (Dade Behring, Tokyo, Japan) [17]. CRP concentration is known to be a prognostic factor for all-cause mortality in the general Japanese population [26].

Ethical issues

We obtained and used information for each participant in the Tsurugaya Project after confirming that written consent had been obtained. The Ethics Committee of Tohoku University Graduate School of Medicine (Sendai, Japan) reviewed and approved the study protocol.

Statistical analysis

We conducted four types of statistical analysis:

1. Correlation analysis to assess the association between the JDI and the ONA scores
2. Multiple regression analysis to simulate the MJDI
3. Correlation analysis to assess the association between Japanese dietary indices and nutrient intake

4. Multiple regression analysis to assess the association between the JDI and biomarkers

For the first analysis, we calculated the Spearman's correlation coefficient between JDI and ONA score.

Then, to modify the JDI for more precise prediction of overall nutrient adequacy, we used a multiple linear regression model to obtain standardized coefficients for each factor in the JDI relative to the ONA score. The multivariate model was adjusted for energy intake. Then, we applied two steps to define the MJDI: (a) from among the nine JDI factors, selection of those that were significantly related to the ONA score, and (b) summation of the standardized coefficients for each of the selected predictive items in the JDI (i.e., weighting by "standardized coefficients × 10"). The correlation between the MJDI score and the ONA score was also assessed.

In the third analysis, we calculated the Spearman's correlation coefficient between Japanese dietary indices (the JDI score and the MJDI score) and nutrient intakes (12 components). In addition to crude correlation coefficients, we computed coefficients with adjustment for total energy intake by the residual method [27].

Finally, to check whether the JDI is associated with biomarkers of oxidative stress and inflammation, we used a multiple regression model adjusted for sex and age.

All data were analyzed using the IBM SPSS statistics package version 24 (IBM Software Group, Chicago, IL, USA). All statistical tests described here were two-sided, and differences at $P < 0.05$ were accepted as significant.

Results

Characteristics of the participants

The study participants included 471 men (41.7%) and 658 women (58.3%), with a mean (SD) age of 75.6 (4.7) y.

JDI and ONA scores

The correlation between the JDI and the ONA score is shown in Figure 1. The JDI was significantly correlated with the ONA score (Spearman's correlation coefficient = 0.248; $P < 0.001$).

The association between each of the JDI food items and the ONA score is shown in Table 2. All seven food items, with the exception of miso soup and coffee, predicted the ONA score significantly. The standardized coefficients for "green & yellow vegetables" (0.4) and "fish & shellfish" (0.2) were higher, and the standardized coefficient for "rice" (−0.2) was lower. Thus, the MJDI was defined by these standardized coefficients for the seven food items (not including miso soup and coffee) in the JDI (Table A.2).

The correlation between the MJDI and the ONA score is shown in Figure 2. The MJDI was significantly correlated with the ONA score (Spearman's correlation coefficient = 0.515; $P < 0.001$).

JDI and nutrient intake

The correlations between the JDI and nutrient intake are shown in Table 3. In the energy-adjusted results, the JDI was positively correlated with all nine beneficial nutrients. The JDI was negatively correlated with two nutrients (saturated fat and sugar) except for sodium. However, the JDI score was positively correlated with sodium intake. Coefficients of correlation between the JDI and other parameters (saturated fatty acid [%], sodium/potassium ratio) were negative values, but were lower than that for the nutrient intake.

Similar results were obtained for the MJDI, except for saturated fat (i.e., a higher MJDI score was correlated with a higher saturated fat intake).

JDI and biomarkers

Associations between indices of the Japanese diet and markers of oxidative stress/inflammation are shown in Table 4.

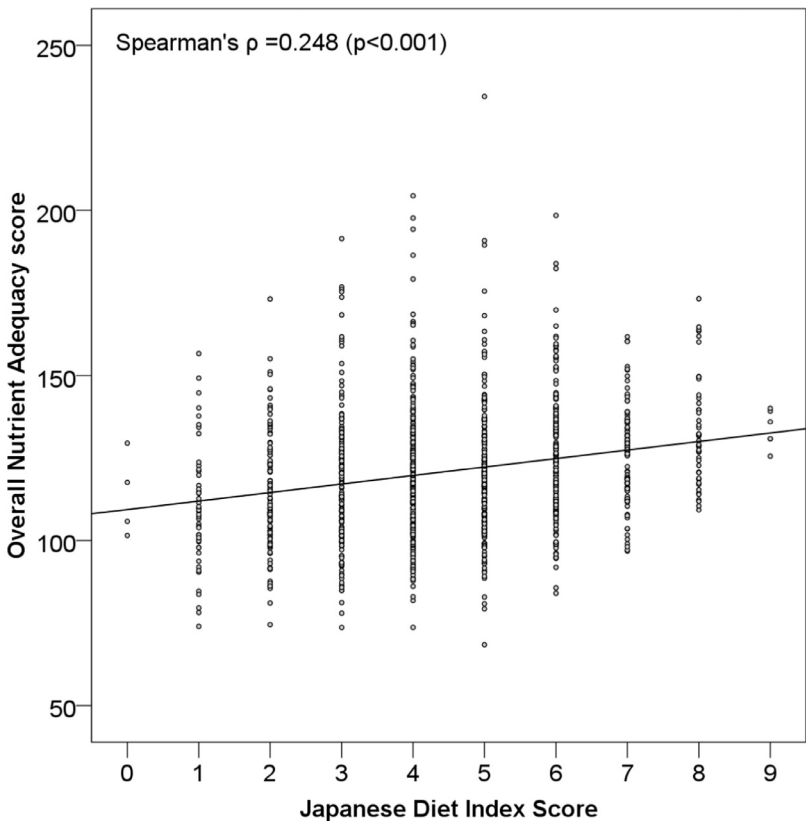

Fig. 1. Correlation between the Japanese Diet Index and the overall nutrient adequacy score (N = 1129).

Table 2
Multiple regression analysis to calculate the weight (standardized β toward ONA score) of each factor of the Japanese Diet Index score (N = 1129)

	β	(95% CI)	*P*-value	Standardized β
Components of Japanese Diet Index score (Dummy variable)*				
Rice	−8.80	(−10.75 to 6.85)	<0.001	−0.2
Miso soup	0.92	(−1.01 to 2.85)	0.351	0.0
Fish & shellfish	9.00	(7.00 to 10.99)	<0.001	0.2
Green & yellow vegetables	17.32	(15.37 to 19.27)	<0.001	0.4
Seaweeds	3.21	(1.26 to 5.16)	0.001	0.1
Pickled vegetables	3.02	(1.13 to 4.92)	0.002	0.1
Green tea	3.19	(1.31 to 5.07)	0.001	0.1
Beef & pork	3.14	(1.19 to 5.10)	0.002	0.1
Coffee	−1.14	(−3.04 to 0.77)	0.242	0.0
Energy intake (kcal)	−0.01	(−0.012 to −0.007)	<0.001	

ONA, overall nutrient adequacy
*Dummy variable (<median [reference], ≥median).

Although the JDI tended to be associated with lower oxidative stress, no significant relationship was observed (Spearman's coefficient = −0.083; $P = 0.362$). The MJDI was significantly associated with lower oxidative stress (Spearman's coefficient = −0.159; $P = 0.004$).

With regard to the inflammation marker, no significant relationships were observed in either the JDI ($P = 0.498$) or the MJDI ($P = 0.554$).

Discussion

In this cross-sectional study, the JDI was positively correlated with all nine beneficial nutrients, and negatively correlated with two (saturated fat and sugar), except for sodium. Additionally, we found a significant positive correlation between the JDI score and the ONA score. These suggest that adhering to a Japanese diet defined by the JDI score is associated with better nutrient intake, with the exception of sodium.

Among the major nutrients, the JDI score was correlated with sodium intake. Although the recent systematic review did not support the contention that sodium reduction has net beneficial effects in a population with normal blood pressure in terms of cardiovascular disease prevention [28], this result may suggest a demerit of the Japanese diet in having high sodium content, as has been noted previously [29–31]. On the other hand, the JDI score also was correlated with potassium intake. This result is also consistent with a previous study [31], Therefore, the Japanese diet may be related to a lower ratio of dietary sodium to potassium [32]. Indeed, the JDI score was inversely correlated with the sodium/potassium ratio in our preliminary results (Table 3).

Based on the associations between each of the factors of the JDI and ONA score, we simulated a weighted index: the MJDI. The

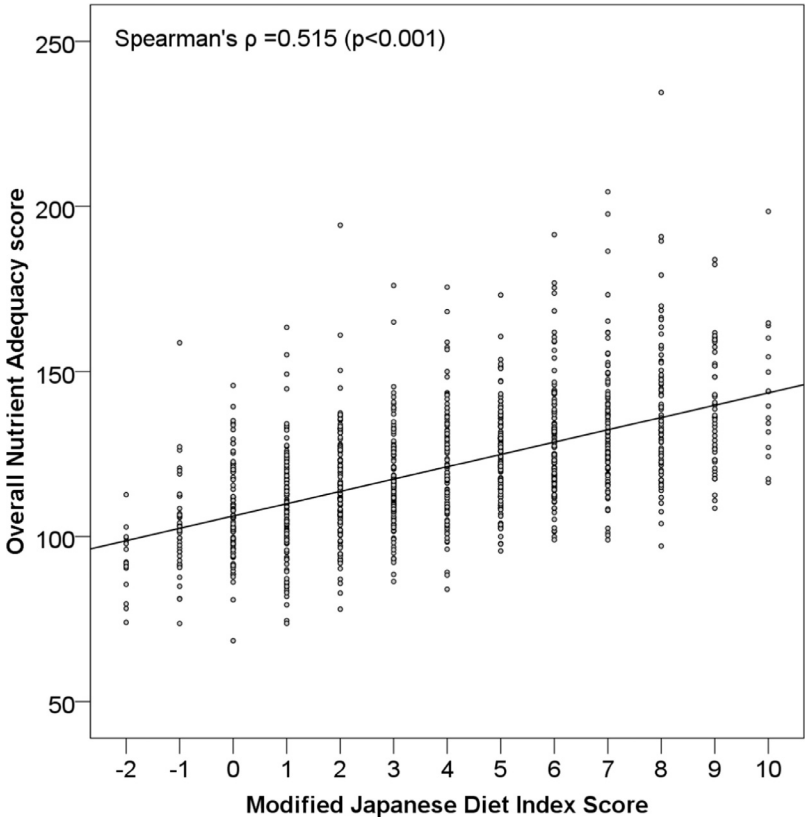

Fig. 2. Correlation between the modified Japanese Diet Index and the overall nutrient adequacy score (N = 1129).

Table 3
Correlations between Japanese dietary indices and nutrient intakes (N = 1129)

	Spearman's ρ			
	Crude		Energy-adjusted	
	Japanese Diet Index	Modified Japanese Diet Index	Japanese Diet Index	Modified Japanese Diet Index
Nutrient intakes*				
Protein (g)	0.373	0.481	0.229	0.439
Fiber (g)	0.441	0.585	0.327	0.531
Vitamin A (μgRAE)	0.295	0.498	0.107	0.341
Vitamin C (mg)	0.398	0.557	0.297	0.481
Vitamin E (mg)	0.312	0.603	0.125	0.574
Calcium (mg)	0.395	0.530	0.260	0.444
Iron (mg)	0.459	0.574	0.367	0.567
Potassium (mg)	0.416	0.615	0.301	0.598
Magnesium (mg)	0.434	0.567	0.333	0.561
Saturated fat (g)	0.116	0.275	−0.163	0.094
Sodium (mg)	0.361	0.428	0.208	0.316
Sugar (g)	−0.024	0.129	−0.173	−0.007
Other parameters				
Saturated fatty acid, %†	−0.033	−0.057		
Sodium/Potassium	−0.025	−0.187		

*Components of the NRF9.3 index; 9 beneficial nutrients (protein; fiber; vitamins A, C, and E; calcium; iron; potassium; and magnesium) and 3 nutrients to limit (saturated fat, sodium, and sugar).
†Saturated fatty acid %: saturated fatty acid (g)/all fatty acid (g).

Table 4
Associations between Japanese diet indices and oxidative stress/inflammation (N = 1103)

	Coefficient (*P*-value)*			
	Oxidative stress marker (8-iso-prostaglandin F2 α)		Inflammation marker (log-transformed C-reactive protein)	
Japanese Diet Index	−0.083	(0.362)	−0.006	(0.498)
Modified Japanese Diet Index	−0.159	(0.004)	−0.003	(0.554)

*Multiple linear regression model adjusted for sex and age (continuous).

MJDI encourages a higher intake of "green and yellow vegetables" and "fish and shellfish," and a lower intake of "rice," even within the Japanese dietary pattern. Through such weighting, the positive correlation with the nutrient intake became stronger in nine beneficial nutrients. Because white rice (the type eaten by most people) is composed almost entirely of carbohydrate, it is natural that a diet composed largely of rice would have a low nutrient density. Thus, the MJDI penalizes rice-based meals (not including vegetables), such as "rice bowl" dishes (*donburi* in Japanese), despite the fact that such meals are a common style of Japanese food. On the other hand, the bigger weighting of "green and yellow vegetables" in the MDJI would suggest that mixed vegetable dishes such as the traditional Japanese-style set meal *ichiju-sansai* would be nutritionally advantageous. In a recent Japanese study, a dietary pattern with a preponderance of vegetable dishes was found to contribute to a lower risk for cardiovascular disease mortality. [33] Additionally, the MJDI was associated with lower oxidative stress, similar to previous findings in studies of healthy diet patterns [34–38]. This result may suggest that the MJDI is more useful for defining the healthier Japanese diet than the JDI score.

However, even if the MJDI had been applied, the results indicating a high sodium content would not have changed, despite the exclusion of miso soup (which is considered to be a source of salt intake in the Japanese diet [39]). A recent Japanese study reported that "seasonings" are the major food group contributing to total sodium intake, with seasonings such as salt or soy sauce accounting for >60% of total sodium intake [40]. Therefore, a change in the usage of seasonings might significantly help decrease the sodium content of the Japanese diet, rather than changes in specific types of food items. In fact, a previous report has indicated that a diet with reduced amounts of salt components, including seasonings, was associated with a lower risk for all-cause mortality in the Japanese population [5].

This study had several limitations. First, because it was based on the food frequency questionnaire method, which is a memory-based dietary assessment method, we could not rule out the possibility that intake of some nutrients may have been misclassified. Especially in the results for the ONA score, considerable systematic error might have been present. Indeed, it has been reported that BDHQ underestimates sodium intake [21]. Although we used objective indicators such as oxidative stress markers in the present study, a further study using more accurate dietary information will therefore be needed. Second, the present study did not consider functional ingredients in Japanese food. For example, although miso soup generally contains some sodium, one previous study found that it had a preventive association with hypertension [41]. To evaluate whether the Japanese diet is indeed healthy, functional food ingredients also should be considered in a future study. Third, we were unable to confirm the external validity. For example, the participants of the present study were only elderly persons. It was unclear whether the findings of the present study would be applicable to the younger generation, even among Japanese. Further studies conducted in other settings will also be needed.

Conclusions

The present findings suggest that adhering to a Japanese dietary pattern defined by the JDI score is associated with better overall nutrient intake. However, high sodium intake is one noteworthy characteristic.

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Table A1
Values of Japanese Dietary Reference Intakes for calculation of overall nutrient adequacy score

Components of overall nutrient adequacy score[†]	RDA[*] Men	RDA[*] Women
Nutrients to encourage (9 items)		
Protein	60 g	50 g
Fiber	19 g	17 g
Vitamin A	800 μgRAE	650 μgRAE
Vitamin C	100 mg	100 mg
Vitamin E	6.5 mg	6.0 mg
Calcium	700 mg	650 mg
Iron	7.0 mg	6.0 mg
Potassium	3000 mg	3000 mg
Magnesium	320 mg	270 mg
Nutrients to limit (2 items)		
Saturated fat	≤7%[‡]	≤7%[‡]
Sodium[§]	<3200 mg	<2800 mg

RDA, Recommended dietary allowance
*As nutrients for which RDA values have not been published, we adopted the Tentative Dietary Goal value (fiber, saturated fat, potassium, sodium) or Adequate Intake value (vitamin E).
[†]Mean of 11 nutrient adequacy ratios of nutrient intake relative to RDA. Nutrient adequacy ratios were calculated as Nutrient intakes(energy standardized)/RDAs for each of 9 nutrients whose intake is desirable or RDAs/Nutrient intakes(energy standardized) for each of 2 nutrients whose intake should be limited. All nutrient intakes except for saturated fat were standardized by energy intake; we assumed that RDA values should be applied when the energy intake was equivalent to the energy requirement for Dietary Reference Intakes (2200 kcal for men, 1750 kcal for women [at a "normal" level of physical activity]). For example: standardized protein intake = Protein intake/energy intake × 2200 was used for men.
[‡]% energy intake.
[§]By conversion of salt intake (<8 g for men, <7 g for women) to sodium.

Table A2
Point scores for calculation of the modified Japanese Diet Index[*]

	Point (weight)
Rice	−2
Fish & shellfish	2
Green & yellow vegetables	4
Seaweeds	1
Pickled vegetables	1
Green tea	1
Beef & pork	1

*For each of the 7 dietary components consumed habitually (rice, fish and shellfish, green and yellow vegetables, seaweeds, pickled vegetables, green tea), participants received the corresponding score if their intake was more than or equal to the sex-specific median. For the component that was not consumed habitually (beef and pork), participants received the corresponding score if their intake was below the sex-specific median. Thus, the modified Japanese Diet Index score ranged from −2 to 10.

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