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ORIGINAL CONTRIBUTION

Diet quality scores in relation to metabolic risk factors in Japanese adults: a cross-sectional analysis from the 2012 National Health and Nutrition Survey, Japan

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Abstract
Objective Associations between the overall quality of Japanese diets and metabolic risk factors are largely unknown. This cross-sectional study investigated this issue using data from the 2012 National Health and Nutrition Survey, Japan.
Methods Dietary intake was assessed by a 1-day weighed dietary record in 15,618 Japanese adults aged ≥ 20 years. Overall diet quality was assessed by adherence to the Japanese Food Guide Spinning Top (JFG score), its modified version (modified JFG score), the Mediterranean diet score (MDS) and the Dietary Approaches to Stop Hypertension (DASH) score. Metabolic risk factors included BMI, waist circumference, blood pressure, total, HDL- and LDL-cholesterol and glycated haemoglobin.
Results While DASH score was consistently associated with favourable nutrient intake patterns (including higher micronutrient and dietary fibre intakes and lower SFA and sodium intakes), other scores were associated with both favourable and unfavourable aspects (e.g., lower micronutrient intakes for JFG score, higher SFA intakes for modified JFG score and higher sodium intakes for MDS). The associations with metabolic risk factors were also inconsistent and unexpected, including positive associations of JFG and modified JFG scores with LDL-cholesterol, inverse associations of MDS with HDL-cholesterol and null associations of DASH score with blood pressure.
Conclusions This study did not show expected and consistent associations of the four available diet quality scores with nutrient intakes and metabolic risk factors in Japanese adults. This in turn suggests the need for a scientific base on which to develop an appropriate tool for assessing the quality of diets in the Japanese context.

Keywords Diet quality · Japan · National survey · Food intake · Nutrient intake · Metabolic risk factors

Introduction

Dietary patterns of the Japanese have long attracted worldwide interest, mainly because of their low prevalence of coronary artery disease and long-life expectancy [1, 2]. Recently, the Japanese Food Guide Spinning Top (JFG) was developed to provide recommendations on food selection and quantities for a healthful diet that can be easily adopted by the public, while taking account of the typical style of Japanese meals (i.e., combination of a staple food, a main dish and side dishes) [3]. Two large-scale population-based prospective cohort studies have shown that adherence to the JFG (i.e., JFG score) is inversely associated with lower total mortality, among women at least [4, 5]. The main purpose of the JFG is to provide recommendations in a quite simple and straightforward fashion, with a particular focus on people with little interest in diet, and to be easily utilised by the food industry [3]. Unfortunately, however, the JFG is not based

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on scientific evidence on what the Japanese actually eat [3]. Additionally, while the JFG score has been associated with favourable aspects of nutrient intake (such as higher intakes of dietary fibre and micronutrients [4, 6, 7]), it has also been associated with unfavourable aspects (such as higher intakes of SFA [4] and sodium [6, 7]). Thus, a modified version of the JFG score (i.e., modified JFG score) has been developed, and has been shown to be associated with nutrient intakes in the expected directions, at least among women [7]. Nevertheless, associations between the overall quality of Japanese diets, assessed by an a priori approach, and metabolic risk factors in free-living settings are largely unknown, given that only one study among young, highly selected women has investigated this issue [6].

The Mediterranean diet score (MDS) is one of the most established diet quality indices in the world. This diet is characterised by high consumption of olive oil, fruits, vegetables, non-refined breads and cereals, potatoes, legumes and nuts; moderate consumption of fish and poultry; low consumption of dairy products, red meat, processed meats and sweets; and moderate wine intake with meals [8]. A second is the Dietary Approach to Stop Hypertension (DASH), originally developed in the US. This dietary pattern promotes the consumption of fruits, vegetables and low-fat dairy products; includes whole grains, poultry, fish and nuts; and attempts to reduce the intakes of red meat, sweets, sugar-containing beverages, total fat, saturated fat and cholesterol [9]. A number of systematic reviews and meta-analyses have consistently shown that both MDS [8, 10, 11] and DASH score [12–14] are associated with favourable profiles of metabolic risk factors and lower mortality. However, these findings are mainly derived from Western countries. Given that Japanese diets are typically characterized by a high consumption of refined grains, soybean products, seaweeds, vegetables, fish and green tea and a low consumption of whole grains, nuts, processed meat and soft drinks [15, 16], the same results would not necessarily be expected in Japan.

The aim of the present cross-sectional study was to investigate the quality of Japanese diets assessed by the JFG score, modified JFG score, MDS and DASH score in relation to metabolic risk factors, based on data from the 2012 National Health and Nutrition Survey, Japan (NHNSJ).

Methods

Data source and analytic sample

The NHNSJ is an annual nationwide nutrition survey which has been conducted since 1945 by local public health centres under the supervision of the Ministry of Health, Labour and Welfare on the basis of the Health Promotion Law. The present cross-sectional study was based on data from the 2012 NHNSJ, with permission from the Ministry of Health, Labour and Welfare, Japan. Full details of the 2012 NHNSJ have been described elsewhere [16]. Briefly, 475 (out of about one million) census units were randomly sampled as survey areas based on the population census. All non-institutionalised Japanese people aged ≥ 1 year living in these areas (approximately $n = 61{,}000$) were invited to participate. Excluded from the survey were institutionalised individuals, those with a foreign citizenship, those not consuming self-selected diets, those consuming a special diet (mainly due to some diseases) and infants aged < 1 year. A total of 12,750 of 24,555 eligible households (52%) took part in the survey. The survey was conducted from 25 October to 7 December 2012.

The number of participants aged ≥ 20 years was 30,639 in the 2012 NHNSJ (Fig. 1). Of these, the number of participants with missing information on dietary intake, anthropometric measurements and lifestyle variables was 3913, 8593 and 14,044, respectively (some had more than one missing variable). After excluding 246 lactating and 136 pregnant women, the final sample used in this analysis comprised 15,618 male and non-lactating and non-pregnant female participants aged ≥ 20 years with complete information on the variables of interest. For the analysis based on waist circumference (WC), systolic and diastolic blood pressure, total, HDL- and LDL-cholesterol and glycated haemoglobin, participants with missing information were further excluded ($n = 344$, 1341, 2119 and 2156, respectively). The participants included in the present analysis ($n = 15{,}618$) differed somewhat from those excluded from the analysis ($n = 1032$–15,021 depending on variables): our excluded participants were more likely to be men, be younger, be current smokers and be physically inactive, and have lower mean energy intake (EI), body mass index (BMI) and WC (all $P < 0.0001$).

This survey was conducted according to the guidelines laid down in the Declaration of Helsinki, and verbal informed consent was obtained from all individual participants. Under the Statistics Act, the Ministry of Health, Labour and Welfare anonymized individual-level data collected from the NHNSJ, and provided the first author with the datasets for this study. In accordance with the Ethical Guidelines of Epidemiological Research established by the Ministry of Education, Culture, Sports, Science and Technology and the Ministry of Health, Labour and Welfare, an institutional review board approval was not required for this analysis.

Dietary assessment

Dietary intake data were collected using a 1-day weighed household dietary record, as detailed elsewhere [16–19]. Briefly, the main record-keeper (usually the main cook in

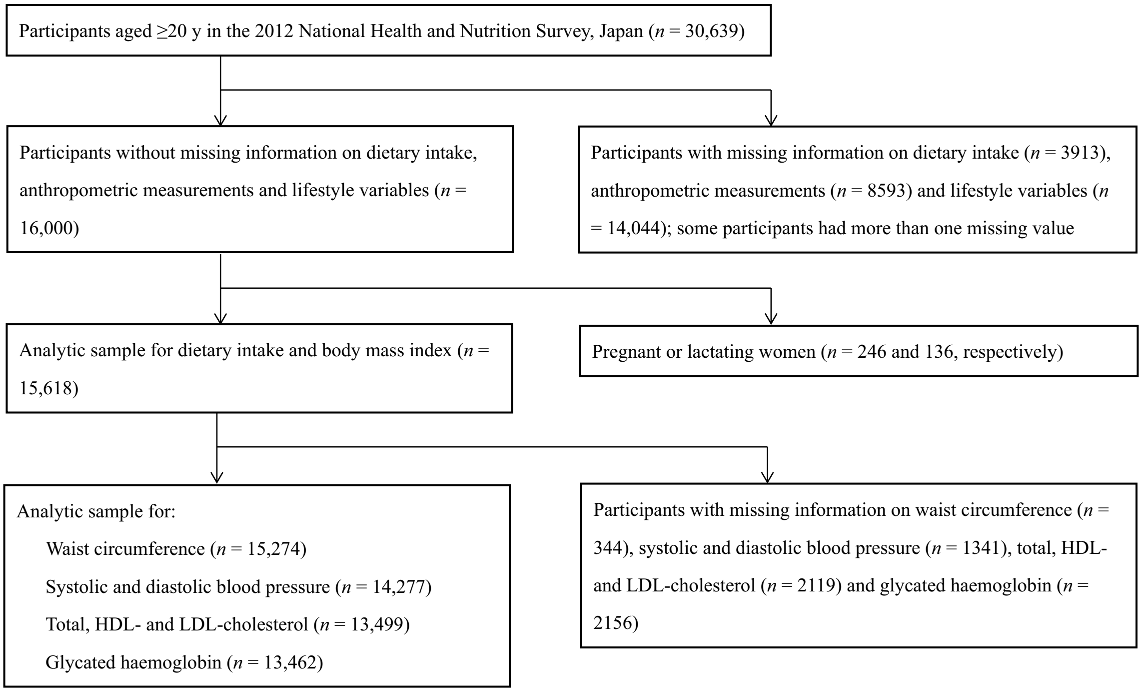

Fig. 1 Flow diagram of the study participants

the household) was given both written and verbal instructions in the home by a trained fieldworker, all of whom were registered dietitians, on how to conduct the dietary record as well as its purpose. The main record-keeper was asked to record and weigh all foods and drinks (except drinking water) consumed by household members on the recording day. Thus, the dietary record included data on all members of the household. When household members shared foods from the same dish, the record-keeper was asked to record approximate proportions of the food taken by each member. When weighing was not possible (e.g., eating out), the record-keeper was asked to record as much information as possible, including the portion size consumed and details of any leftovers. To maximise participation, the recording day was freely selected by each household from any day except Sundays, national holidays and days with special events (e.g., wedding party or funeral). Within a few days after dietary recording (usually the next weekday), a trained fieldworker visited the household to collect the diary and check the completeness of food recording, and record additional information if necessary.

In accordance with a study manual of the NHNSJ, trained fieldworkers converted the estimates of portion sizes recorded using household measures into weights, and coded all individual food items based on the Standard Tables of Food Composition in Japan [20]. After the collected dietary records were checked at the local centre, trained fieldworkers input the dietary intake data using a software application specifically developed for the NHNSJ [21]. The input data were then compiled by trained investigators at the central office to create the whole dietary dataset.

Estimates of daily intake for foods, energy and selected nutrients for each individual were calculated from the record of household food consumption, and for shared dishes or foods, approximate proportions consumed by each household member, based on the Standard Tables of Food Composition in Japan [20]. Food grouping (shown in Supplemental Table 1) was based on the similarity of nutrient profiles or culinary usage of the foods, mainly according to the Standard Tables of Food Composition in Japan [20] and the classification of food groups used in the NHNSJ [16]. Values of food and nutrient intake were energy-adjusted using the density method (i.e., % of energy for energy-providing nutrients and amount per 4184 kJ of energy for foods and other nutrients). The nutrients examined in the present study included protein, fat, SFA, MUFA, PUFA, n-3 and n-6 PUFA, linoleic acid, alpha-linolenic acid, EPA, DHA, carbohydrate, alcohol, dietary fibre and selected vitamins (including vitamins A and C and folate) and minerals (including sodium, potassium, calcium, magnesium and iron). These were selected mainly to allow a comprehensive assessment of intake while considering current dietary intake patterns in Japanese [16].

The utility of this household dietary record for estimating dietary intake at the individual level in the Japanese population has been examined [22]. Briefly, dietary intakes among young women (aged about 20 years) estimated by this 1-day household dietary record by mothers (mean age 49 years) were compared with those estimated by a 1-day weighed dietary record which was independently conducted by the young women themselves ($n = 32$). Mean differences between intakes estimated by the two methods were 6.2% for energy, 5.7% for protein, 6.7% for fat and 6.3% for carbohydrate, while Pearson correlation coefficients were 0.90 for energy, 0.89 for protein, 0.91 for fat and 0.90 for carbohydrate. Additionally, in previous analyses based on the NHNSJ, mean value of the ratio of EI to estimated energy requirement was 1.04 for children [23] and 0.98 for adults [24].

Calculation of diet quality scores

The following four existing diet quality scores were used as indicators for overall diet quality: the JFG score, modified JFG score, MDS and DASH score. The calculation method for the JFG and modified JFG scores has been described in detail elsewhere [7] and in Supplemental Table 2. In brief, the JFG score is based on six components recommended in the Japanese Food Guide Spinning Top (namely 'grain dishes', 'vegetable dishes', 'fish and meat dishes', 'milk', 'fruits' and 'snacks, confection and beverages'). The modified JFG score is similar to the JFG score, but includes sodium from seasonings as one component (seven components in total) and does not apply upper cutoff values for those dietary components where increased consumption is advocated, for Japanese women at least ('grain dishes', 'vegetable dishes', 'fish and meat dishes', 'milk' and 'fruits'). We used the 10th percentile of energy-adjusted sodium intake from seasonings as the recommended range to maximise the distribution of the component score [25]. When intake was within the recommended range, a score of 10 was assigned for each of the components in both the JFG and modified JFG scores. The values of the six scores for the JFG score and of the seven scores for the modified JFG score were then totalled to provide an overall score of AJFG and JDS, which ranged from 0 to 60 and from 0 to 70, respectively.

The MDS (Supplemental Table 3) represents the Mediterranean diet type, based on the consumption of nine components (vegetables; legumes; fruits, nuts and seeds; cereals; fish; unsaturated to saturated fat ratio; dairy products; meat; and alcohol) [26, 27]. Regarding alcohol, moderate intake (i.e., 10–50 g/day for men and 5–25 g/day for women) was assigned a score of one. For dairy products and meat, intake below the sex-specific median was assigned a score of one; for other components, intake above the sex-specific median was assigned a score of one. Scores for the nine components were summed to give a total possible range of zero to nine, with a higher score reflecting better consistency with a Mediterranean-type diet.

The Fung's DASH score, originally developed for the US Nurse's Health Study, consists of eight components, namely fruits and fruit juice; vegetables; whole grain foods; nuts and legumes; low-fat dairy products; red and processed meats; sweetened beverages; and sodium [28]. We modified the sweetened beverages group to better account for the multiple food sources of added sugar in the Japanese diet and included soft drinks, confectioneries and sugar. Participants were classified for each component into sex-specific quintiles by intake (Supplemental Table 4). Whole grain foods and low-fat dairy products were not included as score components because of the large number of non-consumers of these items in the NHNSJ (95 and 74%, respectively). Scores ranged from 1 to 5 for each quintile; for fruits and fruit juice, vegetables, and nuts and legumes, higher intakes were given higher scores, while for red and processed meats, soft drinks, confectioneries and sugar, and sodium, higher intakes were given lower scores. Scores for the six components were summed, giving a total possible score range of 6, indicating lowest adherence, to 30, for maximum adherence.

Assessment of metabolic risk factors

Anthropometric measurements were performed on approximately 90% of the participants by trained fieldworkers using standardised procedures. Body height (to the nearest 0.1 cm) and weight (to the nearest 0.1 kg) were measured while the participants were barefoot and wearing light clothes only. WC was measured at the level of the umbilicus (to the nearest 0.5 cm) at the end of a normal respiration while the participant was standing erect and with the arms at the side and the feet together. Otherwise, height, weight and WC were measured either by other household members at home or self-reported. BMI (kg/m^2) was calculated as weight (kg) divided by height (m) squared. Systolic and diastolic blood pressures were measured by trained fieldworkers on the right arm using a standard mercury sphygmomanometer after the participant had been sitting quietly for ≥ 5 min. A second measurement was carried out 1–2 min after the first, and the mean value of the two was used in the analysis. Non-fasting blood samples were collected and analysed for serum total, LDL- and HDL-cholesterol and glycated haemoglobin concentrations at a commercial laboratory [16, 21, 29].

Assessment of other variables

In accordance with the NHNSJ report [16], six age categories were defined (20–29, 30–39, 40–49, 50–59, 60–69 or ≥ 70 years). Information on smoking status (never, past or current) and habitual alcohol drinking (no or yes) and habitual exercise (no or yes) during the preceding year was also collected. Dietary reporting status was evaluated on the basis of the ratio of reported EI to basal metabolic rate

(BMR) (Goldberg's cut-off) [30], as detailed elsewhere [17]. In brief, BMR was estimated using sex-specific equations developed for Japanese, based on age and body height and weight [31, 32]. Participants were identified as plausible, under- and over-reporters of EI according to whether the individual's ratio was within, below or above the 95% confidence limits for agreement between EI:BMR and a physical activity level for sedentary lifestyle (i.e., 1.55) [30]. As a result, under-, plausible and over-reporters were defined as having an EI:BMR of < 0.87, 0.87–2.75 and > 2.75, respectively.

Statistical analysis

All statistical analyses were performed for men and women separately, using SAS statistical software (version 9.4, SAS Institute Inc, Cary, North Carolina). All reported *P* values are two-tailed, and *P* values < 0·05 were considered statistically significant. Differences in metabolic risk factors and dietary characteristics between men and women were evaluated using independent *t* test. Associations between the diet quality scores were examined using Pearson correlation coefficients. Differences in diet quality scores across categories of basic characteristics were examined based on independent *t* test or ANOVA. When the overall *P* value from ANOVA was < 0.05, a Bonferroni post hoc test was performed. Associations of diet quality scores with nutrient intakes and metabolic risk factors were investigated by linear regression analyses using the PROC REG procedure, with adjustment for potential confounding factors including age, smoking status, habitual alcohol drinking, habitual exercise and dietary reporting status; analyses without adjustment for habitual alcohol drinking provided similar results (data not shown). For analyses on systolic and diastolic blood pressure, total, HDL- and LDL-cholesterol and glycated haemoglobin, further adjustment was made for BMI. The analyses were repeated after excluding participants with the use of medication for hypertension, dyslipidaemia and diabetes.

Data have not been weighted to take account of unequal probabilities of selection resulting from the sample design and non-response, because of a lack of information for doing so (i.e., sampling weights) [16].

Results

Sample characteristics

The present analysis included 6552 men and 9066 women. Men had higher mean values of BMI, WC, systolic and diastolic blood pressure, glycated haemoglobin and EI while women had higher mean values of total, HDL- and LDL-cholesterol (Table 1). Mean values of intakes of all nutrients (Table 1) and food groups (Supplemental Table 5) examined were higher in women than in men, with the exception of higher intakes of alcohol, rice, noodles, meat, alcoholic beverages and soft drinks in men and no sex differences in EPA, DHA, other grains, fish, fruit juice, vegetable juice or seasonings. For diet quality scores, the JFG, modified JFG and DASH scores were on average higher in women while MDS was higher in men (Table 1). While the correlation between the JFG and modified JFG scores was (as expected) strong, correlations of the JFG and modified JFG scores with MDS were almost null and those with the DASH score were moderate (Supplemental Table 6). The correlation between MDS and DASH scores was also moderate.

Associations between diet quality scores and basic characteristics

In both men (Table 2) and women (Table 3), all diet quality scores were positively associated with age. Participants reporting habitual exercise had higher mean values of all diet scores irrespective of sex. Never smokers had higher mean values of all diet scores compared with past and current smokers, except that male past smokers had higher MDS and DASH score. Women without habitual alcohol drinking had higher mean values of all diet scores, while for men the JFG and modified JFG scores were higher in nondrinkers and MDS was higher in drinkers, with no difference in DASH score. Plausible EI reporters had higher mean values of all diet scores in men, while the associations in women were inconsistent, with plausible reporters having a higher JFG score and over-reporters having higher modified JFG and DASH scores.

Associations between diet quality scores and nutrient intakes

Associations between diet quality scores and nutrient intakes were generally similar in both men (Table 4) and women (Table 5). Irrespective of sex, the JFG score was positively associated with intakes of carbohydrate, dietary fibre, vitamin C and calcium and inversely with intakes of protein, PUFA, n−3 PUFA, EPA, DHA, alcohol, magnesium and iron. Only in men, the JFG score was also associated inversely with intakes of total fat, MUFA, n-6 PUFA, linoleic acid, alpha-linolenic acid, folate, sodium and potassium. There was a positive association between the JFG score and SFA intake in women only. For modified JFG score, there were positive associations with intakes of protein, SFA, carbohydrate, dietary fibre, vitamins A and C, folate, potassium, calcium and magnesium and inverse associations with intakes of alcohol and sodium in both men and women. The modified JFG score also showed inverse associations with intakes of MUFA, PUFA (total, n−3 and

Table 1 Metabolic risk factors and dietary characteristics of the participants: the 2012 National Health and Nutrition Survey, Japan

	Men ($n = 6552$)[a]		Women ($n = 9066$)[b]		P[c]
	Mean	SD	Mean	SD	
Metabolic risk factors					
Body mass index (kg/m^2)	23.7	3.3	22.6	3.6	< 0.0001
Waist circumference (cm)	85.8	9.0	81.5	10.2	< 0.0001
Systolic blood pressure (mmHg)	135.5	17.7	129.0	19.2	< 0.0001
Diastolic blood pressure (mmHg)	81.7	11.2	77.1	10.7	< 0.0001
Total cholesterol (mmol/l)	5.04	0.88	5.28	0.89	< 0.0001
HDL-cholesterol (mmol/l)	1.42	0.39	1.64	0.4	< 0.0001
LDL-cholesterol (mmol/l)	2.95	0.79	3.05	0.79	< 0.0001
Glycated haemoglobin (%)	5.78	0.78	5.71	0.63	< 0.0001
Energy intake (kJ/d)	9205	2452	7343	1895	< 0.0001
Nutrient intake					
Protein (% of energy)	14.5	3.0	15.1	3.0	< 0.0001
Fat (% of energy)	24.1	7.3	26.0	7.5	< 0.0001
SFA (% of energy)	6.6	2.6	7.2	2.7	< 0.0001
MUFA (% of energy)	8.7	3.3	9.2	3.3	< 0.0001
PUFA (% of energy)	5.6	1.9	6.0	2.1	< 0.0001
$n-3$ PUFA (% of energy)	1.1	0.7	1.2	0.7	< 0.0001
n−6 PUFA (% of energy)	4.4	1.7	4.8	1.8	< 0.0001
Linoleic acid (% of energy)	4.3	1.7	4.6	1.8	< 0.0001
Alpha-linolenic acid (% of energy)	0.60	0.29	0.65	0.31	< 0.0001
EPA (% of energy)	0.15	0.18	0.14	0.19	1.00
DHA (% of energy)	0.26	0.30	0.26	0.30	0.79
Carbohydrate (% of energy)	55.7	9.4	57.0	8.8	< 0.0001
Alcohol (% of energy)	4.4	6.7	1.1	3.2	< 0.0001
Dietary fibre (g/4184 kJ)	7.3	2.8	8.8	3.2	< 0.0001
Vitamin A (µg/4184 kJ)[d]	274	447	323	467	< 0.0001
Folate (µg/4184 kJ)	178	87	211	95	< 0.0001
Vitamin C (mg/4184 kJ)	61.7	40.5	79.9	47.7	< 0.0001
Sodium (mg/4184 kJ)	2142	751	2285	785	< 0.0001
Potassium (mg/4184 kJ)	1329	409	1540	465	< 0.0001
Calcium (mg/4184 kJ)	245	113	296	128	< 0.0001
Magnesium (mg/4184 kJ)	136	38	151	43	< 0.0001
Iron (mg/4184 kJ)	4.1	1.4	4.6	1.5	< 0.0001
Diet quality score					
JFG score[e]	32.5	8.5	35.1	8.2	< 0.0001
Modified JFG score[f]	44.2	9.6	47.3	8.9	< 0.0001
MDS[g]	4.3	1.7	4.1	1.7	< 0.0001
DASH score[h]	17.8	3.6	18.0	3.5	0.02

JFG Japanese Food Guide Spinning Top, *MDS* Mediterranean diet score, *DASH* Dietary Approaches to Stop Hypertension

[a]$n = 6395$ for waist circumference, 5862 for systolic and diastolic blood pressures, 5563 for total, HDL- and LDL-cholesterol and 5551 for glycated haemoglobin

[b]$n = 8879$ for waist circumference, 8415 for systolic and diastolic blood pressures, 7936 for total, HDL- and LDL-cholesterol and 7911 for glycated haemoglobin

[c]P values for differences between men and women based on independent t test

[d]Retinol equivalent

[e]Possible score ranging from 0 to 60

[f]Possible score ranging from 0 to 70

[g]Possible score ranging from 0 to 9

[h]Possible score ranging from 6 to 30

Table 2 Diet quality scores according to categories of basic characteristics in men ($n = 6552$): the 2012 National Health and Nutrition Survey, Japan

	n	%	JFG score[a]		Modified JFG score[b]		MDS[c]		DASH score[d]	
			Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age (years)										
20–29	378	5.8	31.6[ab]	7.7	42.0[a]	8.4	3.2[a]	1.6	15.7[a]	3.4
30–39	747	11.4	31.2[b]	8.1	41.4[a]	8.6	3.5[b]	1.6	16.1[a]	3.3
40–49	811	12.4	32.0[a,b]	8.4	42.0[a]	8.9	3.7[b]	1.7	16.7[b]	3.4
50–59	940	14.4	31.3[b]	8.8	42.1[a]	9.5	4.2[c]	1.7	17.3[c]	3.5
60–69	1724	26.3	32.4[a,c]	8.9	44.7[b]	9.8	4.6[d]	1.6	18.5[d]	3.4
≥ 70	1952	29.8	33.8[d]	8.3	47.1[c]	9.6	4.8[e]	1.6	19.1[e]	3.4
P[e]			< 0.0001		< 0.0001		< 0.0001		< 0.0001	
Smoking status										
Never	1875	28.6	33.8[a]	8.3	46.1[a]	9.3	4.3[a]	1.7	18.2[a]	3.6
Past	2724	41.6	32.9[b]	8.5	45.1[b]	9.7	4.5[b]	1.7	18.4[b]	3.5
Current	1953	29.8	30.5[c]	8.4	41.1[c]	9.1	4.0[c]	1.7	16.7[c]	3.5
P[e]			< 0.0001		< 0.0001		< 0.0001		< 0.0001	
Habitual alcohol drinking										
No	2023	30.9	34.8	7.9	47.0	9.1	4.1	1.7	17.9	3.8
Yes	4529	69.1	31.4	8.6	42.9	9.5	4.4	1.7	17.8	3.6
P[e]			< 0.0001		< 0.0001		< 0.0001		0.42	
Habitual exercise										
No	4262	65.1	31.9	8.4	43.2	9.3	4.2	1.7	17.5	3.5
Yes	2290	35.0	33.5	8.7	46.1	9.9	4.4	1.7	18.5	3.7
P[e]			< 0.0001		< 0.0001		0.0001		< 0.0001	
Dietary reporting status[f]										
Underreporting	189	2.9	27.7[a]	8.8	39.2[a]	9.2	4.0[a,b]	1.5	16.6[a]	3.7
Plausible reporting	6287	96.0	32.6[b]	8.5	44.3[b]	9.6	4.3[b]	1.7	17.9[b]	3.6
Over-reporting	76	1.2	31.1[b]	10.1	43.4[b]	9.4	3.7[a]	1.8	17.7[a,b]	3.7
P[e]			< 0.0001		< 0.0001		0.002		< 0.0001	

JFG Japanese Food Guide Spinning Top, *MDS* Mediterranean diet score, *DASH* Dietary Approaches to Stop Hypertension

[a]Possible score ranging from 0 to 60

[b]Possible score ranging from 0 to 70

[c]Possible score ranging from 0 to 9

[d]Possible score ranging from 6 to 30

[e]On the basis of independent *t* test for habitual alcohol drinking and habitual exercise and ANOVA for other variables. When the overall *P* from ANOVA was < 0.05, a Bonferroni's post hoc test was performed; values within each variable with unlike superscript letters are significantly different ($P < 0.05$)

[f]Underreporters were defined as participants with the ratio of energy intake to basal metabolic rate (EI:BMR) < 0.87; plausible reporters as participants with an EI:BMR 0.87–2.75; over-reporters as participants with an EI:BMR > 2.75

n−6), linoleic acid and alpha-linolenic acid in men only. For women only, the modified JFG score was positively associated with intakes of total fat, MUFA and iron.

MDS was associated positively with intakes of protein, PUFA (total, n−3 and n−6), linoleic acid, alpha-linolenic acid, EPA, DHA, carbohydrate, dietary fibre, folate, vitamin C, sodium, potassium, magnesium and iron and inversely with intakes of total fat, SFA and MUFA in both sexes. MDS also showed positive associations with intakes of alcohol and vitamin A and an inverse association with calcium intake in men only. The associations for DASH score were quite similar to those for MDS in both men and women, except for an inverse association with sodium, a positive association with calcium (as well as vitamin A in men only) and null association with alcohol.

Table 3 Diet quality scores according to categories of basic characteristics in women (*n* = 9066): the 2012 National Health and Nutrition Survey, Japan

	n	%	JFG score[a]		Modified JFG score[b]		MDS[c]		DASH score[d]	
			Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age (years)										
20–29	448	4.9	32.3[a]	8.4	43.4[a]	8.6	3.3[a]	1.5	16.0[a]	3.3
30–39	1016	11.2	33.4[a,b]	8.8	44.0[a]	9.0	3.4[a]	1.6	16.5[a,b]	3.3
40–49	1288	14.2	33.8[b]	8.4	44.6[a]	8.7	3.5[a]	1.6	16.7[b,c]	3.3
50–59	1502	16.6	35.2[c]	8.3	46.9[b]	8.7	4.0[b]	1.6	17.8[d]	3.4
60–69	2292	25.3	35.6[c]	8.1	48.8[c]	8.5	4.4[c]	1.6	18.8[e]	3.4
≥ 70	2520	27.8	36.4[d]	7.7	49.6[d]	8.4	4.6[d]	1.6	19.0[e]	3.3
P[e]			< 0.0001		< 0.0001		< 0.0001		< 0.0001	
Smoking status										
Never	7676	84.7	35.6[a]	8.1	48.0[a]	8.7	4.1[a]	1.6	18.2[a]	3.5
Past	728	8.0	33.1[b]	8.5	44.5[b]	9.0	3.8[b]	1.7	17.2[b]	3.3
Current	662	7.3	31.4[c]	8.4	42.1[c]	9.0	3.7[b]	1.6	16.4[c]	3.5
P[e]			< 0.0001		< 0.0001		< 0.0001		< 0.0001	
Habitual alcohol drinking										
No	6134	67.7	35.8	8.0	48.3	8.6	4.1	1.6	18.2	3.5
Yes	1659	18.3	33.6	8.5	45.3	9.1	4.0	1.7	17.5	3.4
P[e]			< 0.0001		< 0.0001		< 0.0001		< 0.0001	
Habitual exercise										
No	6588	72.7	34.9	8.3	46.7	8.8	4.0	1.7	17.7	3.5
Yes	2478	27.3	35.6	8.2	48.9	8.9	4.2	1.6	18.7	3.5
P[e]			0.0006		< 0.0001		< 0.0001		< 0.0001	
Dietary reporting status[f]										
Underreporting	227	2.5	28.8[a]	8.9	42.0[a]	8.8	3.9	1.6	17.4[a]	3.6
Plausible reporting	8586	94.7	35.2[b]	8.2	47.4[b]	8.8	4.1	1.7	18.0[b]	3.5
Over-reporting	253	2.8	36.8[c]	7.8	48.8[c]	8.7	4.0	1.6	18.5[b]	3.4
P[e]			< 0.0001		< 0.0001		0.13		0.002	

JFG Japanese Food Guide Spinning Top, *MDS* Mediterranean diet score, *DASH* Dietary Approaches to Stop Hypertension

[a]Possible score ranging from 0 to 60

[b]Possible score ranging from 0 to 70

[c]Possible score ranging from 0 to 9

[d]Possible score ranging from 6 to 30

[e]On the basis of independent *t* test for habitual alcohol drinking and habitual exercise and ANOVA for other variables. When the overall *P* from ANOVA was < 0.05, a Bonferroni's post hoc test was performed; values within each variable with unlike superscript letters are significantly different ($P < 0.05$)

[f]Underreporters were defined as participants with the ratio of energy intake to basal metabolic rate (EI:BMR) < 0.87; plausible reporters as participants with an EI:BMR 0.87–2.75; over-reporters as participants with an EI:BMR > 2.75

Associations between diet quality scores and metabolic risk factors

After adjustment for potential confounding factors, the JFG score was inversely associated with BMI, WC, systolic blood pressure and HDL-cholesterol in both men and women (Table 6). The JFG score was also associated inversely with diastolic blood pressure and positively with LDL-cholesterol in men only. The modified JFG score was similarly associated with metabolic risk factors, except for no associations with BMI in men and HDL-cholesterol in women. Conversely, MDS showed inverse associations with total and LDL-cholesterol in both sexes. MDS was also inversely associated with HDL-cholesterol only in men. For DASH score, there were inverse associations with WC and total and LDL-cholesterol in both men and women. DASH score was also inversely associated with BMI in women only. After excluding participants taking medication for hypertension, dyslipidaemia and diabetes, similar associations between diet quality scores and nutrient intakes (data not shown)

Table 4 Associations between diet quality scores and nutrient intakes in men ($n=6552$): the 2012 National Health and Nutrition Survey, Japan

	JFG score[a]			Modified JFG score[b]			MDS[c]			DASH score[d]		
	β^e	SE[e]	*P*	β^e	SE[e]	*P*	β^e	SE[e]	*P*	β^e	SE[e]	*P*
Protein (% of energy)	−0.08	0.004	<0.0001	0.04	0.004	<0.0001	0.23	0.02	<0.0001	0.10	0.01	<0.0001
Fat (% of energy)	−0.01	0.01	0.23	0.07	0.009	<0.0001	−1.43	0.05	<0.0001	−0.26	0.03	<0.0001
SFA (% of energy)	0.01	0.004	0.0003	0.05	0.003	<0.0001	−0.84	0.02	<0.0001	−0.16	0.009	<0.0001
MUFA (% of energy)	−0.001	0.005	0.83	0.02	0.004	<0.0001	−0.66	0.02	<0.0001	−0.17	0.01	<0.0001
PUFA (% of energy)	−0.01	0.003	<0.0001	−0.001	0.003	0.76	0.17	0.01	<0.0001	0.07	0.007	<0.0001
n−3 PUFA (% of energy)	−0.01	0.001	<0.0001	−0.001	0.001	0.31	0.11	0.005	<0.0001	0.03	0.002	<0.0001
n−6 PUFA (% of energy)	0.000	0.002	0.92	0.000	0.002	1.00	0.06	0.01	<0.0001	0.05	0.006	<0.0001
Linoleic acid (% of energy)	0.002	0.002	0.54	0.000	0.002	0.98	0.06	0.01	<0.0001	0.05	0.006	<0.0001
Alpha-linolenic acid (% of energy)	0.000	0.000	0.80	0.000	0.000	0.71	0.02	0.002	<0.0001	0.01	0.001	<0.0001
EPA (% of energy)	−0.003	0.000	<0.0001	0.000	0.000	0.25	0.03	0.001	<0.0001	0.005	0.0007	<0.0001
DHA (% of energy)	−0.006	0.000	<0.0001	0.000	0.000	0.26	0.04	0.002	<0.0001	0.008	0.001	<0.0001
Carbohydrate (% of energy)	0.38	0.01	<0.0001	0.19	0.01	<0.0001	1.30	0.07	<0.0001	0.25	0.03	<0.0001
Alcohol (% of energy)	−0.28	0.008	<0.0001	−0.27	0.008	<0.0001	−0.05	0.05	0.32	0.01	0.02	0.63
Dietary fibre (g/4184 kJ)	0.03	0.004	<0.0001	0.08	0.004	<0.0001	0.48	0.02	<0.0001	0.32	0.009	<0.0001
Vitamin A (μg/4184 kJ)[f]	−0.97	0.72	0.18	2.58	0.66	<0.0001	1.67	3.66	0.65	11.71	1.75	<0.0001
Folate (μg/4184 kJ)	−0.24	0.13	0.06	1.34	0.11	<0.0001	11.84	0.63	<0.0001	8.20	0.29	<0.0001
Vitamin C (mg/4184 kJ)	0.43	0.06	<0.0001	1.32	0.05	<0.0001	3.58	0.29	<0.0001	3.84	0.13	<0.0001
Sodium (mg/4184 kJ)	−0.83	1.11	0.46	−14.74	1.00	<0.0001	82.66	5.58	<0.0001	−48.36	2.65	<0.0001
Potassium (mg/4184 kJ)	−0.28	0.58	0.63	12.61	0.51	<0.0001	49.72	2.91	<0.0001	44.29	1.32	<0.0001
Calcium (mg/4184 kJ)	0.41	0.16	0.01	4.09	0.14	<0.0001	1.42	0.83	0.09	8.82	0.38	<0.0001
Magnesium (mg/4184 kJ)	−0.29	0.05	<0.0001	0.62	0.05	<0.0001	7.65	0.26	<0.0001	4.28	0.12	<0.0001
Iron (mg/4184 kJ)	−0.01	0.002	<0.0001	0.01	0.00	<0.0001	0.23	0.01	<0.0001	0.11	0.005	<0.0001

Adjustment was made for age (20–29, 30–39, 40–49, 50–59, 60–69 or ≥70 years), smoking status (never, past or current), habitual alcohol drinking (no or yes), habitual exercise (no or yes), and dietary reporting status (under-, plausible or over-reporting)

JFG Japanese Food Guide Spinning Top, *MDS* Mediterranean diet score, *DASH* Dietary Approaches to Stop Hypertension; β regression coefficient

[a]Possible score ranging from 0 to 60

[b]Possible score ranging from 0 to 70

[c]Possible score ranging from 0 to 9

[d]Possible score ranging from 6 to 30

[e]Regression coefficients mean the change of dietary variables with 1-point increase of each of diet quality scores

[f]Retinol equivalent

Table 5 Associations between diet quality scores and nutrient intakes in women ($n = 9066$): the 2012 National Health and Nutrition Survey, Japan

	JFG score[a]			Modified JFG score[b]			MDS[c]			DASH score[d]		
	β^e	SE[e]	P	β^e	SE[e]	P	β^e	SE[e]	P	β^e	SE[e]	P
Protein (% of energy)	−0.09	0.004	< 0.0001	0.03	0.004	< 0.0001	0.23	0.02	< 0.0001	0.09	0.01	< 0.0001
Fat (% of energy)	−0.08	0.009	< 0.0001	−0.007	0.009	0.44	−1.48	0.05	< 0.0001	−0.29	0.02	< 0.0001
SFA (% of energy)	−0.003	0.003	0.46	0.03	0.003	< 0.0001	−0.95	0.01	< 0.0001	−0.18	0.008	< 0.0001
MUFA (% of energy)	−0.03	0.004	< 0.0001	−0.02	0.004	< 0.0001	−0.65	0.02	< 0.0001	−0.18	0.01	< 0.0001
PUFA (% of energy)	−0.03	0.003	< 0.0001	−0.02	0.003	< 0.0001	0.22	0.01	< 0.0001	0.08	0.007	< 0.0001
n−3 PUFA (% of energy)	−0.01	0.0009	< 0.0001	−0.004	0.0009	< 0.0001	0.13	0.004	< 0.0001	0.03	0.002	< 0.0001
n−6 PUFA (% of energy)	−0.02	0.002	< 0.0001	−0.02	0.002	< 0.0001	0.09	0.01	< 0.0001	0.05	0.006	< 0.0001
Linoleic acid (% of energy)	−0.01	0.002	< 0.0001	−0.02	0.002	< 0.0001	0.09	0.01	< 0.0001	0.05	0.006	< 0.0001
Alpha-linolenic acid (% of energy)	−0.002	0.0004	< 0.0001	−0.003	0.0004	< 0.0001	0.03	0.002	< 0.0001	0.01	0.001	< 0.0001
EPA (% of energy)	−0.003	0.0002	< 0.0001	0.000	0.000	0.41	0.03	0.001	< 0.0001	0.005	0.0006	< 0.0001
DHA (% of energy)	−0.006	0.0004	< 0.0001	−0.001	0.000	0.22	0.05	0.002	< 0.0001	0.008	0.0009	< 0.0001
Carbohydrate (% of energy)	0.25	0.01	< 0.0001	0.09	0.01	< 0.0001	1.26	0.05	< 0.0001	0.31	0.03	< 0.0001
Alcohol (% of energy)	−0.07	0.004	< 0.0001	−0.08	0.004	< 0.0001	0.05	0.02	0.008	0.01	0.009	0.26
Dietary fibre (g/4184 kJ)	0.01	0.004	0.0002	0.07	0.004	< 0.0001	0.55	0.02	< 0.0001	0.40	0.009	< 0.0001
Vitamin A (μg/4184 kJ)[f]	−0.65	0.61	0.29	2.68	0.58	< 0.0001	7.16	3.10	< 0.0001	13.60	1.47	< 0.0001
Folate (μg/4184 kJ)	−0.51	0.12	< 0.0001	1.36	0.11	< 0.0001	13.58	0.59	< 0.0001	9.77	0.27	< 0.0001
Vitamin C (mg/4184 kJ)	0.35	0.06	< 0.0001	1.53	0.05	< 0.0001	4.65	0.30	< 0.0001	5.03	0.13	< 0.0001
Sodium (mg/4184 kJ)	−2.77	1.01	0.006	−20.28	0.94	< 0.0001	101.62	5.05	< 0.0001	−42.74	2.42	< 0.0001
Potassium (mg/4184 kJ)	−1.47	0.57	0.01	13.87	0.53	< 0.0001	51.87	2.87	< 0.0001	55.02	1.27	< 0.0001
Calcium (mg/4184 kJ)	0.76	0.16	< 0.0001	5.25	0.15	< 0.0001	−2.86	0.83	0.0006	11.29	0.38	< 0.0001
Magnesium (mg/4184 kJ)	−0.34	0.05	< 0.0001	0.68	0.05	< 0.0001	7.99	0.26	< 0.0001	5.18	0.12	< 0.0001
Iron (mg/4184 kJ)	−0.02	0.002	< 0.0001	−0.002	0.002	0.24	0.26	0.009	< 0.0001	0.13	0.004	< 0.0001

Adjustment was made for age (20–29, 30–39, 40–49, 50–59, 60–69 or ≥70 years), smoking status (never, past or current), habitual alcohol drinking (no or yes), habitual exercise (no or yes), and dietary reporting status (under-, plausible or over-reporting)

JFG Japanese Food Guide Spinning Top, *MDS* Mediterranean diet score, *DASH* Dietary Approaches to Stop Hypertension, *β* regression coefficient

[a]Possible score ranging from 0 to 60

[b]Possible score ranging from 0 to 70

[c]Possible score ranging from 0 to 9

[d]Possible score ranging from 6 to 30

[e]Regression coefficients mean the change of dietary variables with 1-point increase of each of diet quality scores

[f]Retinol equivalent

Table 6 Associations between diet quality scores and metabolic risk factors: the 2012 National Health and Nutrition Survey, Japan

	n	JFG score[a]			Modified JFG score[b]			MDS[c]			DASH score[d]		
		β^e	SE[e]	*P*	β^e	SE[e]	*P*	β^e	SE[e]	*P*	β^e	SE[e]	*P*
Men													
Body mass index (kg/m^2)	6552	−0.02	0.005	0.002	−0.005	0.004	0.27	0.04	0.02	0.15	−0.005	0.01	0.70
Waist circumference (cm)	6395	−0.05	0.01	< 0.0001	−0.03	0.01	0.02	−0.03	0.07	0.66	−0.07	0.03	0.03
Systolic blood pressure (mmHg)	5862	−0.15	0.03	< 0.0001	−0.16	0.02	< 0.0001	0.07	0.13	0.56	−0.12	0.06	0.0502
Diastolic blood pressure (mmHg)	5862	−0.04	0.02	0.008	−0.06	0.02	< 0.0001	−0.08	0.08	0.36	−0.05	0.04	0.25
Total cholesterol (mmol/l)	5563	−0.002	0.001	0.10	−0.001	0.001	0.34	−0.03	0.007	< 0.0001	−0.01	0.003	0.0009
HDL-cholesterol (mmol/l)	5563	−0.004	0.0006	< 0.0001	−0.002	0.0005	0.0002	−0.005	0.003	0.10	0.001	0.001	0.35
LDL-cholesterol (mmol/l)	5563	0.004	0.001	0.0004	0.003	0.001	0.005	−0.03	0.006	< 0.0001	−0.01	0.003	< 0.0001
Glycated haemoglobin (%)	5551	0.001	0.001	0.38	0.001	0.001	0.31	0.004	0.006	0.55	0.004	0.003	0.15
Women													
Body mass index (kg/m^2)	9066	−0.02	0.005	< 0.0001	−0.02	0.004	< 0.0001	0.03	0.02	0.16	−0.05	0.01	< 0.0001
Waist circumference (cm)	8879	−0.06	0.01	< 0.0001	−0.06	0.01	< 0.0001	0.04	0.07	0.58	−0.15	0.03	< 0.0001
Systolic blood pressure (mmHg)	8415	−0.07	0.02	0.002	−0.07	0.02	0.001	0.21	0.11	0.06	−0.05	0.05	0.38
Diastolic blood pressure (mmHg)	8415	−0.02	0.01	0.08	−0.02	0.01	0.22	0.13	0.07	0.05	0.003	0.03	0.93
Total cholesterol (mmol/l)	7936	−0.001	0.001	0.20	0.001	0.001	0.21	−0.03	0.006	< 0.0001	−0.007	0.003	0.013
HDL-cholesterol (mmol/l)	7936	−0.002	0.0005	0.002	0.0001	0.0005	0.88	−0.01	0.003	< 0.0001	0.001	0.001	0.33
LDL-cholesterol (mmol/l)	7936	−0.0002	0.001	0.86	0.001	0.001	0.17	−0.02	0.005	< 0.0001	−0.008	0.003	0.003
Glycated haemoglobin (%)	7911	−0.0002	0.0008	0.84	0.00004	0.0008	0.96	−0.002	0.004	0.58	−0.001	0.002	0.58

Adjustment was made for age (20–29, 30–39, 40–49, 50–59, 60–69 or ≥70 years), smoking status (never, past or current), habitual alcohol drinking (no or yes), habitual exercise (no or yes), and dietary reporting status (under-, plausible or over-reporting). For systolic and diastolic blood pressure, total, HDL- and LDL-cholesterol and glycated haemoglobin, further adjustment was made for body mass index (continuous)

JFG Japanese Food Guide Spinning Top, *MDS* Mediterranean diet score, *DASH* Dietary Approaches to Stop Hypertension, *β* regression coefficient

[a]Possible score ranging from 0 to 60

[b]Possible score ranging from 0 to 70

[c]Possible score ranging from 0 to 9

[d]Possible score ranging from 6 to 30

[e]Regression coefficients mean the change of metabolic risk factors with 1-point increase of each of diet quality scores

and metabolic risk factors (Supplemental Table 7) were observed, although several associations with metabolic risk factors did not reach statistical significance.

Discussion

To our knowledge, this is the first epidemiological study to examine the quality of Japanese diets as assessed by the a priori approach in relation to nutrient intakes and metabolic risk factors, based on data from a national nutrition survey. The DASH score was consistently associated with favourable nutrient intake patterns, including higher intakes of micronutrients and dietary fibre and lower intakes of SFA and sodium. In contrast, the other diet scores were associated with both favourable and unfavourable aspects of nutrient intake (e.g., lower micronutrient intakes for JFG score, higher SFA intakes for modified JFG score and higher sodium intakes for MDS). The associations with metabolic risk factors were also somewhat unexpected, including positive associations of the JFG score and modified JFG score with LDL-cholesterol, inverse associations of MDS with HDL-cholesterol and null associations of the DASH score with blood pressure. Thus, this study did not show expected and consistent associations of the four available diet quality scores with nutrient intakes and metabolic risk factors in Japanese adults, suggesting in turn the need for a scientific base on which to develop an appropriate tool for assessing the quality of diets in the Japanese context.

Consistent with previous studies [4, 6, 7], the JFG score was not associated with nutrient intakes in the favourable direction. Additionally, the modified JFG score was associated with not only favourable (such as higher intakes of dietary fibre and micronutrients and lower sodium intake) but also unfavourable (such as higher SFA intake) aspects of nutrient intake. This is at variance with a previous study in selected populations of young, middle-aged and older women, in which the modified JFG score was consistently associated with favourable nutrient intake patterns [7]. Nevertheless, the present study showed inverse associations of the JFG score and modified JFG score with BMI, WC and blood pressure. The exact reason is not clear but the observations might be explained, at least partly, by some aspects of healthy food intake patterns [33, 34] such as higher intakes of fruits and vegetables and lower intakes of energy-dense foods (e.g., confectioneries) associated with higher JFG score and modified JFG score. Conversely, both the JFG score and modified JFG score were associated positively with LDL-cholesterol and inversely with HDL-cholesterol. This may be due to higher SFA and carbohydrate intakes [35, 36] in relation to higher JFG score and modified JFG score. Thus, this study failed to provide compelling epidemiological evidence for the appropriateness of either the JFG score or modified JFG score for the assessment of diet quality in Japanese.

Despite large differences in dietary habits between Japan and Mediterranean countries, the MDS was associated with favourable nutrient intake patterns, except for higher sodium intake. The MDS also showed inverse associations with total and LDL-cholesterol, which may be due to the lower SFA intake [35, 36] associated with a higher MDS. However, in contrast to previous studies in Western countries [8, 10, 11], the MDS was not associated with other metabolic risk factors examined. For the DASH score, we found consistent associations with favourable nutrient intake patterns, including higher intakes of dietary fibre and micronutrients and lower intakes of SFA and sodium. The DASH score was also inversely associated with BMI, WC and total and LDL-cholesterol, which is consistent with previous studies [12–14]. However, we did not observe the expected inverse association with blood pressure, which may be due to a lack of two DASH components, namely whole grain foods and low-fat dairy products. Taken together, the findings on the MDS and DASH score suggest that neither is an optimal measure for assessing the quality of Japanese diets because they do not fit well at least some aspects of Japanese diets (e.g., low intakes of whole grain foods and dairy products and high sodium intake).

Several limitations of the present study warrant mention. First, the cross-sectional nature of the study does not permit the assessment of causality owing to the uncertain temporality of the association. Only a prospective study would provide better understanding of the relationship between diet quality and metabolic risk factors. Additionally, although NHNSJ intends to represent a nationally representative sample of the non-institutionalised population of Japan, only 52% of households sampled took part in the survey. Further, information on the basic characteristics of households that refused to participate is unfortunately unavailable [16]. Moreover, the exact response rate at the individual level is not known. Thus, a degree of selection bias cannot be ruled out.

All self-reported dietary assessment methods are subject to both random and systematic measurement errors [37]. Given the day-to-day variability in dietary intakes of free-living individuals, estimates of dietary intake derived from the 1-day weighed household dietary record used here are unlikely to represent the usual intakes of individual respondents. As this kind of random error would tend to result in bias towards attenuating relationships, the associations observed here would have been underestimated. Additionally, misreporting of dietary intake, particularly by overweight and obese individuals, is a serious problem associated with self-reported dietary assessment methods [37]. To minimise the possible influence of dietary misreporting, we included dietary reporting status as a confounding factor in our analysis. Moreover, the days of the week were not proportionately selected for dietary assessment and Sundays were intentionally excluded as a survey day (based on the survey protocol), which would likely produce some bias in estimating an average intake. Unfortunately, information on the days selected for dietary recording is not available [16]. Further, as the survey was conducted within a limited period of a year (between 25 October and 7 December 2012), any seasonal variation has not been considered, which could produce some additional bias in estimating average intakes. Most important, although the utility of the household dietary record in estimating dietary intake at the individual level has been previously indicated among young women (but not in men or in women of other age groups) [22], the true validity of this method is unknown. Thus, measurement errors in dietary estimates could at least partly explain unexpected associations between diet quality scores and some of the metabolic risk factors observed here, although we previously observed expected associations between dietary acid load and metabolic risk factors [18]. In any case, several days of dietary assessment, preferably covering all seasons and all days of the week, or the use of a validated dietary assessment questionnaire would have been preferable for estimating usual dietary intake, and the feasibility of this should be considered for the NHNSJ in the future.

Body height, weight and WC were measured by trained fieldworkers in about 90% of the participants, and by a member of the household or were self-reported in the remaining 10%. However, a repeated analysis which included only those participants for which measurement was made by trained fieldworkers ($n = 13{,}829$ for BMI and 13,722 for WC) provided essentially the same results (data not shown), suggesting that any bias associated with this survey procedure was likely negligible, for the present analysis at least. Further, a single assessment of blood metabolites may represent the short-term status only and introduce random errors. This kind of error would tend to bias towards attenuating rather than enhancing relationships. Moreover, although we adjusted for a variety of potential confounding variables, residual confounding could not be ruled out. Further, in contrast to the traditional single food and nutrient approach, dietary pattern analysis (including the use of diet quality scores) has only a limited or no utility for providing inference for potential mechanisms or pathways between diet and health status. Nevertheless, to take account of the complicated interactions and cumulative or synergistic effects occurring among individual dietary components (which is inherently impossible by studying single nutrients or foods in isolation), dietary pattern analysis has emerged as an alternative and complementary approach in nutritional epidemiology [38]. Finally, in view of the multiple analyses and the P values, it is possible that some of the findings in the present study occurred by chance.

In conclusion, in this cross-sectional study based on data from a national nutrition survey in Japan, the four currently available diet quality scores (JFG score, modified JFG score, MDS and DASH score) did not necessarily show expected and consistent associations with nutrient intakes and metabolic risk factors. Future research is needed to develop an appropriate tool for assessing the quality of diets in the Japanese context.

Author contributions KM designed the study, analysed and interpreted the data and wrote the manuscript. MBEL and SS helped in the writing of the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Ethical aspects This survey was conducted according to the guidelines laid down in the Declaration of Helsinki, and verbal informed consent was obtained from all individual participants. Under the Statistics Act, the Ministry of Health, Labour and Welfare anonymized individual-level data collected from the NHNSJ, and provided the first author with the datasets for this study. In accordance with the Ethical Guidelines of Epidemiological Research established by the Ministry of Education, Culture, Sports, Science and Technology and the Ministry of Health, Labour and Welfare, an institutional review board approval was not required for this analysis.

Conflict of interest All authors declare that there was no conflict of interest.

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