Associations between six diet quality scores and adverse cardiometabolic status in young Japanese women: A cross-sectional study

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ABSTRACT

Background and Objectives: This cross-sectional study aimed to examine associations between diet quality scores and adverse cardiometabolic status in young Japanese women. **Methods and Study Design:** In total, 1084 female dietetics students aged 18–22 years completed a validated self-administered diet history questionnaire. Diet quality was assessed using the Diet Quality Score for Japanese (DQSJ), Healthy Eating Index-2015 (HEI-2015), Alternate Healthy Eating Index-2010 (AHEI-2010), Alternate Mediterranean Diet score (AMED), Dietary Approaches to Stop Hypertension score (DASH), and Japanese Food Guide Spinning Top score (JFGST). Adverse cardiometabolic status was defined as the highest quartile of the sum of z scores for waist circumference, a mean value of systolic and diastolic blood pressures, high-density lipoprotein cholesterol (multiplied by −1), triacylglycerol, glucose, and insulin. **Results:** After adjustment for potential confounding factors, adverse cardiometabolic status was significantly associated with all the diet quality scores except for AMED, with adjusted odds ratios (95% confidence interval) in the highest quartile compared with the lowest of 0.39 (0.25–0.61) for DQSJ, 0.40 (0.26–0.61) for DASH, 0.44 (0.30–0.66) for AHEI-2010, 0.59 (0.39–0.88) for HEI-2015, 0.67 (0.45–0.99) for JFGST, and 0.80 (0.54–1.18) for AMED. Associations with each of the cardiometabolic risk factors were most prominent for AHEI-2010 (significant associations with all factors except triacylglycerol), followed by DQSJ (significant associations with all factors except triacylglycerol and glucose). **Conclusions:** This cross-sectional study of young Japanese women showed associations between several diet quality scores and cardiometabolic status. These should be confirmed in other populations, prospectively where possible.

Key Words: diet quality indices, dietary pattern, metabolic syndrome, cardiovascular disease risk, Japan

INTRODUCTION

Diet in Japan has long captured global interest, mainly owing to the long average life expectancy of Japanese.[1,2] Dietary intake among the Japanese is particularly characterized by high intakes of seafood, refined grains, and plant food and low intake of added sugar.[3,4] When assessing the overall diet in specific populations, such as the Japanese, it is essential to take into account the dietary intake in that population.[5-7] One method to assess the overall diet is the *a posteriori* (data-driven) approach, which is suitable for describing dietary patterns that contribute to dietary variation in a specific population.[8,9] Several studies have derived *a posteriori* dietary patterns in Japan,[10-12] although it is important to note that not all components in the patterns necessarily have associations with outcomes.

In contrast, the *a priori* approach aims to assess the overall diet based on current evidence regarding diet and health outcomes or dietary guidelines.[6,8] For example, the Japanese Food Guide Spinning Top (JFGST) score,[13-15] a widely used score in this country, was based on a Japanese dish- and food-based guideline.[16] However, this guideline was not derived from the scientific literature on associations between dietary intake and health outcomes. Indeed, the JFGST is unable to capture at least some critical facets of diet quality, such as higher sodium intake and lower intakes of whole grains, and nuts and seeds, which were identified by the Global Burden of Disease study as the dietary risk factors which most strongly contribute to death in Japan.[17] Until recently, in Japan, no diet quality score had been developed based on evidence regarding diet and health outcomes. Therefore, we recently developed a diet quality score for Japanese (DQSJ), considering the available evidence on dietary intake in Japan and its associations with health outcomes.[18] As expected, the DQSJ has shown inverse associations with the prevalence of inadequate intake of most nutrients.[18] Nevertheless, its associations with health outcomes remain unknown.

In contrast to the diet quality scores specific to particular populations, several diet quality scores have already been used in various populations. The Healthy Eating Index (HEI),[19,20] Alternate Healthy Eating Index (AHEI),[21,22] Mediterranean Diet score,[23,24] and Dietary Approaches to Stop Hypertension score (DASH)[25,26] have been shown to have protective associations with non-communicable diseases in studies mainly from Western countries.[27-33] In non-Western countries, however, the usefulness of these scores is unclear, as only a few studies have examined associations between them and health outcomes, such as all-cause mortality, incidence of diabetes and cardiovascular disease, and cardiometabolic risk factors.[34-45] Particularly in Japan, few studies have examined associations between health outcomes and the

Mediterranean diet [43-45] and DASH,[44,45] and none have been based on the HEI and AHEI. It has still not been revealed whether these scores are applicable to the Japanese population as measures of healthy dietary patterns. Additionally, a comparison of multiple scores, including both scores developed in Japan and other countries, can help explore which diet quality score better reflects the dietary patterns that are favorable for health outcomes.

Here, we examined associations between these six diet quality scores, namely DQSJ, HEI, AHEI, AMED, DASH, and JFGST, and cardiometabolic risk factors using data from young Japanese women. This study population was expected to minimize major confounding factors (e.g., gender, age, alcohol intake, smoking, and educational background) while having sufficient variability in their dietary intake. These characteristics of the study population were assumed to be able to detect associations between diet variables and cardiometabolic status. This assumption was supported by previous studies in which we identified biologically plausible associations between cardiometabolic risk factors and various dietary variables, such as dietary energy density[46] and dietary acid load.[47] This study was an initial step in exploring optimal diet quality scores associated with various health outcomes in Japan.

MATERIALS AND METHODS

Study design and participants

This cross-sectional study was conducted from February to March 2006 and from January to March 2007. The details of the survey design and procedure have been described in previous studies.[15,47-49] Briefly, the main aim of the survey was to examine associations between dietary intake and health status, including biomarkers, in healthy young women. Female dietetic students were recruited from 15 higher-education institutions in Japan. The study was conducted according to the guidelines of the Declaration of Helsinki. Written informed consent was obtained from all participants and also from a parent for participants aged less than 20 years. The study protocol was approved by the Ethics Committee of the National Institute of Health and Nutrition (number: 04045 and 6017).

Participants were asked to answer self-administered lifestyle questionnaires, including dietary intake and other lifestyle factors, 1–4 days before the assessment of cardiometabolic risk factors. Research staff checked the responses using a standardized checklist for this survey, and asked participants to provide any missing values or correct any implausible values.

A total of 1176 Japanese women took part (response rate: 56%). For the present study, 1154 women aged 18–22 years were selected because dietetics students outside this age range are rare in Japan, and their cardiometabolic characters may differ from those of students aged 18–

22 years. We then excluded those who did not complete the survey questionnaire (n 1); those with previously diagnosed diabetes, hypertension, or CVD (n 1); those without measurement of body height and weight (n 2); those currently receiving dietary counseling from a doctor or dietitian (n 13); those with non-fasting blood samples (n 34); those with missing information on one or more cardiometabolic risk factors (n 19); and those with extremely low or high reported energy intakes (<2512 or >16736 kJ/d, n 3).[50] Some women fell into more than one exclusion category, resulting in 1084 women for the final sample. There were no significant differences in diet quality scores, cardiometabolic risk factors, and physical activity level between the final sample and those excluded in the analyses. However, those excluded from analyses had a higher prevalence of current smokers (8.8%) than the final sample (2.3%), albeit that similar results were obtained when only non-smokers were analyzed (data not shown). The sample-size was determined based on feasibility, without a specific sample-size calculation.

Dietary assessment

Dietary habits during the preceding month were assessed using a self-administered diet history questionnaire (DHQ). Details of the DHQ have been reported elsewhere.[51-53] Briefly, DHQ is a 16-page structured questionnaire that asks about the consumption frequency and portion size of selected foods and dietary behaviors. Estimates of the daily intakes of 151 food items, energy, and selected nutrients were calculated using an ad hoc computer algorithm based on the Standard Tables of Food Composition in Japan[54] and comprehensive composition database of added sugar[55] and *trans* fat.[56] Previous studies have reported sufficient validity for intakes of food groups[52] and nutrients[53,55] and HEI-2015[57] derived from DHQ. For example, the Pearson correlation coefficient between DHQ and a 16-d weighed dietary record was 0.57 for HEI-2015 in Japanese women.[57] Dietary supplements were not used in the calculation of dietary intake.

Calculation of diet quality scores

We calculated the six diet quality scores, namely the DQSJ,[18] HEI-2015,[20] AHEI-2010,[21] Mediterranean diet score, DASH score, and JFGST score.[15] For the Mediterranean diet score and DASH score, the alternate Mediterranean diet index (AMED) [58] and Fung's DASH score,[59] respectively, were chosen due to their wide use in studies.[60-62] For all six scores, higher scores indicate a better diet quality.

The DQSJ consisted of 10 components, each giving 0–3 points, for a total possible range of 0–30 points.[18] Scoring was based on the quartile of intake of each component in the study population (Supplementary Table 1). For seven components (fruits, vegetables, whole grains, dairy, nuts, legumes, and fish), the highest quartile was assigned 3 points, whereas for three components (red and processed meat, sugar-sweetened beverages, and sodium), the lowest quartile was assigned 3 points.

The details of the scoring criteria of HEI-2015, AHEI-2010, AMED and DASH are shown in Supplementary Table 2. Briefly, HEI-2015, with a possible score ranging from 0 to 100, was calculated according to a previous study using DHQ.[57] HEI-2015 included nine favorable components (total fruits, whole fruits, total vegetables, greens and beans, whole grains, dairy, total protein, seafood and plant protein, and the ratio of the sum of poly-unsaturated fatty acids [PUFA] and mono-unsaturated fatty acids [MUFA] to saturated fatty acids [SFA]) and four unfavorable components (refined grains, sodium, added sugar, and SFA). AHEI-2010, with a possible score ranging from 0 to 110, was calculated according to a previous study in Japan.[18] AHEI-2010 included five favorable components (whole fruits, vegetables, nuts and legumes, long-chain fats, and PUFA), four unfavorable components (red and processed meat, sugar-sweetened beverages [SSBs], sodium, and *trans* fat), and two components with an optimal intake range (alcohol and whole grains). AMED consisted of nine components, each giving 0 or 1 point, for a total possible range of 0–9 points.[58] It included seven favorable components (fruits and fruit juice, vegetables except for potatoes, whole grain foods, nuts, legumes, fish, and the ratio of MUFA to SFA), one unfavorable component (red and processed meat), and one component with an optimal intake range (alcohol). Fung's DASH score comprised eight components, each giving 1–5 points, for a total possible range of 8–40 points.[59] DASH included five favorable components (fruits and fruit juice, vegetables, whole grain foods, nuts and legumes, and reduced-fat dairy products) and three unfavorable components (red and processed meat, sweetened beverages, and sodium).

The JFGST score assesses adherence to the JFGST, which is a dish- and food-based dietary guideline in Japan.[16] We calculated the JFGST score using a procedure developed by Nishimura et al. (Supplementary Table 3).[15] Briefly, the JFGST score consists of the following six components with recommended amounts depending on sex, age, and physical activity: grain dishes, vegetable dishes, fish and meat dishes, milk, fruits, and snack and alcoholic beverages. We assumed a low level of physical activity for all participants because of their apparently predominantly sedentary lifestyle.[46] The total score of the six components ranged from 0 to 60.

Assessment of cardiometabolic risk factors

Details of assessment are described elsewhere.[15,47-49] Briefly, waist circumference was measured in the standing position at the level of the umbilicus to the nearest 0.1 cm. Systolic and diastolic blood pressure was measured on the left arm using an automatic device after the participant had sat quietly for more than 3 minutes, with a second blood pressure measurement taken about 1 min after the first. The mean values of the two measurements were used; for one participant with only the first measurement, that was used. After measurement of blood pressure, an overnight fast was conducted, and peripheral blood samples were collected. Concentrations of serum high-density lipoprotein (HDL) cholesterol, triacylglycerol, and glucose were measured using enzymatic assay methods, and that of insulin was measured using an immunoradiometric assay. Participants who reported that they ate after 1 am were regarded as having non-fasting blood samples.

Given the low prevalence rate of metabolic syndrome, obesity and overweight, high blood pressure, hyperlipidemia, and diabetes in young Japanese women,[63] we calculated a continuous summary score of metabolic risk, as described in a previous study.[64] A cardiometabolic risk score was computed using the sum of z-score standardization of the following six variables: waist circumference, mean value of systolic and diastolic blood pressures, HLD cholesterol, triacylglycerol, glucose, and insulin. Triacylglycerol and insulin were natural-log transformed before calculation of the z-score owing to their skewed distribution as evaluated using histograms. HDL cholesterol was multiplied by –1 so that a higher score indicates a less favorable cardiometabolic profile. Although various methods have been developed to calculate cardiometabolic risk scores,[65] this summary score was chosen because it includes all of the key dimensions of metabolic syndrome recommended by Eisenmann.[66] We did not conduct age-specific standardization due to the narrow age range in this study population but made adjustment for age in statistical models. For analysis, participants in the highest quartile for cardiometabolic risk score were defined as those with an adverse cardiometabolic status.

Assessment of other variables

Based on the reported home address, the residential area was grouped into one of three residential regions (north [Kanto, Hokkaido, and Tohoku], central [Tokai, Hokuriku, and Kinki], or south [Kyushu and Chugoku]) and into one of three municipality levels (city with a population of more than million, city with a population of less than million, or town and village). A self-reported lifestyle questionnaire assessed current smoking (yes or no) and physical activity. For the latter, average metabolic equivalent hours (MET-hours) per day were calculated using the frequency and duration of five different activities over the preceding month (sleeping, high- and moderate-intensity activities, walking, and sedentary activities).[46] When the sum of the duration of the five activities was not 24 hours per day, we assigned sedentary activities to the remaining time. Body height and weight were measured with light indoor clothes and without shoes. BMI was calculated as body weight (kg) divided by the square of body height (m).

Statistical analysis

All statistical analyses were performed using the SAS statistical software (version 9.4, SAS Institute Inc., Cary, NC, Japan), with two-tailed p values < 0.05 considered statistically significant. Participant characteristics according to adverse cardiometabolic status (yes or no) were compared using the chi-square test for categorical variables and the unpaired t-test for continuous variables. Additionally, to describe the relationship between each diet quality score and participant characteristics, the participants were divided into quartiles of each score, and characteristics across the quartile were compared using the chi-square test for categorical variables and a linear regression model for continuous variables by assigning the mean values of diet quality scores for each quartile. Associations among diet quality scores were examined using Spearman correlation coefficients. Additionally, we calculated Spearman correlation coefficients between the diet quality scores and intakes of food groups and nutrients.

Crude and multivariate-adjusted odds ratios and 95% confident intervals for adverse cardiometabolic status were calculated using logistic regression analysis, with the lowest quartile of diet quality score used as the reference. We tested for linear trends of odds ratios across the quartiles of diet quality scores by assigning mean values for each quartile. Further, univariate and multivariable linear regression analyses were used to examine the associations between the diet quality scores and a cardiometabolic risk score and its components. Right-skewed data (i.e., triacylglycerol and insulin) were analyzed after natural-log transformation. We calculated regression coefficients indicating a difference in cardiometabolic risk factors per 1 standard deviation (SD) difference in each diet quality score. For multivariate analyses, potential confounding factors, determined based on previous literature and a directed acyclic graph approach (Supplementary Figure 1), included age, survey year, residential regions, municipality levels, current smoking, energy intake, and physical activity. Alcohol intake was not considered a covariate because of low alcohol intake (mean, 1.5 g/d) and the fact that several of the diet quality scores used alcohol intake as a component.

RESULTS

Table 1 shows participant characteristics by adverse cardiometabolic status. Adverse cardiometabolic status was associated with residential area but not with survey year, municipality level, smoking status, age, energy intake, or physical activity. Compared to participants without an adverse cardiometabolic status, those with this status had higher BMI, waist circumference, systolic and diastolic blood pressure, triacylglycerol, glucose, and insulin, and lower HDL cholesterol.

The mean (SD) values of diet quality score were 13.5 (4.0) for DQSJ, 50.8 (7.8) for HEI-2015, 57.7 (7.1) for AHEI-2010, 3.8 (1.6) for AMED, 13.4 (4.0) for DASH, and 35.2 (7.0) for JFGST. Significant positive correlations were found between all scores (Supplemental Table 4). DQSJ, HEI-2015, AHEI-2010, AMED, and DASH were moderately to strongly correlated with each other (r = 0.45–0.75). The highest correlation was found between DQSJ and DASH (r = 0.75). JFGST was weakly to moderately correlated with the other five scores (r = 0.22–0.45). Age, survey year, residential area, municipality level, smoking status, and physical activity were not associated with any the diet quality scores, except the associations of age with AHEI-2010, survey year with DQSJ, and smoking status and DQSJ (Supplemental Table 5). Associations with energy intake were not consistent among the six diet quality scores; participants with higher categories of DQSJ, HEI-2015, and AMED had higher mean energy intake, whereas those with higher categories of AHEI-2010 and JFGST had lower mean energy intake. Participants with higher categories of DQSJ (p = 0.099) and HEI-2015 (p = 0.036) tended to have lower mean BMI.

Table 2 shows mean and SD values of intakes of food groups and nutrients and Spearman correlation coefficients between diet quality scores and intake of food groups and nutrients. All scores were positively correlated with intakes of fruits, vegetables, whole grain (except JFGST), dairy (except AMED), legumes, fish, protein, total fiber, vitamin C, potassium, calcium, magnesium, and iron, and negatively with refined grains (except JFGST), SSBs (except AMED), and saturated fat (except DQSJ). On the contrary to the other scores, JFGST were positively correlated with refined grain intake.

The odds ratios for adverse cardiometabolic status according to quartile of diet quality score are shown in Table 3. After adjustment for potential confounding factors, higher DQSJ, HEI-2015, AHEI-2010, and DASH were associated with a lower risk of adverse cardiometabolic status, whereas AMED and JFGST were not significantly associated (p for trend = 0.23 for AMED and 0.0502 for JFGST). The adjusted odds ratio (95% confidence intervals) for adverse cardiometabolic risk in the highest compared with the lowest quartile of diet quality score was 0.39 (0.25–0.61) for DQSJ, 0.40 (0.26–0.61) for DASH, 0.44 (0.30–0.66) for AHEI-2010, 0.59 (0.39–0.88) for HEI-2015, 0.67 (0.45–0.99) for JFGST, and 0.80 (0.54–1.18) for AMED.

Table 4 shows associations between diet quality scores and the cardiometabolic risk score and its components. After adjustment for potential confounding factors, β coefficients (95% confidence intervals) of the cardiometabolic risk score for 1 SD increase in diet quality scores were -0.53 (-0.72, -0.33) for AHEI-2010, -0.49 (-0.69, -0.30) for DQSJ, -0.47 (-0.66, -0.28) for DASH, -0.32 (-0.51, -0.13) for HEI-2015, -0.19 (-0.39, 0.02) for AMED, and 0.03 (-0.17, 0.22) for JFGST. Regarding the components of the cardiometabolic risk score, AHEI-2010 showed significant associations with all factors except triacylglycerol, and DQSJ showed significant associations with all factors except for triacylglycerol and glucose. DASH also showed significant associations with all factors except waist circumference, HDL cholesterol, and triacylglycerol. HEI-2015 showed inverse associations with waist circumference, diastolic blood pressure, and insulin. AMED was associated with lower waist circumference only. JFGST had a negative association with waist circumference and a positive association with systolic blood pressure.

DISCUSSION

This study of young Japanese women found that DQSJ, HEI-2015, AHEI-2010, and DASH were associated with a lower cardiometabolic risk score, indicating favorable cardiometabolic status, whereas AMED and JFGST showed no consistent association. Additionally, DQSJ, AHEI-2010, and DASH were associated with most components of the cardiometabolic risk score, such as lower systolic and diastolic blood pressures and lower insulin. To our knowledge, this is the first study to examine the association of cardiometabolic health with both diet quality scores developed in Western countries (i.e., HEI-2015, AHEI-2010, Mediterranean diet, and DASH) and those developed based on dietary intake in non-Western countries and evidence about diet-health relationships (i.e., DQSJ).

The associations observed between diet quality scores and cardiometabolic risk factors may be reasonable given their correlations with a range of intakes of food groups and nutrients. The associations between lower cardiometabolic risk scores and the four diet quality scores (DQSJ, HEI-2015, AHEI-2010, and DASH) may be particularly due to their positive correlations with whole grain intake and negative correlations with intakes of refined grain and sugar-sweetened beverages. Previous studies suggest that higher whole grain intake and lower intakes of refined grain and sugar-sweetened beverages were associated with favorable status for some cardiometabolic risk factors, such as waist circumference, LDL cholesterol, and fasting glucose.[67-69] For example, whole grain intake may improve cardiometabolic status through increased satiety and the anti-inflammatory effects of its components.[70] On the other hand, the lack of association between AMED and a cardiometabolic risk score may be at least partly due to its null correlation with intakes of sugar-sweetened beverages and a positive correlation with sodium intake which is reported to be associated with the risk of hypertension.[71] Additionally, JFGST had a positive correlation with refined grain intake and no correlation with whole grain intake, which may explain its no consistent association with a cardiometabolic risk score.

The results of the present study were generally aligned with those of previous studies in non-Western countries. The DASH and AHEI have also been consistently reported to show associations with cardiometabolic factors, whereas findings based on AMED are inconsistent. A lower odds ratio of metabolic syndrome was associated with DASH but not with Mediterranean diet score in Iran [38] and Southwest China.[40] Another study in Singapore showed that DASH and AHEI-2010 were associated with a greater number of cardiometabolic risk factors than AMED.[36] Also, a Japanese study showed that DASH was associated with a greater number of cardiometabolic risk factors in the expected directions than Mediterranean diet score.[44] In Southwest China, DASH had a stronger association with blood pressure than AMED,[41] while both were associated with some lipid profiles.[42] Overall, our present and these previous results suggest that DASH may be more strongly associated with cardiometabolic risk factors than Mediterranean diet score in non-Western countries. However, due to the small number of studies and diet quality scores examined in each region, the question of which score better reflects dietary patterns associated with favorable cardiometabolic status, as well as other health outcomes, remains unanswered. Future research comparing multiple diet quality scores will be necessary to determine optimal diet quality scores in Japan and in other populations.

Although JFGST is a measure of adherence to Japanese food- and dish-based guidelines,[16] the JFGST used in previous studies may not be in line with the guidelines because of modifications that some studies made to scoring.[13,44,72] For example, Kurotani and colleagues added the ratio of white and red meat,[13] and several studies omitted the upper limit of some components, such as vegetable dishes and fruits.[13,44,72] Additionally, associations between JFGST and cardiometabolic health were inconsistent in previous studies.[13,14,44,72] In the present study, we scored JFGST with the upper limit as presented in the original guidelines and observed no consistent association between JFGST and cardiovascular risk factors. The present and previous studies may suggest that JFGST, based on the original guidelines, has room for improvement as a measure of diet quality for the Japanese.

It is important to distinguish between statistical significance and clinical importance. In this study, we observed that statistically significant differences in cardiometabolic risk factors per 1 SD diet quality score, but they seemed relatively small. For example, we observed –0.5 to −0.8 cm differences in waist circumference for a 1 SD increase in diet quality scores. Nevertheless, it is important to note that a previous meta-analysis estimated that each centimeter of waist circumference is associated with a 2% higher risk of cardiovascular diseases.[73] However, since this estimate was based on studies primarily conducted in Western countries, research is needed to examine whether observed differences are clinically meaningful in the Japanese. Additionally, as we observed associations between several diet quality scores and cardiometabolic risk factors even in this population, which had a relatively favorable cardiometabolic status, we speculate that other populations with higher cardiometabolic risk may have stronger associations, which are worth examining.

Several limitations of this study warrant mention. First, the study participants were a highly selected population of dietetic students, who probably had healthier lifestyles and greater knowledge of nutrition than the general population, in addition to an only moderate response rate (56%).[74] Although they had similar characteristics to women aged 20–29 years in a Japanese national survey in 2006, such as with regard to intakes of energy (mean, 7196 kJ/day), sodium (3700 mg/day), and fiber (13.0 g/day), as well as BMI (20.7 kg/m^2), systolic blood pressures (109 mmHg), diastolic blood pressure (68 mmHg), and HDL cholesterol (1.82 mmol/L),[63] the findings may not be generalizable to the general Japanese population. Second, self-reported dietary assessment methods are susceptible to substantial measurement error. Although DHQ showed acceptable validity for HEI-2015 and intakes of most food groups and nutrients against 16-day dietary records, it showed relatively low correlation coefficients for some components of diet quality scores, including nuts (Spearman correlation coefficient = 0.20) [52] and sodium (Pearson correlation coefficient = 0.31).[53] Additionally, overweight people have been reported to selectively under-report fatty or sugary food intake,[75,76] which could result in an overestimation of their diet quality. This overestimation would tend to bias towards attenuating the association of diet quality with cardiometabolic risk factors, especially waist circumference. Nevertheless, self-reported data is essential for assessing overall diet quality as no objective marker has been established.[77] Third, higher diet quality appears to reflect an overall healthier lifestyle, which may not have been accurately captured and controlled in our analysis. Although adjustment was attempted for various confounding factors, including smoking status and physical activity, and adjustment for confounding factors had a negligible impact on the observed associations, residual confounding cannot be ruled out. Residual confounding related to healthy lifestyle behaviors may introduce a bias toward overestimating the association of diet quality with cardiometabolic risk factors. Fourth, there is no consensus on an optimal summary cardiometabolic risk score.[65,66] The cardiometabolic risk score we used was chosen *a priori* but arbitrarily. Additionally, the cutoff value was not established based on any disease risk, but rather from the quartile, and the clinical importance of the findings therefore remains uncertain. Future research is needed to explore the optimal cardiometabolic risk score for association with future non-communicable diseases. Fifth, the survey data were collected more than 15 years ago. However, cardiometabolic risk factors were not marginally changed in these 15 years,[78] and associations between diet quality scores and cardiometabolic risk factors unlikely largely changed in these decades. Sixth, since we did not correct for multiple testing, some associations may be due to chance. Additionally, the cross-sectional nature of the study prevents the establishment of causal relationships. Considering the possibility that participants who become aware of an unfavorable cardiometabolic status may have changed their diet in more healthful directions, the associations could be attenuated due to these dietary changes. The relationship between diet quality scores and risk factors should be confirmed in future studies, favorably using prospective designs.

Conclusion

In conclusion, this cross-sectional study of young Japanese women showed that a higher score in DQSJ, HEI-2015, AHEI-2010, and DASH was associated with a favorable cardiometabolic status, whereas AMED and JFGST had no consistent association. Associations were most prominent for AHEI-2010 (significant associations with all factors except triacylglycerol), followed by the DQSJ (significant associations with all factors except triacylglycerol and glucose) and DASH (significant associations with all factors except waist circumference, HDL cholesterol, and triacylglycerol). These results suggest the potential variations in the associations with cardiometabolic status across diet quality scores. Future research should confirm these associations in other populations, preferably using a prospective study design, as well as using other health outcomes.

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CONFLICT OF INTEREST AND FUNDING DISCLOSURE

The authors declare no conflict of interest.

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Table 1. Characteristics of Japanese women aged 18–22 years according to adverse cardiometabolic status†

	All (n=1084)		Adverse cardiometabolic status†				p‡
			No (n=813; 75.0%)		Yes (n=271; 25.0%)		
	Mean	SD	Mean	SD	Mean	SD	
Age (years)	19.6	1.1	19.6	1.1	19.7	1.1	0.24
Energy intake (kJ/day)	7364	1869	7361	1851	7373	1924	0.92
Physical activity (total metabolic equivalents-h/d)	33.9	3.1	34.0	3.0	33.7	3.5	0.16
BMI (kg/m^2)	21.4	2.7	20.7	2.1	23.2	3.5	<0.001
Survey year, n (%)							0.11
2006	447	(41.2)	324	(39.8)	123	(45.4)	
2007	637	(58.8)	489	(60.2)	148	(54.6)	
Residential regions, n (%)							0.004
North (Kanto, Hokkaido, and Tohoku)	625	(57.7)	487	(60.0)	138	(50.9)	
Central (Tokai, Hokuriku, and Kinki)	250	(23.1)	187	(23.0)	63	(23.3)	
South (Kyushu and Chugoku)	209	(19.3)	139	(17.1)	70	(25.8)	
Municipality level, n (%)							0.78
City with population ≥1 million	178	(16.4)	137	(16.8)	41	(15.1)	
City with population <1 million	842	(77.7)	629	(77.4)	213	(78.6)	
Town and village	64	(5.9)	47	(5.8)	17	(6.3)	
Smoking status, n (%)							0.91
Non-current smokers	1059	(97.7)	794	(97.7)	265	(97.8)	
Current smokers	25	(2.3)	19	(2.3)	6	(2.2)	
Metabolic risk factors							
Waist circumference (cm)	72.9	7.1	71.1	5.6	78.4	8.1	<0.001
Systolic blood pressure (mmHg)	106	10.5	104	9.1	114	11.1	<0.001
Diastolic blood pressure (mmHg)	69.3	8.1	67.5	6.9	74.9	8.8	<0.001
HDL cholesterol (mmol/L)	1.8	0.32	1.9	0.3	1.6	0.3	<0.001
Triacylglycerol (mmol/L)	0.69	0.33	0.61	0.22	0.93	0.45	<0.001
Glucose (mmol/L)	4.7	0.36	4.6	0.3	4.9	0.3	<0.001
Insulin (mU/L)	8.4	4.7	7.1	3.3	12.4	6.0	<0.001
Cardiometabolic risk score§	0.0	3.3	-1.4	2.2	4.2	2.2	<0.001

BMI, body mass index; HDL, high-density lipoprotein; Q, quartile; SD, standard deviation.

†Adverse cardiometabolic status was defined as the highest quartile of a cardiometabolic risk score (>1.89).

‡p values for differences between participants according to adverse cardiometabolic status (yes or no) using the chi-square test for categorical variables and the independent t test for continuous variables.

§A cardiometabolic risk score was computed from the sum of z-score standardization of the following six variables: waist circumference, mean value of systolic and diastolic blood pressures, HLD cholesterol (multiplied by -1), triacylglycerol (natural-log transformed), glucose, and insulin (natural-log transformed).

Table 2. Values of mean and standard deviation of intakes of food groups and nutrients and Spearman correlation coefficients between diet quality scores and intakes of food groups and nutrients in Japanese women aged 18–22 years (n 1084)

	Mean	SD	Spearman correlation coefficient					
			DQSJ	HEI-2015	AHEI-2010	AMED	DASH	JFGST
Food groups (g/4184 kJ)								
Fruits†	31.3	30.8	0.52*	0.55*	0.33*	0.41*	0.44*	0.39*
Vegetables†	114	68	0.46*	0.53*	0.45*	0.50*	0.39*	0.35*
Refined grain	212	73	-0.35*	-0.22*	-0.18*	-0.37*	-0.19*	0.24*
Whole grains†	18.5	48.2	0.30*	0.22*	0.33*	0.24*	0.34*	0.05
Dairy†	82.1	72.5	0.42*	0.16*	0.08*	-0.02	0.24*	0.22*
Low fat dairy	17.4	44.7	0.14*	0.15*	0.09*	0.05	0.40*	0.02
Nuts†	0.7	1.1	0.36*	0.10*	0.11*	0.40*	0.06	0.02
Legumes†	18.9	14.4	0.52*	0.41*	0.50*	0.49*	0.49*	0.16*
Fish†	18.6	12.2	0.45*	0.43*	0.22*	0.47*	0.17*	0.14*
Red and processed meat†	24.1	13.1	-0.20*	0.08*	-0.15*	-0.01	-0.35*	0.01
Sugar-sweetened beverages†	30.9	45.8	-0.41*	-0.19*	-0.52*	-0.06	-0.48*	-0.18*
Alcoholic beverages†	10.1	25.3	-0.03	0.00	0.21*	0.04	0.02	-0.11*
Nutrients								
Protein (% energy)	13.5	1.9	0.46*	0.44*	0.23*	0.37*	0.23*	0.11*
Fat (% energy)	29.2	5.2	-0.01	-0.05	-0.18*	0.12*	-0.26*	-0.30*
Saturated fat (% energy)	8.5	2.0	0.06	-0.24*	-0.19*	-0.08*	-0.20*	-0.34*
n-3 fatty acids (g/4184 kJ)	1.2	0.4	0.19*	0.39*	0.15*	0.45*	-0.01	0.01
Carbohydrate (% energy)	55.7	6.0	-0.07*	-0.05	0.06	-0.18*	0.21*	0.27*
Added sugar (% energy)	7.9	2.9	-0.08*	-0.22*	-0.24*	0.05*	-0.13*	-0.39*
Total fiber (g/4184 kJ)	6.9	2.0	0.56*	0.55*	0.55*	0.53*	0.55*	0.32*
Vitamin C (mg/4184 kJ)	47.7	21.9	0.34*	0.52*	0.32*	0.45*	0.35*	0.32*
Sodium (mg/4184 kJ)	2059	498	0.02	0.10*	-0.02	0.23*	-0.06	0.12*
Potassium (mg/4184 kJ)	1112	263	0.61*	0.62*	0.44*	0.49*	0.49*	0.28*
Calcium (mg/4184 kJ)	283	98	0.57*	0.30*	0.27*	0.20*	0.42*	0.15*
Magnesium (mg/4184 kJ)	121	27	0.65*	0.59*	0.55*	0.53*	0.57*	0.26*
Iron (mg/4184 kJ)	3.7	0.8	0.46*	0.49*	0.43*	0.48*	0.40*	0.19*

DQSJ, Diet Quality Score for Japanese; HEI-2015, Healthy Eating Index-2015; AHEI-2010, Alternate Healthy Eating Index-2010; AMED; Alternate Mediterranean Diet; DASH, Dietary Approaches to Stop Hypertension; JFGST, Japanese Food Guide Spinning Top; SD, standard deviation.
†These food groups were defined in the same way as the components of the DQSJ, as described in Supplementary Table 1.
* $p < 0.05$

Table 3. Odds ratios (OR) and 95% confidence intervals (CI) for adverse cardiometabolic status according to the quartile of diet quality scores in Japanese women aged 18–22 years (n 1084)

	Score range	Adverse cardiometabolic status†		Crude model			Adjusted model‡		
		n (yes/no)	% of yes	OR	95% CI	p trend §	OR	95% CI	p trend §
DQSJ									
Q1	2–10	86/170	33.6	1.00	Reference	<0.001	1.00	Reference	<0.001
Q2	11–13	84/205	29.1	0.81	0.56, 1.16		0.80	0.55, 1.15	
Q3	14–16	59/240	19.7	0.49	0.33, 0.71		0.46	0.31, 0.68	
Q4	17–26	42/198	17.5	0.42	0.28, 0.64		0.39	0.25, 0.61	
HEI-2015									
Q1	22.2–46.0	76/195	28.0	1.00	Reference	0.009	1.00	Reference	0.008
Q2	46.1–50.5	76/195	28.0	1.00	0.69, 1.46		1.01	0.69, 1.47	
Q3	50.6–55.0	68/203	25.1	0.86	0.59, 1.26		0.86	0.58, 1.26	
Q4	55.1–86.6	51/220	18.8	0.60	0.40, 0.89		0.59	0.39, 0.88	
AHEI-2010									
Q1	39.2–53.2	91/180	33.6	1.00	Reference	<0.001	1.00	Reference	<0.001
Q2	53.3–57.0	67/204	24.7	0.65	0.45, 0.94		0.61	0.42, 0.90	
Q3	57.1–62.7	60/211	22.1	0.56	0.38, 0.82		0.53	0.36, 0.79	
Q4	62.8–86.5	53/218	19.6	0.48	0.33, 0.71		0.44	0.30, 0.66	
AMED									
Q1	0–2	69/188	26.9	1.00	Reference	0.31	1.00	Reference	0.23
Q2	3–3	59/169	25.9	0.95	0.63, 1.43		0.95	0.63, 1.43	
Q3	4–4	56/172	24.6	0.89	0.59, 1.34		0.88	0.58, 1.34	
Q4	5–8	87/284	23.5	0.84	0.58, 1.20		0.80	0.54, 1.18	
DASH									
Q1	3–10	89/168	34.6	1.00	Reference	<0.001	1.00	Reference	<0.001
Q2	11–13	79/229	25.7	0.65	0.45, 0.94		0.64	0.45, 0.93	
Q3	14–16	60/219	21.5	0.52	0.35, 0.76		0.49	0.33, 0.73	
Q4	17–26	43/197	17.9	0.41	0.27, 0.63		0.40	0.26, 0.61	
JFGST									
Q1	6.2–30.3	79/191	29.5	1.00	Reference	0.06	1.00	Reference	0.0502
Q2	30.4–35.2	65/206	24.0	0.75	0.51, 1.10		0.75	0.51, 1.11	
Q3	35.3–39.8	67/205	24.4	0.77	0.53, 1.13		0.75	0.51, 1.10	
Q4	39.9–53.1	60/211	22.1	0.68	0.46, 1.00		0.67	0.45, 0.99	

Q, quartile.

†Adverse cardiometabolic status was defined as the highest quartile of a cardiometabolic risk score (>1.89). A cardiometabolic risk score was computed from the sum of z-score standardization of the following six variables: waist circumference, mean value of systolic and diastolic blood pressures, HLD cholesterol (multiplied by -1), triacylglycerol (natural-log transformed), glucose, and insulin (natural-log transformed).

‡Adjusted for age (years, continuous), survey year (2006 or 2007), residential regions (north, central, or south), municipality level (city with population ≥1 million, city with population <1 million, or town and village), current smoking (yes or no), energy intake (kJ, continuous), and physical activity (total metabolic equivalents-h/d, continuous).

§p for trend was computed using logistic regression models assigning mean values of diet quality scores as the independent variable.

Table 4. Associations between diet quality scores and a cardiometabolic risk score and its components in Japanese women aged 18–22 years (n 1084)

	DQSJ			HEI-2015			AHEI-2010		
	β	(95% CI)	p	β	(95% CI)	p	β	(95% CI)	p
Cardiometabolic risk score[†]									
Crude	-0.47	(-0.66, -0.27)	<0.001	-0.31	(-0.51, -0.12)	0.002	-0.48	(-0.68, -0.29)	<0.001
Adjusted[‡]	-0.49	(-0.56, -0.22)	<0.001	-0.32	(-0.35, -0.02)	0.001	-0.53	(-0.62, -0.29)	<0.001
Waist circumference (cm)									
Crude	-0.43	(-0.85, -0.01)	0.047	-0.80	(-1.22, -0.38)	<0.001	-0.54	(-0.96, -0.12)	0.01
Adjusted[‡]	-0.62	(-1.05, -0.19)	0.004	-0.83	(-1.25, -0.42)	<0.001	-0.54	(-0.96, -0.12)	0.01
Systolic blood pressure (mmHg)									
Crude	-0.98	(-1.60, -0.35)	0.002	-0.02	(-0.65, 0.60)	0.94	-0.66	(-1.29, -0.04)	0.04
Adjusted[‡]	-0.87	(-1.47, -0.28)	0.004	-0.04	(-0.62, 0.54)	0.89	-0.88	(-1.46, -0.29)	0.004
Diastolic blood pressure (mmHg)									
Crude	-0.95	(-1.43, -0.47)	<0.001	-0.45	(-0.94, 0.03)	0.07	-0.60	(-1.08, -0.12)	0.02
Adjusted[‡]	-0.87	(-1.34, -0.40)	<0.001	-0.46	(-0.92, 0.00)	0.048	-0.75	(-1.22, -0.29)	0.001
HDL cholesterol (mmol/L)									
Crude	0.028	(0.01, 0.05)	0.006	0.005	(-0.01, 0.02)	0.60	0.027	(0.01, 0.05)	0.008
Adjusted[‡]	0.026	(0.01, 0.05)	0.01	0.005	(-0.01, 0.02)	0.61	0.029	(0.01, 0.05)	0.004
Log-triacylglycerol (mmol/L) [§]									
Crude	-0.020	(-0.04, 0.00)	0.10	-0.023	(-0.05, 0.00)	0.06	-0.015	(-0.04, 0.01)	0.21
Adjusted[‡]	-0.018	(-0.04, 0.01)	0.15	-0.022	(-0.05, 0.00)	0.07	-0.018	(-0.04, 0.01)	0.15
Glucose (mmol/L)									
Crude	-0.02	(-0.04, 0.00)	0.053	-0.01	(-0.04, 0.01)	0.18	-0.04	(-0.06, -0.02)	0.001
Adjusted[‡]	-0.02	(-0.04, 0.00)	0.08	-0.01	(-0.03, 0.01)	0.22	-0.04	(-0.06, -0.02)	0.001
Log-insulin (mU/L) [§]									
Crude	-0.06	(-0.09, -0.02)	0.001	-0.03	(-0.07, 0.00)	0.051	-0.06	(-0.10, -0.03)	<0.001
Adjusted[‡]	-0.07	(-0.11, -0.04)	<0.001	-0.04	(-0.07, 0.00)	0.03	-0.07	(-0.10, -0.03)	<0.001

DQSJ, Diet Quality Score for Japanese; HEI-2015, Healthy Eating Index-2015; AHEI-2010, Alternate Healthy Eating Index-2010; AMED; Alternate Mediterranean Diet; DASH, Dietary Approaches to Stop Hypertension; JFGST, Japanese Food Guide Spinning Top; CI, confidence interval; BMI, body mass index; HDL, high-density lipoprotein; SE standard error. β indicates differences in a cardiometabolic risk factors per 1 SD increase in diet quality score.

[†]Adjusted for age (years, continuous), survey year (2006 or 2007), residential regions (north, central, or south), municipality level (city with population ≥1 million, city with population <1 million, or town and village), current smoking (yes or no), energy intake (kJ, continuous), and physical activity (total metabolic equivalents-h/d, continuous).

[‡]A cardiometabolic risk score was computed from the sum of z-score standardization of the following six variables: waist circumference, mean value of systolic and diastolic blood pressures, HLD cholesterol (multiplied by -1), triacylglycerol (natural-log transformed), glucose, and insulin (natural-log transformed).

[§]Triacylglycerol and insulin were natural log-transformed due to right skewness.

Table 4. Associations between diet quality scores and a cardiometabolic risk score and its components in Japanese women aged 18–22 years (n 1084) (cont.)

	AMED			DASH			JFGST		
	β	(95% CI)	p	β	(95% CI)	p	β	(95% CI)	p
Cardiometabolic risk score‡									
Crude	-0.17	(-0.37, 0.03)	0.09	-0.45	(-0.64, -0.26)	<0.001	0.03	(-0.17, 0.22)	0.78
Adjusted‡	-0.19	(-0.28, 0.07)	0.07	-0.47	(-0.59, -0.26)	<0.001	0.03	(-0.09, 0.24)	0.79
Waist circumference (cm)									
Crude	-0.40	(-0.82, 0.02)	0.06	-0.37	(-0.79, 0.06)	0.09	-0.61	(-1.03, -0.18)	0.005
Adjusted‡	-0.59	(-1.03, -0.16)	0.008	-0.41	(-0.83, 0.00)	0.052	-0.59	(-1.02, -0.17)	0.006
Systolic blood pressure (mmHg)									
Crude	-0.31	(-0.94, 0.31)	0.33	-1.19	(-1.81, -0.57)	<0.001	0.45	(-0.17, 1.08)	0.16
Adjusted‡	-0.42	(-1.04, 0.19)	0.17	-1.12	(-1.71, -0.54)	<0.001	0.60	(0.01, 1.18)	0.048
Diastolic blood pressure (mmHg)									
Crude	-0.31	(-0.79, 0.17)	0.21	-0.99	(-1.47, -0.51)	<0.001	0.050	(-0.43, 0.53)	0.84
Adjusted‡	-0.33	(-0.82, 0.15)	0.18	-0.96	(-1.42, -0.50)	<0.001	0.13	(-0.34, 0.59)	0.60
HDL cholesterol (mmol/L)									
Crude	0.008	(-0.01, 0.03)	0.44	0.017	(0.00, 0.04)	0.10	-0.013	(-0.03, 0.01)	0.20
Adjusted‡	0.000	(-0.02, 0.02)	0.97	0.018	(0.00, 0.04)	0.07	-0.010	(-0.03, 0.01)	0.35
Log-triacylglycerol (mmol/L) §									
Crude	-0.009	(-0.03, 0.02)	0.48	-0.014	(-0.04, 0.01)	0.27	0.013	(-0.01, 0.04)	0.30
Adjusted‡	-0.004	(-0.03, 0.02)	0.77	-0.015	(-0.04, 0.01)	0.21	0.010	(-0.01, 0.03)	0.43
Glucose (mmol/L)									
Crude	0.00	(-0.02, 0.02)	0.79	-0.03	(-0.05, -0.01)	0.006	0.00	(-0.02, 0.03)	0.71
Adjusted‡	0.00	(-0.02, 0.02)	0.87	-0.03	(-0.05, -0.01)	0.006	0.00	(-0.02, 0.03)	0.70
Log-insulin (mU/L) §									
Crude	-0.01	(-0.05, 0.02)	0.43	-0.06	(-0.09, -0.03)	0.001	0.00	(-0.03, 0.04)	0.94
Adjusted‡	-0.03	(-0.06, 0.01)	0.16	-0.06	(-0.10, -0.03)	<0.001	0.00	(-0.03, 0.04)	0.90

DQSJ, Diet Quality Score for Japanese; HEI-2015, Healthy Eating Index-2015; AHEI-2010, Alternate Healthy Eating Index-2010; AMED; Alternate Mediterranean Diet; DASH, Dietary Approaches to Stop Hypertension; JFGST, Japanese Food Guide Spinning Top; CI, confidence interval; BMI, body mass index; HDL, high-density lipoprotein; SE standard error. β indicates differences in a cardiometabolic risk factors per 1 SD increase in diet quality score.

†Adjusted for age (years, continuous), survey year (2006 or 2007), residential regions (north, central, or south), municipality level (city with population ≥1 million, city with population <1 million, or town and village), current smoking (yes or no), energy intake (kJ, continuous), and physical activity (total metabolic equivalents-h/d, continuous).

‡A cardiometabolic risk score was computed from the sum of z-score standardization of the following six variables: waist circumference, mean value of systolic and diastolic blood pressures, HLD cholesterol (multiplied by -1), triacylglycerol (natural-log transformed), glucose, and insulin (natural-log transformed).

§Triacylglycerol and insulin were natural log-transformed due to right skewness.