J Nutr Health Aging. 2019;23(9):896-903

SCORE-BASED AND NUTRIENT-DERIVED DIETARY PATTERNS ARE ASSOCIATED WITH DEPRESSIVE SYMPTOMS IN COMMUNITY-DWELLING OLDER JAPANESE: A CROSS-SECTIONAL STUDY

Y. YOKOYAMA[1], A. KITAMURA[1], T. YOSHIZAKI[1,2], M. NISHI[1], S. SEINO[1], Y. TANIGUCHI[1], H. AMANO[1], M. NARITA[1], S. SHINKAI[1]

1. Tokyo Metropolitan Institute of Gerontology, 35-2, Sakaecho, Itabashi-ku, Tokyo 173-0015, Japan; 2. Department of Food and Life Sciences, Faculty of Food and Nutritional Sciences, Toyo University, 1-1-1, Izumino, Itakura-machi, Ora-gun, Gunma 374-0193, Japan. Corresponding author: Yuri Yokoyama, PhD, Research Team for Social Participation and Community Health, Tokyo Metropolitan Institute of Gerontology, 35-2, Sakaecho, Itabashi-ku, Tokyo 173-0015, Japan, Tel: +81(3)3964-3241, Fax: +81(3)3579-4776, E-mail: yokoyama@tmig.or.jp

Abstract: *Objectives:* This study evaluated associations of score-based and nutrient-derived dietary patterns with depressive symptoms in community-dwelling older Japanese. *Design:* Cross-sectional study. *Setting:* Community-based. *Participants:* 982 community-dwelling adults aged 65 years or older. *Measurements:* Score-based pattern was assessed by using dietary variety score (DVS), which covers 10 food group items in Japanese meals. Nutrient-derived dietary patterns were identified by using reduced rank regression (RRR), with folate, vitamin C, magnesium, calcium, iron, and zinc intakes as response variables. Depressive symptoms were assessed with the Geriatric Depression Scale. Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated for these dietary patterns in multivariate logistic regression analyses with potential confounders. The lowest consumption category was used as the reference group. *Results:* The prevalence of depressive symptoms was 13.5%. Higher DVS was associated with fewer depressive symptoms (OR=0.52, 95% CI=0.27-1.03 for the highest vs the lowest DVS; P for trend=0.031). The first RRR dietary pattern score was characterized by high intakes of fish, soybean products, potatoes, most vegetables, mushrooms, seaweeds, fruits, and green tea and a low intake of rice and was inversely associated with the prevalence of depressive symptoms (OR=0.53, 95% CI=0.30-0.92; P for trend=0.030). *Conclusion:* Greater dietary variety and a dietary pattern characterized by high intakes of fish, soybean products, potatoes, most vegetables, mushrooms, seaweeds, fruit, and green tea and a low intake of rice were consistently associated with lower prevalence of depressive symptoms in community-dwelling older Japanese. Therefore, both patterns identified the components of dietary habits essential to depression prevention.

Key words: Dietary patterns, dietary variety, reduced rank regression.

Introduction

Depression is a common mental health disorder and imposes substantial burdens on individuals and societies (1, 2). Depression is highly prevalent in older adults (1) and is associated with reduced quality of life and increased risks of suicide, functional decline, dementia, and frailty (2-4). Identifying effective prevention strategies for depression is thus an important public-health priority worldwide.

Diet is a modifiable factor in depressive symptoms, and increasing evidence indicates a link between dietary factors and such symptoms (5-8). Most previous studies focused on the association of depression with specific nutrients or foods, such as B vitamins, n-3 polyunsaturated fatty acids, fish, and fruits and vegetables (5, 6), Although evidence regarding individual nutrients and foods is important, people eat meals comprising several foods, and the complex combinations of nutrients are likely to have interactive effects (9). Thus, researchers should use a dietary patterns approach to consider the effects of dietary quality derived from whole diets rather than from specific nutrients or foods (7, 8). Several such approaches have been used to assess dietary quality, including a priori (hypothesis-driven) approaches, which use diet quality scores or indices such as the Mediterranean diet score or healthy eating index, a posteriori (data-driven) approaches, which use statistical methods such as factor analysis/principal component analysis and cluster analysis and, more recently, hybrid approaches that use reduced rank regression (RRR), which combines the characteristics of the first two approaches (10).

This study uses a priori and hybrid approaches to study dietary quality in relation to depressive symptoms. Although several indices of diet quality have been developed, we focus instead on dietary variety. Consumption of a greater variety of foods is considered more beneficial than a monotonous diet; thus, dietary variety is mentioned in current dietary guidelines for Americans and Japanese (11, 12). Several indices for assessing dietary variety have been developed (13-16). Dietary variety score (DVS) was developed by Kumagai et al. as a measure of diet quality that considers variety among 10 consumed food groups (16). Because of its simplicity, DVS has been used in research and practice among Japanese older adults (17-20). Our previous study showed that greater dietary variety was associated with lower risk for future declines in physical performance among community-dwelling older adults (18); however, associations with depressive symptoms have not been examined.

Received April 24, 2019
Accepted for publication May 21, 2019

Published online August 5, 2019, http://dx.doi.org/10.1007/s12603-019-1238-2

RRR (the hybrid approach) identifies the linear combination of food groups (i.e., the dietary pattern) that best explains variation in a set of response variables (nutrients and biomarkers) hypothesized to be intermediates between food groups and health outcome (21). In comparison with other methods, RRR appears to be a more appropriate and promising statistical method for identifying dietary patterns associated with intakes of nutrients known to be related to an outcome measure. It combines prior information about the pathway from diet to depression and dietary information from a study population. RRR has recently been used in nutritional epidemiology, and several studies have examined associations of dietary patterns assessed by RRR with depressive symptoms (22-24).

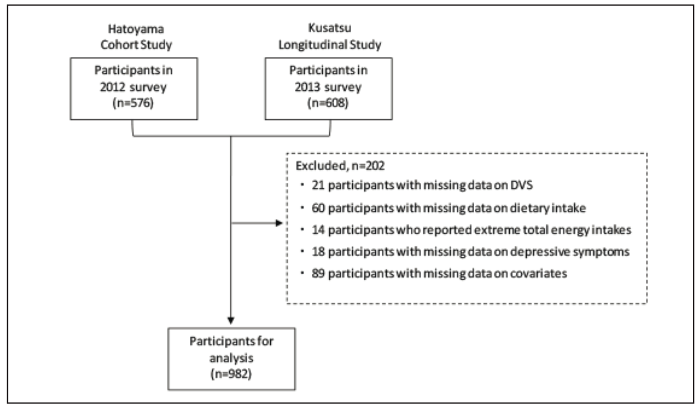
Analytical approaches have unique strengths and limitations, and the use of the above two methods for the same population, after controlling for the identical potential confounders, may improve our understanding of diet and depression. RRR is useful in examining dietary patterns specific to the outcome of interest. However, because RRR requires detailed dietary assessment and analysis and depends on the data available, it is not always applicable to the general population of older adults. In contrast, DVS may be more useful in public-health studies assessing population adherence to current dietary guidelines. Because DVS can be evaluated with a short food-based questionnaire, assessment is less burdensome for older adults and does not require nutrient analysis and complicated calculations. If the association between DVS and depression is similar to that identified by RRR, DVS can be used as a dietary screening tool to identify depression risk in older adults. Therefore, the aim of the present study was to evaluate score-based and nutrient-derived dietary patterns associated with depressive symptoms in community-dwelling older Japanese.

Materials and methods

The present study used data previously collected for the Hatoyama Cohort Study and Kusatsu Longitudinal Study, the designs and protocols for which have been reported elsewhere (25, 26). The participants were recruited from among older adults aged 65 to 84 years who were randomly stratified by age and area (in the Hatoyama Cohort Study) or had participated in community-based health checkups (in the Kusatsu Longitudinal Study). In the present analysis, we used a sample combined from the two studies. Because data on dietary intake and demographic characteristics were collected in the 2012 survey of the Hatoyama Study and the 2013 survey of Kusatsu Study, data for both time points were used in our cross-sectional study. This study was approved by the Ethics Committee of the Tokyo Metropolitan Institute of Gerontology, and written informed consent was obtained from all participants.

Of the 1184 participants who agreed to participate in the study (n=576 in the Hatoyama Cohort Study; n=608 in the Kusatsu Longitudinal Study), we excluded participants with missing information on DVS (n=21) or dietary intake (n =60), those who reported energy intakes <600 kcal/d or ≥4000 kcal/d (n =14), and those with missing data on depressive symptoms (n=18) or covariates of the present study (n=89). Ultimately, data from 982 participants (505 men and 477 women) aged 65 to 97 years were included in the analyses (Figure 1).

Figure 1
Flowchart of participant selection



Depressive symptoms

The Geriatric Depression Scale (GDS) short-form was used to assess depressive symptoms. The GDS is a 15-item scale with scores ranging from 0 to 15 points (27, 28). A cutoff point of 5/6 was adopted, and score of ≥6 points was considered to indicate the presence of depressive symptoms (28).

Score-based dietary pattern

Diet index–based pattern was measured by using DVS, developed by Kumagai et al (16). The DVS comprises 10 food-based components, including meat, fish/shellfish, eggs, milk, soybean products, green/yellow vegetables, potatoes, fruits, seaweed, and fats/oils, which make up a large proportion of daily main and side dishes for Japanese (29). A score of 1 was assigned to items «eaten almost daily», and a score of 0 was assigned to items «not eaten almost daily». The total score for the DVS thus ranges from 0 to 10 points; higher scores indicate greater dietary variety. We categorized the DVS into three categories: low (DVS=0-3), medium (DVS=4-6), and high (DVS≥7 points) (18).

Dietary patterns derived from RRR

Habitual dietary intakes during the preceding 1-month period were assessed with a validated, self-administered, brief diet history questionnaire (BDHQ) (30, 31). Dietary intake of 58 food and beverage items, energy, and specific nutrients were calculated by using an ad hoc computer algorithm based on the Standard Tables of Food Composition in Japan (32). The validation procedure for the BDHQ has been described elsewhere (30, 31).

RRR analysis was used to identify dietary patterns. RRR

Table 1
Explained variation in nutrient and food intake and Spearman rank correlation between nutrients (response variable) and RRR-derived dietary patterns

	Dietary patterns						**Total explained variation**
	1	**2**	**3**	**4**	**5**	**6**	
Explained variation in food intake, %	7.36	2.27	2.27	2.36	2.04	2.27	18.56
Explained variation in nutrients, %	74.71	12.03	6.89	3.32	1.97	1.02	99.94
Spearman rank correlation coefficient							
Folate	0.90*	-0.31*	-0.09	-0.08	0.11*	-0.13*	
Vitamin C	0.80*	-0.49*	0.09	0.25*	-0.06	0.07	
Magnesium	0.94*	0.10	0.05	-0.11	-0.28*	-0.05	
Calcium	0.78*	0.28*	0.47*	-0.02	0.11*	0.02	
Iron	0.93*	-0.03	-0.23*	-0.17*	-0.01	0.18*	
Zinc	0.77*	0.46*	-0.30*	0.22*	-0.01	-0.01	

*P<0.001.

derives the linear functions of food groups that explain as much variation as possible in response variables (e.g., nutrients or biomarkers) (21). The RRR method has been described in detail by Hoffman et al. (21). Fifty-two food and beverage items were used as predictors; six items were excluded, namely, sugar added to coffee and black tea, three items usually added during cooking (salt, oil, and sugar), table salt and salt-containing seasoning at the table, and soup consumed with noodles. Response variables were selected for six nutrients—folate, vitamin C, magnesium, calcium, iron, and zinc—because these response variables were used in a previous study in which the first RRR dietary pattern score was associated with lower depressive symptoms (22) and because these nutrients were reported to protect against depressive symptoms in previous studies (33-40). The six nutrients selected as response variables and the 52 food and beverage items were energy-adjusted with the density method. The extracted first dietary pattern score for each participant was categorized into tertiles (T1-T3).

Covariates

The covariates used in the analyses were sex, age, study area, education, living arrangement (single, with spouse only, or other), smoking habit (never, former, or current smoker), drinking habit (never/rarely, sometimes, or every day), exercise habit (defined as engaging in exercise for 20 minutes or longer more than three times per week during the previous 6 months), self-perceived chewing ability (can chew anything/almost anything, cannot chew much), mobility limitations (identified through self-reported difficulty in walking 1 km or climbing 10 steps without resting), frequency of going outdoors, self-reported medical history (hypertension, diabetes mellitus, heart disease, stroke, cancer, chronic obstructive pulmonary disease), experience of hospitalization during the past year, body mass index (calculated as weight in kilograms divided by height in meters squared), energy intake, and hours slept per night.

Statistical analysis

The characteristics of the study population in relation to depression status were compared by using the Mann–Whitney U test for continuous variables or the chi-square test for categorical variables. Associations between the dietary pattern extracted by RRR and nutrients as response variables were evaluated by using Spearman rank correlation coefficients. Odds ratios (ORs) and 95% confidence intervals (CIs) for depression were calculated for each category of DVS (Low–High groups) and primary dietary pattern score (T1–T3). The lowest category of each score was used as the reference in the analyses. The first model was the crude model (model 1). The next model (model 2) was adjusted for age (years, continuous), sex (dummy, 0 = men, 1 =women, and study area (dummy, 0 = Hatoyama, 1 = Kusatsu) and further adjusted, in model 3, for education (years, continuous), living arrangement (dummy, 0 = single, 1 = with spouse only, 2 = other), smoking habit (dummy, 0 = current, 1 = former, 2 = never), drinking habit (dummy, 0 = every day, 1 = sometimes, 2 = none/rarely), exercise habit (dummy, 0 = no, 1 = yes), self-perceived chewing ability (dummy, 0 = can chew anything/almost anything, 1 = cannot chew much), mobility limitation (dummy, 0 = no, 1 = yes), frequency of going outdoors (dummy, 0 = no, 1 = yes), medical history (hypertension, diabetes, cancer, stroke, heart disease, chronic obstructive pulmonary disease) (dummy, 0 = no, 1 = yes), experience of hospitalization during the past year (dummy, 0 = no, 1 = yes), body mass index (kg/m^2, continuous), total energy intake (kcal/d, continuous), and hours slept per night (hour, continuous). Tests for linear trends were conducted by using each category of DVS and dietary pattern score as a continuous variable in the logistic regression models. A two-sided P-value of <0.05 was regarded as statistically significant. Dietary pattern analyses (RRR) were performed with SAS version 9.4, and the remaining analyses were performed with IBM SPSS Statistics version 23.

Table 2
Factor loadings of food items in dietary pattern 1 derived by RRR

Food group	Factor loadings[a]
Low-fat milk and yogurt	0.07
Milk and yogurt	0.08
Chicken	0.07
Pork/beef	0.06
Ham/sausage/bacon	0.05
Liver	0.05
Squid/octopus/shrimp/shellfish	0.10
Small fish with bones	**0.23**
Canned tuna	0.06
Dried fish/salted fish	**0.16**
Oily fish	0.10
Lean fish	0.11
Egg	0.13
Tofu/atsuage[b]	**0.25**
Natto	**0.17**
Potatoes	**0.20**
Pickled green leaves vegetables	0.09
Other pickles	0.07
Lettuces/cabbage (raw)	**0.20**
Green leaves vegetables	**0.31**
Cabbage/Chinese cabbage	**0.25**
Carrots/pumpkin	**0.26**
Japanese radish/turnip	**0.21**
Other root vegetables	**0.23**
Tomatoes	**0.18**
Mushrooms	**0.24**
Seaweeds	**0.22**
Western-type confectioneries	-0.09
Japanese confectioneries	-0.04
Rice crackers/rice cake/okonomiyaki[c]	-0.03
Ice cream	-0.09
Citrus fruits	0.11
Persimmons/strawberries/kiwifruits	**0.15**
Other fruits	0.09
Mayonnaise/dressing	0.04
Bread	-0.08
Buckwheat noodles	-0.01
Japanese wheat noodles	0.01
Chinese noodles	-0.08
Spaghetti and macaroni	-0.02
Green tea	**0.15**
Black tea/Oolong tea	0.01
Coffee	-0.01
Cola drink/soft drink	-0.12
100% fruits and vegetable juice	0.06
Rice	**-0.16**
Miso soup	-0.02
Sake	-0.10
Beer	-0.10
Shochu[d]	-0.14
Whisky	-0.08
Wine	-0.04

a. Factor loadings with an absolute value of ≥0.15 are shown in bold; b. atsuage: deep-fried tofu; c. okonomiyaki: meat/fish and vegetable pancake; d. Shochu: a Japanese distilled beverage

Results

Table 1 shows explained variation in nutrients and food intake and Spearman rank correlation between nutrients (response variable) and RRR-derived dietary patterns. In total, RRR extracted six dietary patterns, which in total explained 18.56% of the variation in the food groups and 99.94% of the variation in the response variables. The first RRR pattern accounted for 7.36% of the variation in the food groups and 74.71% of explained the total variation in all responsible variables, whereas the remaining dietary patterns explained less than 2.36% and 12.03% of the variation. Thus, we used the first RRR pattern in subsequent analyses. The first RRR pattern was highly correlated with intakes of each nutrient (all Spearman rank correlation coefficients ≥0.77, P<0.001). The first RRR pattern score was moderately associated with DVS (Pearson correlation coefficient=0.38, P<0.001).

Factor loading and explained variation of the first pattern obtained from RRR are shown in Table 2. Factor loadings represent the magnitude and direction of the contribution of each food group to the pattern. A high positive loading indicates a strong direct association between the food group and the pattern, whereas a high negative loading reflects a strong inverse association. Foods with an absolute factor loading of more than 0.15 were considered to be characteristics of the dietary pattern and included small fish with bones, dried fish/salted fish, soybean products, potatoes, vegetables, mushrooms, seaweeds, Persimmons/strawberries/kiwifruits, and green tea; rice was the only food with a factor loading less than –0.15.

Table 3 shows the characteristics of the study participants in relation to depression status. The prevalence of depressive symptoms (GDS ≥6 points) was 13.5%, and the mean (SD) DVS for all participants was 4.3 (2.4) points. As compared with participants without depressive symptoms, those with depressive symptoms were significantly older, had less

Table 3
Characteristics of the study population, by depression status

	Total	No depression	Depression	p[a]
No. of participants	982	849	133	
Age (y)	73.8 (5.6)	73.6 (5.6)	74.5 (5.4)	0.023
Education (y)	11.6 (3.0)	11.6 (3.0)	11.1 (2.8)	0.034
Women (%)	48.6	49.5	42.9	0.156
Living alone (%)	16.1	15.5	19.5	0.327
Alcohol (%)				
Daily	23.9	25.1	16.5	0.096
Sometimes	14.4	14.0	16.5	
None/rarely	61.7	60.9	66.9	
Smoking (%)				
Current	9.5	8.7	14.3	0.043
Former	34.7	34.2	38.3	
Never	55.8	57.1	47.4	
Self-perceived chewing ability (%)				
Can chew anything/most things	97.6	98.5	91.7	<0.001
Do not chew much	2.4	1.5	8.3	
Exercise habit (%)	55.6	58.0	40.6	<0.001
Outdoors more than once a day (%)	78.3	80.1	66.9	<0.001
Mobility limitation (%)	15.8	13.4	30.8	0.001
Medical history (%)				
Hypertension	46.0	45.5	49.6	0.371
Diabetes	12.9	12.7	14.3	0.617
Cancer	11.3	11.0	13.5	0.382
Stroke	6.7	6.1	10.5	0.059
Heart disease	15.8	14.6	23.3	0.010
COPD	4.9	4.7	6.0	0.517
Hospitalization (%)	8.9	8.0	14.3	0.018
BMI (kg/m^2)	23.2 (3.1)	23.2 (3.1)	23.1 (3.4)	0.539
Energy intake (kcal/day)	2028 (550)	2052 (550)	1871 (524)	0.001
Hours slept per night (h)	7.4 (1.3)	7.4 (1.3)	7.1 (1.4)	0.076

Abbereviations: COPD, chronic obstructive pulmonary disease; BMI, Body mass index; Data are means (SD) or percentages; a. P values are based on Mann-Whitney U test, for continuous variables, and the chi-square test, for categorical variables.

education, were more likely to smoke, had lower chewing ability, and were less likely to have an exercise habit. In addition, they went outdoors less frequently, were more likely to have mobility limitations, heart disease, and experience of hospitalization during the past year, and had lower energy intakes.

Table 4 shows the ORs for depressive symptoms in relation to DVS category and tertiles of dietary pattern score derived from RRR. Higher DVS was significantly associated with decreased prevalence of depressive symptoms in model 1 and model 2. After further adjustment for other covariates (model 3), the inverse association was attenuated but remained significant: the multivariable-adjusted ORs for depressive symptoms in the lowest through highest DVS categories were 1.00 (reference), 0.68 (95% CI, 0.43-1.07), and 0.52 (0.27-1.03), respectively (P for trend=0.031). The first RRR dietary pattern was also inversely associated with the prevalence of depressive symptoms in model 1 and model 2. After additional adjustment, the ORs for the highest tertiles of RRR dietary pattern score were almost identical. The multivariable-adjusted

Table 4
Odds ratios and 95% confidence intervals for depressive symptoms, by category of dietary variety score and tertile of dietary pattern scores derived by RRR

	Number of cases/ participants	Model 1[a] OR (95%CI)	Model 2[b] OR (95%CI)	Model 3[c] OR (95%CI)
Dietary Variety Score				
Low (0-3)	76/386	1.00 (Reference)	1.00 (Reference)	
Medium (4-6)	43/418	0.47 0.31 -0.70)	0.49 (0.33 -0.74)	0.68 (0.43 -1.07)
High (7-10)	14/178	0.35 (0.19 -0.63)	0.35 (0.19 -0.64)	0.52 (0.27 -1.03)
P for trend		<0.001	<0.001	0.031
RRR pattern				
T1	54/327	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
T2	49/328	0.89 (0.58 -1.35)	0.84 (0.54 -1.30)	0.90 (0.56 -1.45)
T3	30/327	0.51 (0.32 -0.82)	0.51 (0.31 -0.85)	0.53 (0.30 -0.92)
P for trend		0.006	0.010	0.030

Abbereviations: OR, odds ratio; CI, confidence interval; T, tertile; a. Model 1: crude. b. Model 2: adjusted for sex, age, and study site. c. Model 3: adjusted for variables in Model 2 plus education, living alone, smoking and drinking habits, exercise habit, self-perceived chewing ability, mobility limitation, frequency of going outdoors, medical history (hypertension, diabetes, cancer, stroke, heart disease, and chronic obstructive pulmonary disease), hospitalization, body mass index, energy intake, and hours slept per night.

ORs for depressive symptoms in the lowest through highest tertiles of pattern from RRR were 1.00 (reference), 0.90 (95% CI, 0.56-1.45), and 0.53 (0.30-0.92), respectively (P for trend=0.030).

Discussion

In this cross-sectional study, we evaluated the associations of score-based and nutrient-derived dietary patterns with depressive symptoms in community-dwelling older Japanese. Both the score-based score (DVS) and RRR dietary pattern score were significantly associated with lower ORs for depressive symptoms. To our knowledge, this is the first study to apply different dietary pattern approaches, and in particular DVS, to the same population and examine associations of these dietary patterns with depression symptoms.

RRR has recently been used in nutritional epidemiology, and several studies reported an association of RRR dietary pattern score with depressive symptoms (22-24). A previous cross-sectional study of the Japanese population utilized RRR analysis with the same response variables used in our study. A dietary pattern characterized by high intakes of vegetables, fruits, mushrooms, seaweeds, soybean products, and green tea was associated with lower prevalence of depressive symptoms (22). A longitudinal study of an Italian population used RRR analysis (with EPA+DHA, folate, magnesium, and zinc as response variables) and found that a dietary pattern characterized by high intakes of vegetables, fruits, grains, potatoes, fish, and olive oil and moderate intakes of red and processed meat was significantly associated with lower depressive symptoms (23). Although RRR analysis likely depends on the dataset available for a given population, we were able to determine that the present dietary pattern was consistent with the findings of previous studies.

Using previous findings (22, 33-40), we chose intakes of folate, vitamin C, magnesium, calcium, iron, and zinc as response variables in RRR analysis. Although several pathways have been implicated in mental illness, these vitamins and minerals may protect neuronal cells against oxidative damage and are involved in synthesis and metabolism of neurotransmitters that affect mood (41). Because our RRR-derived pattern was positively correlated with intakes of each nutrient (Pearson correlation coefficients all ≥0.77), RRR analysis succeeded in extracting a dietary pattern that both reflected intakes of nutrients known to be related to depressive symptoms and was associated with depressive symptoms.

Although the correlation between first RRR pattern score and DVS was moderate, we noted commonalities across diet quality measures. Both approaches considered fish, soybean products, potatoes, vegetables, seaweeds, and fruit. A recent meta-analysis of observational studies reported associations of a priori methods (e.g., diet quality scores) and a posteriori dietary patterns (e.g., principal component analysis) with depression. A healthy dietary pattern (characterized by higher intakes of fruit, vegetables, fish, and whole grains) was inversely associated with depression (7). Although several approaches have been used to identify dietary patterns, past and present results suggest that a dietary pattern with higher intakes of beneficial foods (e.g., fruits/vegetables and fish) reduces depression risk.

In the present study, age- and sex-adjusted ORs for depression were significantly lower for participants in the highest DVS categories those for those in the lowest categories, and this association remained significant after adjustment for additional covariates. As compared with the dietary pattern derived by RRR, the magnitude of attenuation after adjustment for other covariates was relatively large. In particular, the association was attenuated after additional adjustment for energy intake (data not shown). Higher DVS was associated with higher energy intake (whereas RRR pattern score was associated with lower energy intake); thus, total energy intake might confound the association between depression risk and DVS. A recent analysis of longitudinal data reported that energy intakes started to decrease in men and women in their 40s to 70s (42) and that dietary variety declined in women in their 60s (43). The present and previous findings suggest that total energy intake has a role in depression and that, in addition to dietary variety, consuming a diet with sufficient energy content is important.

In contrast, the magnitude of the decreased risk was as large as that for the highest tertile of RRR dietary pattern score. Unlike RRR method, score-based patterns such as DVS represent ideal dietary patterns and do not identify dietary patterns specific to a disease of interest. Nevertheless, our findings indicate that DVS also captures dietary patterns relevant to depression risk. DVS is a simple measure of dietary quality and can be assessed with a short food-based questionnaire. It is less burdensome for older adults and does not require nutrient analysis or complicated calculations and therefore might be valuable in assessing dietary quality associated with depressive symptoms for non-specialist researchers and health care providers in the community.

The strengths of this study include its large population sample of community-living older adults and the use of a food frequency questionnaire validated for Japanese populations. Additionally, by using two dietary pattern approaches, this study yielded insights for developing strategies that might prevent depression by modifying diet.

The limitations of this study also warrant mention. First, because it is a cross-sectional study, the direction of the associations cannot be determined. Thus, we could not exclude the possibility that the choice of foods determining the dietary pattern had changed as a result of depressive symptoms. Second, despite adjustment, the possibility of residual confounding cannot be ruled out. Although we adjusted for important covariates, our analysis may not encompass all factors that potentially affect depressive symptoms. Finally, this study included community-dwelling older people who were relatively well functioning and able to participate in the assessments at the community center on their own. Furthermore, as compared with the included participants, those excluded from statistical analyses were less educated, went outdoors less frequently, and were more likely to be living alone, to have been hospitalized during the past year, and to have mobility limitations and depression. Hence, we cannot exclude the possibility of selection bias.

Conclusions

In conclusion, greater dietary variety and a dietary pattern characterized by high intakes of fish, soybean products, potatoes, most vegetables, mushrooms, seaweeds, fruits, and green tea and a low intake of rice were inversely associated with the prevalence of depressive symptoms. Our findings indicate that improvement in diet quality may help prevent depression and that both the score-based approach and empirically driven RRR approach are valuable for evaluating diet associated with depressive symptoms. Future studies, especially those with a prospective design, are needed in order to confirm these associations.

Ethical Standards: The ethics committee of the Tokyo Metropolitan Institute of Gerontology approved this study, which complies with the current laws of Japan.

Acknowledgments: We are very grateful to the study participants and to the staff of the Tokyo Metropolitan Institute of Gerontology for their cooperation in this study, and to Professor Toshiharu Ninomiya and Mio Ozawa, Department of Epidemiology and Public Health, Graduate School of Medical Sciences, Kyushu University, for their helpful comments and assistance with the RRR method. This research was supported by JSPS KAKENHI Grants JP 20390190, JP 21390212, JP 24390173 and JP18K17994 from the Japan Society for the Promotion of Science, by research grants from the Research Institute of Science and Technology for Society (RISTEX), by the Japan Science and Technology Agency, and by the towns of Hatoyama and Kusatsu.

Conflicts of interest: None of the authors has a conflict of interest to declare.

References

1. World Health Organization (2017) Depression and Other Common Mental Disorders Global Health Estimates. https://apps.who.int/iris/bitstream/handle/10665/254610/WHO-MSD-MER-2017.2-eng.pdf?sequence=1. Accessed 18 March 2019
2. Lepine JP, Briley M. The increasing burden of depression. Neuropsychiatr Dis Treat 2011;7:3-7.
3. Diniz BS, Butters MA, Albert SM, Dew MA, Reynolds CF, 3rd. Late-life depression and risk of vascular dementia and Alzheimer's disease: systematic review and meta-analysis of community-based cohort studies. Br J Psychiatry 2013;202:329-335.
4. Soysal P, Veronese N, Thompson T, Kahl KG, Fernandes BS, Prina AM, Solmi M, Schofield P, Koyanagi A, et al. Relationship between depression and frailty in older adults: A systematic review and meta-analysis. Ageing Res Rev 2017;36:78-87.
5. Murakami K, Sasaki S. Dietary intake and depressive symptoms: a systematic review of observational studies. Mol Nutr Food Res 2010;54:471-488.
6. Saghafian F, Malmir H, Saneei P, Milajerdi A, Larijani B, Esmaillzadeh A. Fruit and vegetable consumption and risk of depression: accumulative evidence from an updated systematic review and meta-analysis of epidemiological studies. Br J Nutr 2018;119:1087-1101.
7. Lai JS, Hiles S, Bisquera A, Hure AJ, McEvoy M, Attia J. A systematic review and meta-analysis of dietary patterns and depression in community-dwelling adults. Am J Clin Nutr 2014;99:181-197.
8. Rahe C, Unrath M, Berger K. Dietary patterns and the risk of depression in adults: a systematic review of observational studies. Eur J Nutr 2014;53:997-1013.
9. Hu FB. Dietary pattern analysis: a new direction in nutritional epidemiology. Curr Opin Lipidol 2002;13:3-9.
10. Tucker KL. Dietary patterns, approaches, and multicultural perspective. Appl Physiol Nutr Metab 2010;35:211-218.
11. U.S. Department of Health and Human Services and U.S. Department of Agriculture (2015) 2015 – 2020 Dietary Guidelines for Americans. 8th Edition. https://health.gov/dietaryguidelines/2015/guidelines/. Accessed 18 March 2019
12. The Ministry of Agriculture, Forestry and Fisheries of Japan (2016). Main points of the revision of "Dietary guideline for Japanese". http://www.maff.go.jp/j/syokuiku/attach/pdf/shishinn-3.pdf. Accessed 18 March 2019
13. Kant AK, Schatzkin A, Harris TB, Ziegler RG, Block G. Dietary diversity and subsequent mortality in the First National Health and Nutrition Examination Survey Epidemiologic Follow-up Study. Am J Clin Nutr 1993;57:434-440.
14. Drewnowski A, Henderson SA, Driscoll A, Rolls BJ. The Dietary Variety Score: assessing diet quality in healthy young and older adults. J Am Diet Assoc 1997;97:266-271.
15. Bernstein MA, Tucker KL, Ryan ND, O'Neill EF, Clements KM, Nelson ME, Evans WJ, Fiatarone Singh MA. Higher dietary variety is associated with better nutritional status in frail elderly people. J Am Diet Assoc 2002;102:1096-1104.
16. Kumagai S, Watanabe S, Shibata H, Amano H, Fujiwara Y, Shinkai S, Yoshida

H, Suzuki T, Yukawa H, et al. Effects of dietary variety on declines in high-level functional capacity in elderly people living in a community. Nihon koshu eisei zasshi 2003;50:1117-1124. (in Japanese)
17. Yokoyama Y, Nishi M, Murayama H, Amano H, Taniguchi Y, Nofuji Y, Narita M, Matsuo E, Seino S, et al. Association of Dietary Variety with Body Composition and Physical Function in Community-dwelling Elderly Japanese. J Nutr Health Aging 2016;20:691-696.
18. Yokoyama Y, Nishi M, Murayama H, Amano H, Taniguchi Y, Nofuji Y, Narita M, Matsuo E, Seino S, et al. Dietary Variety and Decline in Lean Mass and Physical Performance in Community-Dwelling Older Japanese: A 4-year Follow-Up Study. J Nutr Health Aging 2017;21:11-16.
19. Seino S, Nishi M, Murayama H, Narita M, Yokoyama Y, Nofuji Y, Taniguchi Y, Amano H, Kitamura A, Shinkai S. Effects of a multifactorial intervention comprising resistance exercise, nutritional and psychosocial programs on frailty and functional health in community-dwelling older adults: A randomized, controlled, cross-over trial. Geriatr Gerontol Int 2017;17:2034-2045.
20. Kimura M, Moriyasu A, Kumagai S, Furuna T, Akita S, Kimura S, Suzuki T. Community-based intervention to improve dietary habits and promote physical activity among older adults: a cluster randomized trial. BMC Geriatr 2013;13:8.
21. Hoffmann K, Schulze MB, Schienkiewitz A, Nöthlings U, Boeing H. Application of a New Statistical Method to Derive Dietary Patterns in Nutritional Epidemiology. Am J Epidemiol 2004;159:935-944.
22. Miki T, Kochi T, Kuwahara K, Eguchi M, Kurotani K, Tsuruoka H, Ito R, Kabe I, Kawakami N, et al. Dietary patterns derived by reduced rank regression (RRR) and depressive symptoms in Japanese employees: The Furukawa nutrition and health study. Psychiatry Res 2015;229:214-219.
23. Vermeulen E, Stronks K, Visser M, Brouwer IA, Schene AH, Mocking RJ, Colpo M, Bandinelli S, Ferrucci L, Nicolaou M. The association between dietary patterns derived by reduced rank regression and depressive symptoms over time: the Invecchiare in Chianti (InCHIANTI) study. Br J Nutr 2016;115:2145-2153.
24. Vermeulen E, Stronks K, Visser M, Brouwer IA, Snijder MB, Mocking RJT, Derks EM, Schene AH, Nicolaou M. Dietary pattern derived by reduced rank regression and depressive symptoms in a multi-ethnic population: the HELIUS study. Eur J Clin Nutr 2017;71:987-994.
25. Murayama H, Nishi M, Shimizu Y, Kim MJ, Yoshida H, Amano H, Fujiwara Y, Shinkai S. The Hatoyama Cohort Study: design and profile of participants at baseline. J Epidemiol. 2012;22:551-558.
26. Shinkai S, Yoshida H, Fujiwara Y, Amano H, Fukaya T, Ri S, Watanabe N, Watanabe S, Kumagai O, et al. A 10-year community intervention for disability prevention and its effect on healthy aging in Kusatsu town. Nihon koshu eisei zasshi 2013;60:596-605. (in Japanese)
27. Burke WJ, Roccaforte WH, Wengel SP. The short form of the Geriatric Depression Scale: a comparison with the 30-item form. J Geriatr Psychiatry Neurol 1991;4:173-178.
28. Schreiner AS, Hayakawa H, Morimoto T, Kakuma T. Screening for late life depression: cut-off scores for the Geriatric Depression Scale and the Cornell Scale for Depression in Dementia among Japanese subjects. Int J Geriatr Psychiatry 2003;18:498-505.
29. The Ministry of Health Labour and Welfare of Japan (2006) National Health and Nutrition Survey in Japan, 2006. https://www.mhlw.go.jp/bunya/kenkou/eiyou08/01.html. Accessed 18 March 2019 (in Japanese)
30. Kobayashi S, Murakami K, Sasaki S, Okubo H, Hirota N, Notsu A, Fukui M, Date C. Comparison of relative validity of food group intakes estimated by comprehensive and brief-type self-administered diet history questionnaires against 16 d dietary records in Japanese adults. Public Health Nutr 2011;14:1200-1211.
31. Kobayashi S, Honda S, Murakami K, Sasaki S, Okubo H, Hirota N, Notsu A, Fukui M, Date C. Both Comprehensive and Brief Self-Administered Diet History Questionnaires Satisfactorily Rank Nutrient Intakes in Japanese Adults. J Epidemiol 2012;22:151-159.
32. Science and Technology Agency, 2010, Standard Tables of Food Composition in Japan, 2010. Ministry of Education, culturem Sports, Science and Technology, Tokyo (in Japanese)
33. Miki T, Kochi T, Eguchi M, Kuwahara K, Tsuruoka H, Kurotani K, Ito R, Akter S, Kashino I, et al. Dietary intake of minerals in relation to depressive symptoms in Japanese employees: the Furukawa Nutrition and Health Study. Nutrition 2015;31:686-690.
34. Gilbody S, Lightfoot T, Sheldon T. Is low folate a risk factor for depression? A meta-analysis and exploration of heterogeneity. J Epidemiol Community Health 2007;61:631-637.
35. Bae YJ, Kim SK. Low dietary calcium is associated with self-rated depression in middle-aged Korean women. Nutr Res Pract 2012;6:527-533.
36. Jacka FN, Overland S, Stewart R, Tell GS, Bjelland I, Mykletun A. Association between magnesium intake and depression and anxiety in community-dwelling adults: the Hordaland Health Study. Aust N Z J Psychiatry 2009;43:45-52.
37. Oishi J, Doi H, Kawakami N. Nutrition and Depressive Symptoms in Community-dwelling Elderly Persons in Japan. Acta Med Okayama 2008;63:9-17.
38. Vashum KP, McEvoy M, Milton AH, McElduff P, Hure A, Byles J, Attia J. Dietary zinc is associated with a lower incidence of depression: findings from two Australian cohorts. J Affect Disord 2014;166:249-257.
39. Woo J, Lynn H, Lau WY, Leung J, Lau E, Wong SY, Kwok T. Nutrient intake and psychological health in an elderly Chinese population. Int J Geriatr Psychiatry 2006;21:1036-1043.
40. Murakami K, Mizoue T, Sasaki S, Ohta M, Sato M, Matsushita Y, Mishima N. Dietary intake of folate, other B vitamins, and omega-3 polyunsaturated fatty acids in relation to depressive symptoms in Japanese adults. Nutrition 2008;24:140-147.
41. Parletta N, Milte CM, Meyer BJ. Nutritional modulation of cognitive function and mental health. J Nutr Biochem 2013;24:725-743.
42. Otsuka R, Kato Y, Nishita Y, Tange C, Tomida M, Nakamoto M, Imai T, Ando F, Shimokata H. Age-related Changes in Energy Intake and Weight in Community-dwelling Middle-aged and Elderly Japanese. J Nutr Health Aging 2016;20:383-390.
43. Otsuka R, Nishita Y, Tange C, Tomida M, Kato Y, Imai T, Ando F, Shimokata H. Age-Related 12-Year Changes in Dietary Diversity and Food Intakes among Community-Dwelling Japanese Aged 40 to 79 Years. J Nutr Health Aging 2018;22:594-600.