Original Article

Association of dietary diversity with all-cause mortality by body mass index in Japanese older adults: An age-specific prospective cohort study (NISSIN Project)

Saeka Takabayashi[1], Takumi Hirata[2,3], Wenjing Zhao[2,4], Takashi Kimura[2], Shigekazu Ukawa[5], Kazuyo Tsushita[6], Kenji Wakai[7], Takashi Kawamura[8], Masahiko Ando[9], Akiko Tamakoshi[1,2]

[1] Department of Public Health, Graduate School of Medicine, Hokkaido University, North 15 West 7, Kita-ku, Sapporo 060-8638, Japan,

[2] Department of Public Health, Hokkaido University Faculty of Medicine, North 15 West 7, Kita-ku, Sapporo 060-8638, Japan

[3] Institute for Clinical and Translational Science, Nara Medical University, 840 Shijo-cho, Kashihara 634-8522, Japan

[4] School of Public Health and Emergency Management, Southern University of Science and Technology, 1088 Xueyuan Avenue, Shenzhen 518055, P.R. China

[5] Department of Social Services and Clinical Psychology, Graduate School of Human Life Science, Osaka City University, Sugimoto 3-3-138, Sumiyoshi-ku, Osaka 558-8585, Japan

[6] Comprehensive Health Science Center, Aichi Health Promotion Public Interest Foundation

[7] Department of Preventive Medicine, Nagoya University, Graduate School of Medicine, Nagoya, Japan

[8] Kyoto University Health Service, Yoshida Hon-machi, Sakyo-ku, Kyoto, Japan

[9] Center for Advanced Medicine and Clinical Research, Nagoya University Hospital, Nagoya, Japan

Short title: Effect of dietary diversity on mortality

Corresponding author: Akiko Tamakoshi, Department of Public Health, Hokkaido University Graduate School of Medicine, North 15 West 7 Kita-ku, Sapporo, 060-8638, Japan

Tel: +81-11-706-5068

Fax: +81-11-706-7805

E-mail: tamaa@med.hokudai.ac.jp

Authorship: Saeka Takabayashi and Akiko Tamakoshi were in charge of the study design. Saeka Takabayashi analysed the data and wrote the manuscript. Akiko Tamakoshi, Kenji Wakai, Takashi Kawamura, and Masahiko Ando implemented the survey. Akiko Tamakoshi, Takumi Hirata, Wenjing Zhao, Takashi Kimura, Shigekazu Ukawa, Kazuyo Tsushita, Kenji Wakai, Takashi Kawamura, and Masahiko Ando critically reviewed the manuscript.

ABSTRACT

Aim: Dietary diversity may reduce the risk of malnutrition, although it is also linked to obesity. We examined whether dietary diversity is associated with all-cause mortality in Japanese older adults based on their body mass index (BMI).

Methods: The current study included 2,944 people aged 64–65 years who participated in the NISSIN project from 1996 to 2005. Dietary diversity was measured using the Food Variety Score (FVS), which calculates the frequency of all food items consumed daily using a self-administered food frequency questionnaire. Participants were divided into tertiles according to their FVS (first: low, second: middle, third: high). Multivariate adjusted hazard ratios (HRs) with 95% confidence intervals (CIs) were calculated using the Cox proportional hazard regression model. For the stratified analysis, BMI was used to divide the participants into three groups—lean (BMI <20), normal (BMI 20–24.9), and overweight/obese (BMI ≥25).

Results: Overall, 454 (30.7%) men and 222 (15.2%) women died over a median follow-up period of 16.6 years. No significant association was observed between FVS and all-cause mortality. However, when grouped by BMI, for the participants in the lean group, the multivariate adjusted HRs were 0.56 (CI: 0.32–0.96) for the middle FVS and 0.50 (CI: 0.25–1.02) for the high FVS, compared with the low FVS (*p for trend*=0.059). In overweight/obese women, although not significant, total mortality was higher in the middle and high FVS.

Conclusions: These findings indicate that dietary diversity should be promoted in lean older Japanese adults.

Keywords: dietary diversity, mortality, body mass index, Food Variety Score, older adults

INTRODUCTION

Dietary diversity is a proxy measurement of nutrient adequacy[1] and is linked to a decrease in all-cause mortality.[234] Older adults have a higher risk of malnutrition[5] because of appetite loss,[6] reduced chewing ability,[7] or their socioeconomic conditions.[8] Dietary diversity may reduce the risks of malnutrition and loss of weight through both adequate nutrient intake and an increase in total energy intake (TEI).[9] However, that is also linked to obesity due to an excessive TEI.[10,11] Both high and low body mass index (BMI) are important predictors of all-cause mortality.[12] Thus, the association of dietary diversity with all-cause mortality may be influenced by BMI, but no studies have examined the effect of BMI on the association of dietary diversity with all-cause mortality.

This study examined the association of dietary diversity with all-cause mortality and the effect of BMI in older adults. Dietary diversity was evaluated by the number of different types of food consumed, which increased the TEI.[9]

METHODS

Study design and population

The study population was sampled from the New Integrated Suburban Seniority Investigation (NISSIN) Project, a prospective age-specific cohort study, from 1996 to 2005. Details of this cohort have been reported elsewhere.[13]Briefly, residents of Nisshin city, Aichi prefecture who were 65 years old when they participated in the survey from 1996 to 2005 were invited to participate in the free health examinations conducted annually by the local government. The baseline survey consisted of a medical checkup, including somatometry and blood tests, and a self-administered questionnaire, which included a food frequency questionnaire (FFQ).

This cohort enrolled 3,073 participants who provided informed consent. The overall response rate was 43.9%. The exclusion criteria were as follows: relocation from the city prior to the start of the follow-up period (n = 2), not completing the entire FFQ (n = 112), presence of extreme TEI estimated by the FFQ (<500 kcal or >5000 kcal daily, n= 10),[14] and missing values for >40 of 90 items in the FFQ (n = 5). After applying the exclusion criteria, 2,944 (1,481 men and 1,463 women) were eligible for this study.

This study was approved by the Ethics Committees of Hokkaido University Graduate School of Medicine (Medicine 14-037), the Ethics Committees of the National Center for Geriatrics and Gerontology in Japan, the Ethics Committee of Nagoya University Graduate School of Medicine, and the Ethics Committees of Aichi Medical University School of Medicine. Informed consent was adopted in the form of an opt-out from 1996 to 2001 (and there were many such refusals) and written informed consent was required from 2002 to 2005.

Dietary assessment and dietary diversity

Dietary assessment was conducted using a validated self-administered FFQ, which contained 90-modern Japanese food items or dishes. Eight vitamins and other products were excluded because the frequency of intake was not asked and added rice with portion sizes.[15] The following food groups are included in the calculation of FSV; Rice, Bread, Noodles, Other cereals, Potatoes, Sugar, Confectionery, Oils and fats, Nuts, Beans, Seafood, Meat, Eggs, Dairy product, Fruits, Mushrooms, Algae, Seasoning, Green/Yellow vegetables, Other vegetables. The participants were asked to report the average frequency of consumption over the past year.

There were nine options for questions about the frequency of food items or dishes: less than once per month, once per month, 2–3 times per month, once per week, 2–4 times per week, 5–6 times per week, once per day, 2–3 times per day, and more than 3 times per day. To measure dietary diversity, we used the Food Variety Score (FVS), the most widely used measure of dietary diversity,[16] which counts all the food items consumed in a day. To calculate the FVS, the frequencies for once per month, 2–3 times per month, once per week, 2–4 times per week, and 5–6 times per week were converted to 1/30, 2.5/30, 1/7, 3/7, and 5.5/7 times. If the consumption frequency of the same food items or dishes was more than once per day, it was counted as 7/7 times. The TEI was calculated based on the FFQ in accordance with the Japanese food composition table.[15]

Assessment of nutrient adequacy

To evaluate nutrient adequacy, the nutrient adequacy ratio (NAR), the ratio of a participant's intake to the recommended dietary allowance (RDA) or tentative dietary goals (DG) according to the Dietary Reference Intakes for Japanese (2020),[17] was calculated for each of the 10 nutrients. Cholesterol was used as the recommended value, which is less than 200 mg/day is desirable for the purpose of preventing severe cases of dyslipidemia[17] The NAR was calculated as follows:

$$NAR = \frac{Actual\ nutrient\ intake\ of\ a\ nutrient\ (per\ day)}{RDA, DG\ or\ recommended\ value\ of\ a\ given\ nutrient}$$

Moreover, except for already energy adjusted saturated fat**,** we energy-adjusted NAR using estimated energy requirement (EER) and TEI (NAR × EER (kcal/d) / TEI (kcal/d).[18] The physical activity to identify EER is assumed low.[19] For eight nutrients (proteins, dietary fiber, vitamin C, potassium, calcium, magnesium, iron, and zinc) in which a deficient supply could pose health risks the NARs above 1 were set to 1 (Range: 0 to 1). This was because a nutrient with a high NAR could not compensate for a nutrient with a low NAR[20] when calculating the mean adequacy ratio (MAR). Similarly, for two nutrients (saturated fat and cholesterol) in which excess supply could be a health risk, NARs below 1 were set to 1 (Range: ≧1).

The MAR was calculated as an overall measure of nutrient adequacy.[16] The eight nutrients were used and the MAR was calculated as follows (Range: 0 to 1).:

$$MAR = \frac{\sum NAR}{Number\ of\ nutrients (= 8)}$$

The mean excess ratio (MER) was used as an indicator of nutrient restriction. [21] The two nutrients were used, and the MER was calculated as follows (Range: ≧0):

$$MER = \frac{\sum NAR}{Number\ of\ nutrients\ (= 2)} - 1$$

Body mass index (BMI)

Weight and height were measured during the medical checkup to calculate body mass index (BMI, kg/m^2). Using BMI, participants were divided into three groups: lean (BMI <20), normal (BMI 20–24.9), and overweight/obese (BMI ≥25), which is applied when considering malnutrition in older adults.[22]

Covariates

A self-administered questionnaire was used to evaluate sociodemographic and lifestyle factors. The medical status included hypertension, hyperlipidaemia, and diabetes mellitus; Hypertension was identified as a systolic or diastolic blood pressure higher than 140 or 90 mmHg, respectively, or self-reported hypertension. Hyperlipidaemia was defined as total cholesterol ≥220 mg/dL, LDL cholesterol (total cholesterol - HDL cholesterol -

triglyceride/5) ≥140 mg/dL, triglyceride ≥150 mg/dL, HDL cholesterol <40 mg/dl, and/or self-reported hyperlipidaemia. Diabetes mellitus was identified as haemoglobin A1c (HbA1c) ≥6.5%, fasting plasma glucose ≥126 mg/dL, or self-reported diabetes mellitus.

Self-reported history of disease included clinically diagnosed heart disease (yes or no), cerebrovascular disease (yes or no), and cancer (yes or no).

Outcome follow-up

Each participant underwent an annual follow-up until death, transfer out of the city, or until the end of the follow-up period (31 December 2019). The date of death and transfer out of the city was confirmed using the resident registry. The transfer out of the city was treated as a censored case.

Statistical analysis

Participants were divided into tertiles according to their FVS (first: low, second: middle, third: high): overall in sex-stratified tertiles, not in tertiles of men and women together. The characteristics of each group were described. The differences in the characteristics among the groups were examined using the Pearson's chi-square test (categorical variables), analysis of variance (ANOVA) (continuous variables).

A multivariate Cox proportional hazards regression model was used to calculate hazard ratios (HRs) and the corresponding 95% confidence intervals (CIs) of the risk of subsequent all-cause mortality according to the FVS with participants in the low FVS being used as the reference group. In the stratified analysis by BMI, participants were divided into three BMI groups (lean, normal, overweight/obese). Two sensitivity analyses were performed: 1. Excluding participants with a history of heart disease, cerebrovascular disease, and cancer, 2. Excluding participants who died or moved within 3 years from baseline.

Analyses were carried out by the following models: adjusted for survey year and sex (except for the stratified analysis by sex in Tables 2–3 and Supplemental Tables 2), (model 1); adjusted for living alone (yes, no, or unknown), education (lower than high school, high school or above, or unknown), smoking status (never, former, current, or unknown), alcohol consumption (never, current or unknown)), habitual exercise (seldom, <1 times/week, ≥1 times/week or unknown).

In addition to model 1, model 2 was adjusted for history of heart disease (yes, no), cerebrovascular disease (yes, no), cancer (yes, no) (except for the sensitivity analysis 1 in Table 2 and Supplemental Table 2), medical status of hypertension (yes, no), hyperlipidaemia (yes, no) and diabetes mellitus (yes, no).In addition to model 2, model 3 was adjusted for BMI (lean, normal, overweight/obese) (except for Table 3, Supplemental Tables 2),

In addition to model 3, model 4 was adjusted for BMI category and TEI (continuous).

The *p* value for the trend across the mean values of the tertile of the FVS was calculated. Statistical significance was set at $p < 0.05$. All statistical analyses were performed using JMP Pro 16.0.0 for Mac (SAS Institute, Cary, NC, USA).

RESULTS

In total, 454 (30.7%) men and 222 (15.2%) women died over the median follow-up period of 16.6 years and 17.6 years, respectively.

Table 1 shows the baseline characteristics according to the tertile of their FVS. Compared to the participants in the low FVS, the participants in the high FVS were more likely to have a high school education or higher, exercise habitually and those were less likely to be living alone. The high FVS were fewer current smokers. In the analysis by BMI, the high FVS of all the BMI groups were more likely to have a high school education or higher (Supplemental Table 1).

FVS was positively associated with total nutrient adequacy, as indicated by MAR. However, the FVS was also positively associated with MER which is an indicator of excess nutrients. The results of the analysis by BMI were similar (Supplemental Table 1).

Table 2 shows the multivariate adjusted HRs and corresponding 95% CIs for the association of FVS with all-cause mortality overall or by sex. No significant association of the FVS with all-cause mortality was observed. This association did not change in the sensitivity analyses 1–2.

The interaction between FVS and BMI was significant (*p* <0.001). Table 3 shows the multivariate adjusted HRs and the corresponding 95% CIs for the association of FVS with all-cause mortality by BMI (lean, normal, overweight/ obese) or by sex and BMI. In the lean group, although it contains non-significant results, the multivariate adjusted HRs were 0.56 (CI: 0.32–0.96) for the middle FVS and 0.50 (CI: 0.25–1.02) for the high FVS, compared with the low FVS *(p for trend*=0.059). This association did not change in sensitivity analyses 1–2 (Supplemental Tables 2). No consistent association was found among BMI standards and overweight/obesity.

In men, the interaction between FVS and BMI was not significant *(p* for interaction=0.182); however, in women, this interaction was significant (*p* for interaction<0.001). In women lean/standard BMI, all-cause mortality was lower in the medium/high FVS than in the low FVS, although this was not statistically significant. Conversely, overweight/obese women had higher all-cause mortality in the medium/high FVS than in the low FVS, although the association was not significant. This association did not change in the sensitive analysis 1-2 (Supplemental Tables 2).

DISCUSSION

This is the first study to examine the association between dietary diversity and all-cause mortality among older adults, along with the effect of modification by BMI. No significant association was observed between FVS and all-cause mortality. However, in the stratified analysis by BMI, in the lean group, although it contains non-significant results, including sensitivity analyses, all-cause mortality was consistently lower in the medium and high FVS than in the low FVS. Moreover, in women, although the association was not significant, overweight/obesity had consistently higher all-cause mortality in the medium/high FVS than in the low FVS.

In the stratified analysis by BMI, all-cause mortality was lower in the medium/high FVS compared to the low FVS in the lean group. One possible reason for this is that an increase in the FVS raised the MAR, which indicated the overall nutrient adequacy and reduced deficiencies of nutrients with antioxidant and anti-inflammatory functions, leading to a reduction in all-cause mortality.[23] Another reason might be the necessity to obtain and prepare various foods to consume different types of foods. Individuals with a higher dietary diversity have a lower decline in higher functional capacity[24]. Furthermore, dietary diversity is associated with greater lean mass and improved physical functions.[25] The maintenance of these functional capacities through a higher FVS may have had a protective effect on all-cause mortality. These considerations suggest that it was more plausible to have more significant results for women who are generally the primary cooks in the home.[26] Among women, in addition to the lean group, this may be one reason why all-cause mortality was lower in the medium/high FVS compared to the low FVS, even in the BMI standard group.

In contrast, overweight/obese women had higher all-cause mortality in the medium/high FVS than in the low FVS. In women, the association between dietary diversity and all-cause mortality was shown to have a different effect with modification by BMI. One reason for this may be that the nutritional characteristics of the FVS in this study were positively associated with the MER, an indicator of the nutrients that should be restricted. A recent review also points out current evidences didn't support higher dietary diversity as an effective strategy to promote healthy eating patterns among middle-aged adults.[27] Saturated fat intake is associated with cardiovascular disease in a high-risk population for cardiovascular disease.[28] Obesity is a risk factors for cardiovascular disease,[28] and thus, in the overweight and obese group of women, saturated fat intake may have increased total mortality through increased cardiovascular disease. Regarding dietary cholesterol, there is a positive linear association between dietary cholesterol intake and all-cause mortality,[29] with a significantly higher association for women than for men.[29] Thus, the effects of increased risk factors for total mortality and increased MER in overweight and obese women may have outweighed the preventive effects of dietary diversity seen in the lean group.

The strength of this study was its design, which was an age-specific cohort with a long follow-up period. Dietary diversity changes begin around 65 years of age for the

Japanese population,[30] and people at this turning point were recruited for this study. Adjustments for a history of heart disease, cerebrovascular disease, cancer, hypertension, hyperlipidaemia, and diabetes mellitus, which may affect dietary intake, improved the validity of this study's findings. Moreover, the analysis excluded participants who died or moved within 3 years from baseline, and this did not change the findings.

This study has several limitations. First, a response rate of 43.9% suggested a possible selection bias. Generalizing our results to Japanese older adult populations requires caution. Moreover, since the study may be conducted in a relatively health-conscious population because of this response rate, the impact of dietary diversity may have been overestimated. Second, residual confounding may have been likely, although we adjusted for several covariates. Third, the relatively small sample size and small number of deaths did not allow this study to analyse the relationship between the FVS and specific cause of death although the FVS is known to reduce mortality in coronary heart disease.[2] Future studies to examine the relationship would be helpful. Fourth, using self-reported dietary and lifestyle questionnaires and the FFQ may have resulted in some misclassification and residual confounding. However, using a 4-day dietary record validated the FFQ for food groups.[15] In conclusion, these findings indicate that dietary diversity should be promoted in lean older adults. BMI may influence the association between dietary diversity and all-cause mortality.

Acknowledgements

The authors express their sincere appreciation to the Health Center and Hygiene Department of Nisshin City for their generous cooperation in collecting the baseline and follow-up data. This study was supported by the Japanese Society for the Promotion of Science KAKENHI Grant Numbers JP15390197, JP25893003, JP26460760, JP26520105, and JP20K02392, the Uehara Memorial Foundation, Mitsui Sumitomo Insurance Welfare Foundation, Health Promotion Foundation, and Pfizer Health Research Foundation.

Disclosure statement: All authors declare that there are no conflicts of interest.

Data Availability Statement: Data cannot be shared for privacy or ethical reasons.

REFERENCES

1. Tavakoli S, Dorosty-Motlagh AR, Hoshiar-Rad A, Eshraghian MR, Sotoudeh G, Azadbakht L, et al. Is dietary diversity a proxy measurement of nutrient adequacy in Iranian elderly women? Appetite [Internet]. 2016 Oct 1 [cited 2017 Jan 12];105:468–76. Available from: http://linkinghub.elsevier.com/retrieve/pii/S0195666316302392
2. Masset G, Scarborough P, Rayner M, Mishra G, Brunner EJ. Can nutrient profiling help to identify foods which diet variety should be encouraged? Results from the Whitehall II cohort. Br J Nutr [Internet]. 2015 Jun 14 [cited 2017 Jan 13];113(11):1800–9. Available from: http://www.journals.cambridge.org/abstract_S000711451500094X
3. Kobayashi M, Sasazuki S, Shimazu T, Sawada N, Yamaji T, Iwasaki M, et al. Association of dietary diversity with total mortality and major causes of mortality in the Japanese population: JPHC study. Eur J Clin Nutr [Internet]. 2019 Mar 19 [cited 2019 Apr 12];74(1):54−66. Available from: http://www.ncbi.nlm.nih.gov/pubmed/30890778
4. Otsuka R, Tange C, Nishita Y, Kato Y, Tomida M, Imai T, et al. Dietary diversity and all-cause and cause-specific mortality in Japanese community-dwelling older adults. Nutrients. 2020;12(4):1052.
5. Crichton M, Craven D, Mackay H, Marx W, De Van Der Schueren M, Marshall S. A systematic review, meta-analysis and meta-regression of the prevalence of protein-energy malnutrition: Associations with geographical region and sex. Age Ageing. 2019;48(1):38–48.
6. van der Pols-Vijlbrief R, Wijnhoven HAH, Schaap LA, Terwee CB, Visser M. Determinants of protein-energy malnutrition in community-dwelling older adults: A systematic review of observational studies. Ageing Res Rev [Internet]. 2014;18:112–31. Available from: http://dx.doi.org/10.1016/j.arr.2014.09.001
7. Kimura Y, Ogawa H, Yoshihara A, Yamaga T, Takiguchi T, Wada T, et al. Evaluation of chewing ability and its relationship with activities of daily living, depression, cognitive status and food intake in the community-dwelling elderly. Geriatr Gerontol Int. 2013;13(3):718–25.
8. Besora-Moreno M, Llauradó E, Tarro L, Solà R. Social and economic factors and malnutrition or the risk of malnutrition in the elderly: A systematic review and meta-analysis of observational studies. Nutrients. 2020;12(3):1–16.
9. McCrory MA, Burke A, Roberts SB. Dietary (sensory) variety and energy balance. Physiol Behav [Internet]. 2012;107(4):576–83. Available from: http://dx.doi.org/10.1016/j.physbeh.2012.06.012

10. Zhang Q, Chen X, Liu Z, Varma DS, Wan R, Zhao S. Diet diversity and nutritional status among adults in southwest China. PLoS One. 2017;12(2):1–9.
11. Karimbeiki R, Pourmasoumi M, Feizi A, Abbasi B, Hadi A, Rafie N, et al. Higher dietary diversity score is associated with obesity: a case–control study. Public Health [Internet]. 2018;157:127–34. Available from: https://doi.org/10.1016/j.puhe.2018.01.028
12. Ng M, Fleming T, Robinson M, Al. E, (NCD-RisC) NRFC, WHO, et al. Body-mass index and all-cause mortality: individual-participant-data meta-analysis of 239 prospective studies in four continents. Lancet [Internet]. 2016 Aug [cited 2016 Sep 7];388(10046):776–86. Available from: http://linkinghub.elsevier.com/retrieve/pii/S0140673616301751
13. Kitamura T, Kawamura T, Tamakoshi A, Wakai K, Ando M, Ohno Y. Rationale, Design, and Profiles of the New Integrated Suburban Seniority Investigation (NISSIN) Project: A Study of an Age-Specific, Community-Based Cohort of Japanese Elderly. J Epidemiol. 2009;19(5):237–43.
14. Zhao W, Ukawa S, Okada E, Wakai K, Kawamura T, Ando M, et al. The associations of dietary patterns with all-cause mortality and other lifestyle factors in the elderly: An age-specific prospective cohort study. Clin Nutr [Internet]. 2019;38(1):288–96. Available from: https://doi.org/10.1016/j.clnu.2018.01.018
15. Wakai K, Egami I, Kato K, Lin Y, Kawamura T, Tamakoshi A, et al. A Simple Food Frequency Questionnaire for Japanese Diet-Part I. Development of the Questionnaire, and Reproducibility and Validity for Food Groups. J Epidemiol. 2011;9(4):216–26.
16. Hatløy a, Torheim LE, Oshaug a. Food variety--a good indicator of nutritional adequacy of the diet? A case study from an urban area in Mali, West Africa. Eur J Clin Nutr [Internet]. 1998 Dec [cited 2016 Dec 19];52(12):891–8. Available from: http://www.ncbi.nlm.nih.gov/pubmed/9881884
17. Ministry of Health L and W of J. Dietary Reference Intakes for Japanese (2020) [Internet]. 2020 [cited 2022 July 9]. Available from：https://www.mhlw.go.jp/content/10900000/000862500.pdf
18. Okubo H, Sasaki S, Murakami K, Takahashi Y. Nutritional adequacy of four dietary patterns defined by cluster analysis in Japanese women aged 18-20 years. Asia Pac J Clin Nutr. 2010;19(4):555–63.
19. Murakami K, Livingstone MBE, Sasaki S, Takahashi Y, Okubo H, Hosoi Y, et al. 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. Eur J Nutr [Internet]. 2018 May 1 [cited 2016 Jan 26];58(5):1–14. Available from: http://dx.doi.org/10.1007/s00394-018-1762-6

20. Marie T. Ruel. Operationalizing Dietary Diversity: A Review of Measurement Issuesand Research Priorities. J Nutr. 2003;133(11 Suppl 2):3911S-3926S.
21. Vieux F, Soler L-G, Touazi D, Darmon N. High nutritional quality is not associated with low greenhouse gas emissions in self-selected diets of French adults. Am J Clin Nutr [Internet]. 2013 Mar 1 [cited 2017 Jan 13];97(3):569–83. Available from: http://www.ncbi.nlm.nih.gov/pubmed/23364012
22. Wolters M, Volkert D, Streicher M, Kiesswetter E, Torbahn G, O'Connor EM, et al. Prevalence of malnutrition using harmonized definitions in older adults from different settings – A MaNuEL study. Clin Nutr. 2019;38(5):2389–98.
23. Jayedi A, Rashidy-Pour A, Parohan M, Sadat Zargar M, Shab-Bidar S. Dietary antioxidants, circulating antioxidant concentrations, total antioxidant capacity, and risk of all-causemortality: A systematic review and dose-responsemeta-analysis of prospective observational studies. Adv Nutr. 2018;9(6):701–16.
24. Otsuka R, Kato Y, Nishita Y, Tange C, Nakamoto M, Tomida M, et al. Dietary diversity and 14-year decline in higher-level functional capacity among middle-aged and elderly Japanese. Nutrition [Internet]. 2016;32(7–8):784–9. Available from: http://dx.doi.org/10.1016/j.nut.2016.01.022
25. Yokoyama Y, Nishi M, Murayama H, Amano H, Taniguchi Y, Nofuji Y, 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 Heal Aging. 2017;21(1):11–6.
26. Choi JY, Baumgartner J, Harnden S, Alexander BH, Town RJ, D'Souza G, et al. Increased risk of respiratory illness associated with kerosene fuel use among women and children in urban Bangalore, India. Occup Environ Med [Internet]. 2015 Feb 1 [cited 2020 Sep 25];72(2):114–22. Available from: https://pubmed.ncbi.nlm.nih.gov/25341423/
27. de Oliveira Otto MC, Anderson CAM, Dearborn JL, Ferranti EP, Mozaffarian D, Rao G, et al. Dietary Diversity: Implications for Obesity Prevention in Adult Populations: A Science Advisory From the American Heart Association. Circulation. 2018;138(11):e160–8.
28. Guasch-Ferré M, Babio N, Martínez-González MA, Corella D, Ros E, Martín-Peláez S, et al. Dietary fat intake and risk of cardiovascular disease and all-cause mortality in a population at high risk of cardiovascular disease. Am J Clin Nutr. 2015;102(6):1563–73.
29. O'Neil CE, Nicklas TA, Fulgoni VL. Nutrient intake, diet quality, and weight/adiposity parameters in breakfast patterns compared with no breakfast in adults: National health and nutrition examination survey 2001-2008. J Acad Nutr Diet [Internet]. 2014;114(12):S27–43. Available from: http://dx.doi.org/10.1016/j.jand.2014.08.021

30. Otsuka R, Nishita Y, Tange C, Tomida M, Kato Y, Imai T, et al. Age-Related 12-Year Changes in Dietary Diversity and Food Intakes Among Community-Dwelling Japanese Aged 40 to 79 Years. J Nutr Health Aging [Internet]. 2018 May 30 [cited 2019 Apr 12];22(5):594–600. Available from: http://www.ncbi.nlm.nih.gov/pubmed/29717759

Supplemental Table 1. Baseline characters of participants according to FVS by BMI group or by sex and BMI group.

Supplemental Table 2. Multivariate-adjusted HRs and corresponding 95% CIs for the association of FVS with all-cause mortality by BMI group or by sex and BMI group excluding participants with history of heart disease, cerebrovascular disease, and cancer or excluding participants died or moved within 3 years from baseline.

Table 1. Baseline characters of participants according to the tertile of their FVS overall or by sex.

	ALL		FVS 1st (low)		FVS 2nd (middle)		FVS 3rd (high)		*P value*
ALL									
Number of participants	2,944		981	33.3	983	33.4	980	33.3	
FVS (mean, SD)	20.9	7.6	13.5	3.4	20.4	2.9	29.0	5.6	<0.001
Women (n, %)	1,463	49.7	487	49.6	489	49.8	487	49.7	1.0
Living alone (n, %)	117	4.0	54	5.5	36	3.7	27	2.8	0.028
Education ≧ High School (n, %)	2,016	68.5	576	58.7	715	72.7	725	74.0	<0.001
Current Smoking (n, %)	521	17.7	208	21.2	169	17.2	144	14.7	<0.001
Current Drinking (n, %)	1,305	44.3	433	44.1	443	45.1	429	43.8	0.667
Habitual Exercise (≧1 times/week) (n, %)	1,486	50.5	440	44.9	504	51.3	542	55.3	<0.001
Heart Disease (Yes) (n, %)	107	3.6	44	4.5	30	3.1	33	3.4	0.204
Cerebrovascular disease (Yes) (n, %)	129	4.4	37	3.8	45	4.6	47	4.8	0.506
Cancer (Yes) (n, %)	111	3.8	32	3.3	40	4.1	39	4.0	0.589
Hypertension (Yes) (n, %)	1,354	46.0	476	48.5	451	45.9	427	43.6	0.089
Hyperlipidemia (Yes) (n, %)	1,903	64.6	629	64.1	643	65.4	631	65.4	0.819
Diabetes mellitus (Yes) (n, %)	318	10.8	104	10.6	110	11.2	104	10.6	0.891
BMI <20 (kg/m^2) (n, %)	371	12.6	125	12.7	119	12.1	127	13.0	0.025
BMI≧25 (kg/m^2) (n, %)	662	22.5	252	25.7	195	19.8	215	21.9	0.025
TEI (kcal/day) (mean, SD)	1,909	611	1,481	395	1,841	437	2,406	583	<0.001
MAR (mean, SD)	0.87	0.10	0.81	0.11	0.88	0.08	0.92	0.06	<0.001
MER (mean, SD)	0.29	0.31	0.21	0.31	0.30	0.31	0.36	0.28	<0.001
Men									
Number of participants	1,481	100.0	494	33.4	494	33.4	493	33.3	
FVS (mean, SD)	17.6	6.7	10.6	2.5	17.1	1.6	25.1	4.6	<0.001
Living alone (n, %)	26	1.8	15	3.0	6	1.2	5	1.0	0.099
Education ≧ High School (n, %)	1,064	71.8	333	67.4	373	75.7	358	72.6	0.048
Current Smoking (n, %)	467	31.5	174	35.2	153	31.0	140	28.4	0.239
Current Drinking (n, %)	1,019	68.8	334	67.6	352	71.3	333	67.6	0.330
Habitual Exercise (≧1 times/week) (n, %)	757	51.1	228	46.2	256	51.8	273	55.4	0.072

Heart Disease (Yes) (n, %)	72	4.9	26	5.3	20	4.1	26	5.3	0.589
Cerebrovascular disease (Yes) (n, %)	77	5.2	20	4.1	28	5.7	29	5.9	0.365
Cancer (Yes) (n, %)	49	3.3	7	1.4	19	3.9	23	4.7	0.012
Hypertension (Yes) (n, %)	762	51.5	275	55.7	249	50.4	238	48.3	0.057
Hyperlipidemia (Yes) (n, %)	859	58.0	288	58.3	289	58.5	282	57.2	0.906
Diabetes mellitus (Yes) (n, %)	155	10.5	45	9.1	53	10.7	57	11.5	0.453
BMI <20 (kg/m^2) (n, %)	144	9.7	54	10.9	45	9.1	45	9.1	0.115
BMI≧25 (kg/m^2) (n, %)	372	25.1	140	28.3	110	22.3	122	24.8	0.115
TEI (kcal/day) (mean, SD)	1,909	604	1,512	425	1,845	466	2,369	568	<0.001
MAR (mean, SD)	0.84	0.10	0.77	0.11	0.86	0.08	0.90	0.06	<0.001
MER (mean, SD)	0.34	0.35	0.24	0.36	0.36	0.36	0.42	0.31	<0.001
Women									
Number of participants	1,463	100.0	487	33.3	489	33.4	487	33.6	
FVS (mean, SD)	23.3	7.6	15.4	3.1	22.7	1.9	31.9	5.0	<0.001
Living alone (n, %)	91	6.2	39	8.0	30	6.1	22	4.5	0.209
Education ≧ High School (n, %)	952	65.1	243	49.9	342	69.9	367	75.4	<0.001
Current Smoking (n, %)	54	3.7	34	7.0	16	3.3	4	0.8	<0.001
Current Drinking (n, %)	286	19.6	99	20.3	91	18.6	96	19.7	0.790
Habitual Exercise (≧1 times/week) (n, %)	729	49.8	212	43.5	248	50.7	269	55.2	<0.001
Heart Disease (Yes) (n, %)	35	2.4	18	3.7	10	2.0	7	1.4	0.058
Cerebrovascular disease (Yes) (n, %)	52	3.6	17	3.5	17	3.5	18	3.7	0.979
Cancer (Yes) (n, %)	62	4.2	25	5.1	21	4.3	16	3.3	0.358
Hypertension (Yes) (n, %)	592	40.5	201	41.3	202	41.3	189	38.8	0.632
Hyperlipidemia (Yes) (n, %)	1,044	71.4	341	70.0	354	72.4	349	71.7	0.703
Diabetes mellitus (Yes) (n, %)	104	7.1	32	6.5	42	8.6	30	6.2	0.283
BMI <20 (kg/m^2) (n, %)	227	15.5	71	14.6	74	15.2	82	16.8	0.211
BMI≧25 (kg/m^2) (n, %)	290	19.8	112	23.0	85	17.4	93	19.1	0.211
TEI (kcal/day) (mean, SD)	1,910	16	1,451	360	1,837	406	2,441	597	<0.001
MAR (mean, SD)	0.89	0.08	0.84	0.09	0.91	0.07	0.93	0.06	<0.001
MER (mean, SD)	0.24	0.25	0.18	0.25	0.24	0.25	0.31	0.24	<0.001

FVS: Food Variety Score, TEI: total energy intake, BMI: body mass index, MAR: mean adequacy ratio, MER: mean excess ratio

Differences in characters across FVS were examined by Pearson’s chi-square test (categorical variables) or ANOVA (continuous variables).

Table 2. Multivariate-adjusted HRs and corresponding 95% CIs for the association of FVS with all-cause mortality overall or by sex.

	FVS						
	1st (low)		2nd (middle)		3rd (high)		*P for trend*
All (n=2,944)							
FVS mean, SD	13.5	3.4	20.4	2.9	29.0	5.6	
Person-year	15,755		16,100		15,472		
Cases	245		208		223		
Model1[1]	1.00		0.84	(0.70-1.00)	0.95	(0.79-1.14)	0.618
Model2	1.00		0.88	(0.73-1.06)	1.00	(0.84-1.21)	0.870
Model3[1]	1.00		0.87	(0.72-1.05)	1.02	(0.85-1.23)	0.759
Model4	1.00		0.84	(0.69-1.02)	0.93	(0.74-1.18)	0.579
Excluding participants with history of heart disease, cerebrovascular disease, and cancer (n=2,615)							
FVS mean, SD	13.5	3.5	20.4	3.0	29.0	5.7	
Person-year	14,048		14,329		13,837		
Cases	215		179		187		
Model1[1]	1.00		0.82	(0.67-1.00)*	0.89	(0.73-1.08)	0.280
Model2	1.00		0.87	(0.71-1.07)	0.96	(0.78-1.16)	0.613
Model3[2]	1.00		0.87	(0.71-1.07)	0.97	(0.79-1.18)	0.706
Model4	1.00		0.86	(0.69-1.06)	0.92	(0.71-1.19)	0.393
Excluding participants died or moved within 3 years from baseline (n=2,825)							
FVS mean, SD	13.5	3.4	20.3	2.9	28.9	5.6	
Person-year	15,583		15,921		15,633		
Cases	232		195		210		
Model1[1]	1.00		0.83	(0.68-1.00)	0.92	(0.76-1.10)	0.409
Model2	1.00		0.87	(0.72-1.05)	0.97	(0.80-1.17)	0.794
Model3[1]	1.00		0.86	(0.71-1.04)	0.98	(0.81-1.19)	0.915
Model4	1.00		0.84	(0.69-1.03)	0.93	(0.73-1.19)	0.581
Men							
All (n=1,481)							
FVS mean, SD	11.6	2.5	18.1	1.6	26.1	4.6	

Person-year	7,666		7,892		7,349		
Cases	158		137		159		
Model1[2]	1.00		0.84	(0.67-1.06)	1.07	(0.86-1.33)	0.494
Model2	1.00		0.89	(0.71-1.12)	1.12	(0.90-1.40)	0.268
Model3[1]	1.00		0.88	(0.70-1.11)	1.14	(0.91-1.43)	0.205
Model4	1.00		0.85	(0.66-1.08)	1.03	(0.78-1.36)	0.797
Excluding participants with history of heart disease, cerebrovascular disease, and cancer (n=1,292)							
FVS mean, SD	11.4	2.6	17.9	1.6	25.9	4.5	
Person-year	6,626		6,878		6,502		
Cases	138		120		130		
Model1[2]	1.00		0.85	(0.66-1.08)	0.97	(0.76-1.23)	0.847
Model2	1.00		0.90	(0.70-1.15)	1.02	(0.80-1.30)	0.823
Model3[2]	1.00		0.91	(0.71-1.17)	1.04	(0.82-1.33)	0.688
Model4	1.00		0.87	(0.67-1.13)	0.96	(0.71-1.30)	0.823
Excluding participants died or moved within 3 years from baseline (n=1,414)							
FVS mean, SD	11.6	2.5	18.0	1.6	25..891	4.4	
Person-year	7,534		7,770		7,487		
Cases	150		129		149		
Model1[2]	1.00		0.84	(0.66-1.07)	1.02	(0.81-1.28)	0.811
Model2	1.00		0.89	(0.70-1.13)	1.06	(0.85-1.34)	0.540
Model3[1]	1.00		0.88	(0.69-1.12)	1.08	(0.86-1.36)	0.439
Model4	1.00		0.86	(0.67-1.10)	1.04	(0.78-1.39)	0.737
Women							
All(n=1,463)							
FVS mean, SD	15.4	3.1	22.7	1.9	31.9	5.0	
Person -year	8,090		8,208		8,123		
Cases	87		71		64		
Model1[2]	1.00		0.81	(0.59-1.11)	0.73	(0.53-1.01)	0.059
Model2	1.00		0.86	(0.62-1.19)	0.78	(0.56-1.10)	0.157
Model3[1]	1.00		0.85	(0.61-1.17)	0.81	(0.58-1.14)	0.223

Model4	1.00		0.82	(0.58-1.16)	0.74	(0.47-1.16)	0.186
Excluding participants with history of heart disease, cerebrovascular disease, and cancer (n=1,323)							
FVS mean, SD	15.4	3.1	22.9	1.9	32.0	5.0	
Person -year	7,421		7,451		7,335		
Cases	77		59		57		
Model1[2]	1.00		0.77	(0.55-1.08)	0.75	(0.53-1.06)	0.109
Model2	1.00		0.80	(0.57-1.14)	0.79	(0.55-1.13)	0.215
Model3[2]	1.00		0.79	(0.55-1.12)	0.80	(0.56-1.14)	0.227
Model4	1.00		0.77	(0.53-1.12)	0.76	(0.47-1.22)	0.254
Excluding participants died or moved within 3 years from baseline (n=1,411)							
FVS mean, SD	15.37	3.02	22.64	1.85	31.87	5.10	
Person -year	8,050		8,151		8,146		
Cases	82		66		61		
Model1[2]	1.00		0.80	(0.57-1.10)	0.73	(0.52-1.02)	0.058
Model2	1.00		0.82	(0.59-1.15)	0.76	(0.54-1.07)	0.129
Model3[1]	1.00		0.82	(0.58-1.14)	0.79	(0.56-1.12)	0.238
Model4	1.00		0.77	(0.54-1.10)	0.69	(0.44-1.10)	0.164

HR, hazard ratio; CI, confidence interval; FVS, food variety score; TEI, total energy intake; BMI, body mass index.

*$p<0.05$, **$p<0.01$

Analysed by Cox proportional hazard regression model

Model 1[1] (adjusted for sex, survey year)

Model 1[2] (adjusted for survey year)

Model 2 (model 1 plus adjusted for living alone, education, smoking, drinking, habitual exercise)

Model 3[1] (model 2 plus adjusted for history of heart disease, cerebrovascular disease, cancer, and medical status of hypertension, hyperlipidaemia, and diabetes mellitus)

Model 3[2] (model 2 plus adjusted for medical status of hypertension, hyperlipidaemia, and diabetes mellitus)

Model 4 (model 3 plus adjusted for BMI category, TEI)

p for trend is calculated across the mean values of FVS.

Table 3. Multivariate–adjusted HRs and corresponding 95% CIs for the association of FVS with all-cause mortality by BMI group or by sex and BMI group.

	FVS						
	1st (low)		2nd (middle)		3rd (high)		*P for trend*
All (n=2,944)							
BMI <20 group (n=371)							
FVS mean, SD	14.1	3.6	20.9	3.3	30.2	6.0	
Person-year	1,927		2,033		1,858		
Cases	37		30		29		
Model1[1]	1.00		0.60	(0.37-0.99)*	0.64	(0.39-1.06)	0.105
Model2	1.00		0.65	(0.39-1.08)	0.67	(0.40-1.12)	0.157
Model3	1.00		0.62	(0.37-1.04)	0.67	(0.40-1.13)	0.164
Model4	1.00		0.56	(0.32-0.96)*	0.50	(0.25-1.02)	0.059
BMI 20-24.9 group (n=1,911)							
FVS mean, SD	13.8	3.3	20.5	2.8	29.0	5.5	
Person-year	10,310		10,513		10,232		
Cases	164		117		142		
Model1[1]	1.00		0.74	(0.58-0.94)*	0.92	(0.74-1.16)	0.579
Model2	1.00		0.78	(0.61-0.99)*	0.99	(0.79-1.25)	0.942
Model3	1.00		0.79	(0.62-1.00)	1.02	(0.81-1.28)	0.801
Model4	1.00		0.78	(0.61-1.00)	0.98	(0.73-1.30)	0.909
BMI≧25 group (n=662)							
FVS mean, SD	12.3	3.3	19.6	3.1	28.4	5.5	
Person-year	3,514		3,601		3,340		
Cases	47		53		57		
Model1[1]	1.00		1.05	(0.71-1.56)	1.27	(0.86-1.87)	0.215
Model2	1.00		1.07	(0.72-1.59)	1.25	(0.84-1.86)	0.256
Model3	1.00		1.12	(0.75-1.68)	1.25	(0.84-1.88)	0.276
Model4	1.00		1.08	(0.70-1.66)	1.16	(0.69-1.95)	0.585

Men (n=1,481)							
BMI <20 group (n=144)							
FVS mean, SD	10.99	2.48	17.52	1.87	26.49	5.88	
Person-year	691		740		626		
Cases	22		21		20		
Model1[2]	1.00		0.73	(0.39-1.35）	0.76	(0.40-1.42)	0.426
Model2	1.00		0.88	(0.46-1.69)	0.84	(0.43-1.64)	0.622
Model3	1.00		0.74	(0.38-1.45)	0.85	(0.43-1.67)	0.716
Model4	1.00		0.63	(0.31-1.27)	0.53	(0.21-1.34)	0.188
BMI 20-24.9 group (n=965)							
FVS mean, SD	11.9	2.5	18.3	1.5	26.0	4.3	
Person-year	5,128		5,211		4,947		
Cases	103		78		102		
Model1[2]	1.00		0.80	(0.60-1.08)	1.10	(0.83-1.45)	0.351
Model2	1.00		0.84	(0.62-1.13)	1.17	(0.89-1.54)	0.185
Model3	1.00		0.86	(0.64-1.17)	1.20	(0.91-1.58)	0.144
Model4	1.00		0.86	(0.63-1.18)	1.19	(0.85-1.68)	0.238
BMI≧25 group (n=372)							
FVS mean, SD	11.09	2.64	17.61	1.92	26.12	4.74	
Person-year	1,846		1,942		1,775		
Cases	33		34		41		
Model1[2]	1.00		0.89	(0.55-1.44)	1.22	(0.77-1.94)	0.325
Model2	1.00		0.92	(0.56-1.49)	1.19	(0.74-1.91)	0.426
Model3	1.00		0.96	(0.59-1.57)	1.16	(0.71-1.91)	0.526
Model4	1.00		0.85	(0.50-1.43)	0.91	(0.49-1.69)	0.812
Women (n=1,463)							
BMI <20 group (n=227)							
FVS mean, SD	16.13	2.57	23.04	2.03	32.52	4.87	

Person-year	1,236		1,293		1,232		
Cases	15		9		9		
Model1[2]	1.00		0.39	(0.16-0.94)*	0.52	(0.21-1.28)	0.151
Model2	1.00		0.36	(0.13-0.97)*	0.68	(0.27-1.68)	0.339
Model3	1.00		0.37	(0.13-1.04)	0.62	(0.23-1.65)	0.297
Model4	1.00		0.35	(0.12-1.06)	0.54	(0.14-2.06)	0.339
BMI 20-24.9 group (n=946)							
FVS mean, SD	15.7	3.0	22.7	1.7	31.9	5.1	
Person-year	5,182		5,302		5,285		
Cases	61		39		40		
Model1[2]	1.00		0.63	(0.42-0.94)*	0.64	(0.43-0.96)*	0.031
Model2	1.00		0.67	(0.44-1.01)	0.69	(0.46-1.05)	0.088
Model3	1.00		0.67	(0.44-1.02)	0.72	(0.48-1.10)	0.136
Model4	1.00		0.62	(0.40-0.96)*	0.58	(0.33-1.00)	0.049
BMI≧25 group (n=290)							
FVS mean, SD	13.8	3.4	22.3	2.3	31.4	5.0	
Person-year	1,668		1,659		1,565		
Cases	14		19		16		
Model1[2]	1.00		1.34	(0.67-2.69)	1.34	(0.65-2.78)	0.431
Model2	1.00		1.49	(0.72-3.10)	1.33	(0.61-2.90)	0.483
Model3	1.00		1.46	(0.69-3.10)	1.26	(0.56-2.81)	0.597
Model4	1.00		1.96	(0.85-4.51)	2.18	(0.75-6.30)	0.162

HR, hazard ratio; CI, confidence interval; FVS, food variety score; TEI, total energy intake; BMI, body mass index.

*P<0.05, **P<0.01

Analysed by Cox proportional hazard regression model

Model 1[1] (adjusted for sex, survey year)

Model 1[2] (adjusted for survey year)

Model 2 (model 1 plus adjusted for living alone, education, smoking, drinking, habitual exercise)

Model 3 (model 2 plus adjusted for history of heart disease, cerebrovascular disease, cancer, and medical status of hypertension, hyperlipidaemia, and diabetes mellitus)
Model 4 (model 3 plus adjusted for TEI)