Research Square

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Comparing two methods for deriving dietary patterns associated with risk of metabolic syndrome among middle-aged and elderly Taiwanese adults with impaired kidney function

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Research

Keywords: Dietary pattern analysis, Metabolic syndrome, Principal component analysis, Reduced rank regression

Posted Date: March 17th, 2020

DOI: https://doi.org/10.21203/rs.3.rs-17475/v1

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Abstract

Background Dietary patterns were associated with the risk of chronic disease development and outcome-related diseases. In this study, we aimed to compare the correlation between dietary patterns and metabolic syndrome (MetS) using two methods for identifying dietary patterns.

Methods The participants (n = 25,569) aged ≥ 40 years with impaired kidney function were retrieved from Mei Jau (MJ) Health Screening database from 2008 to 2010. Dietary patterns were identified by principal component analysis (PCA) and reduced rank regression (RRR) from twenty-two food groups using PROC FACTOR and PROC PLS functions.

Results We identified two similar dietary pattern characteristics (high intakes of deep fried foods, preserved or processed foods, dipping sauce, meat, sugary drinks, organ meats, jam/honey, fried rice/flour products, instant noodles and eggs) derived by PCA and RRR. Logistic regression analysis revealed that RRR-derived dietary pattern scores were positively associated with an odds ratio (OR = 1.70, 95% CI: 1.56, 1.86) of having MetS than PCA-derived dietary pattern scores (OR = 1.38, 95% CI: 1.27, 1.51). The correlations between RRR-derived dietary pattern scores and elevated systolic and diastolic blood pressure (OR = 1.30 for both) or high density lipoprotein cholesterol in women (OR = 1.32) were statistically significant but not significant in PCA-derived dietary pattern scores.

Conclusions Our findings suggest that RRR gives better results when studying behavior related dietary patterns in association with MetS. RRR may be more preferable to provide dietary information for developing dietary guidelines among people with MetS. Further studies with prospective measurements are needed to verify whether RRR is a useful analytic tool for the association between dietary patterns and other chronic diseases.

Background

Chronic disease such as chronic kidney disease and cardiovascular disease has been elevated in the older people, and might be worsened in the presence of metabolic syndrome (MetS) [1]. MetS is defined as a cluster of metabolic disorders characterized by central obesity, dyslipidemia, elevated blood pressure and hyperglycemia [2]. Individuals with MetS were more likely to develop impaired kidney function or the later stage of chronic kidney disease [3]. Previous studies found that the prevalence of metabolic syndrome among dialytic patients in the United States and Finland was 69.3% [4] and 55.7% [5], respectively.

The risk of metabolic syndrome was correlated with dietary intake. Dietary patterns have been used to assess the association between dietary intake and chronic disease [6]. Dietary patterns may provide better information regarding the diet and disease relationship beyond the effects of dietary intake for single nutrient or food [7]. Dietary patterns in relation to MetS were investigated in previous studies. The Western dietary pattern characterized by high intakes of protein, processed foods and refined grains was positively associated with the prevalence of MetS, whereas the healthy dietary pattern with high consumption of vegetables, fruits and dairy products was negatively correlated with MetS [8, 9].

Various methods derived dietary patterns in the epidemiological studies including hypothesis-driven method (a priori), data-driven method (a posteriori) or a combination with these two methods [10]. Principal component analysis (PCA), a data-driven method, generates dietary patterns based upon inter correlations between original food intake variables. PCA tends to explain as much variation in dietary intake as possible, and is more likely to represent actual dietary habits in population [11]. However, PCA may have poor correlation with disease risk because behavior-related patterns are not necessarily predictors of the disease of interest [11]. To overcome this issue, a combination method using both a priori and a posteriori approach such as reduced rank regression (RRR) was recently proposed to derive the dietary pattern. This RRR method can explain as much variation in response to disease as possible. Therefore, to compare the dietary patterns derived from PCA with those generated using the RRR method provides more reliable correlation with the disease outcome although the foods in RRR-derived dietary pattern may not be behaviorally associated [12]. A cohort study showed that an increased RRR score was associated with a higher odds ratio of having MetS than an increased PCA pattern in a Northern German population as comparing both PCA and RRR methods [13]. However, the numbers of the participants in the previous study were relatively modest. Therefore, study in the larger population is needed.

The objectives of this study were to investigate and compare the association between dietary patterns and risk of metabolic syndrome among middle-aged and elderly Taiwanese adults with impaired kidney function using both PCA and RRR methods to derive the dietary pattern. In comparison with two different research methodologies, we expected that the dietary pattern derived from RRR method was more strongly associated with MetS among middle-aged and elderly Taiwanese adults with impaired kidney function.

Methods

Study participants

The data of the participants with impaired kidney function were retrieved from the database of the Mei Jau (MJ) private health screening centers in Taiwan from 2008 to 2010. The MJ Group has four health screening centers located in Taipei, Taoyuan, Taichung and Kaohsiung, and provides health examination periodically to its members. Participants completed a questionnaire about sociodemographic data, lifestyle and dietary habits prior to anthropometric and biochemical measurements. All participants signed the informed consent authorized by the MJ health screening centers, and the data without personal identification were used for research only. Eligible participants (*n* = 112,140) were aged ≥ 40 years and had impaired kidney function with estimated glomerular filtration rate (eGFR) < 90 mL/min/1.73 m^2 and positive urinary protein. We excluded those who had any types of cancer or virus infection (*n* = 48,169), history of any transplantation (*n* = 1,765), error values in blood analysis and anthropometric measurements (*n* = 1,266), missing data in dietary assessment and other covariates (*n* =

26,605), not complete the questionnaire (n = 212) and multiple entries (n = 8,554). Finally, 25,569 participants were included in the analysis. Taipei Medical University-Joint Institutional Review Board approved this study (TMU-JIRB N201802006).

Assessment of anthropometric and biochemical variables

Body weight and height were observed by an auto-anthropometer (Nakamura KN-5000A, Tokyo, Japan), and body mass index (BMI) was calculated as the ratio of weight (kg) to the square of height (m^2). Waist or hip circumference was measured by a flexible tape. Blood pressure was recorded twice at a 10-minute interval after resting for 5 minutes in the sitting position using a standardized sphygmomanometer. Participants were overnight fasting at least for 8 h before a blood test. Uncompensated Jaffe method with alkaline picrate kinetic test was used to measure creatinine levels and eGFR was calculated using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation. Meanwhile, urinary protein was measured by Roche Miditron M semi-automated computer-assisted urinalysis system (Combur-10 test M dipstick, Basel, Switzerland). Fasting blood glucose (FBG) and blood lipids such as triglycerides (TG), high density lipoprotein cholesterol (HDL-C), low density lipoprotein cholesterol (LDL-C) and total cholesterol (TC) were analyzed (Toshiba C8000 auto-analyzer, Tokyo, Japan) at the MJ health screening central laboratory. The coefficient of variation for all variables ranged from 1% to 3%. The definition of MetS for Asians was to have at least three or more of the followings: (1) waist circumference ≥ 90 cm in men or ≥ 80 cm in women, (2) systolic blood pressure (BP) ≥ 130 mmHg, diastolic BP ≥ 85 mmHg or on anti-hypertensive drug treatment, (3) TG ≥ 1.70 mmol/L (150 mg/dL) or on treatment for lipid abnormality, (4) HDL-C < 1.03 mmol/L (40 mg/dL) in men, < 1.30 mmol/L (50 mg/dL) in women or on treatment for lipid abnormality, (5) FBG ≥ 5.6 mmol/L (100 mg/dL) or on anti-diabetic drug treatment [14].

Assessment of dietary habits and other covariates

Dietary habits were obtained using standardized and validated self-administered semi quantitative food frequency questionnaire (SQ-FFQ). Participants reported the consumption frequency of twenty-two food and beverages items at per day or per week in the past month. The consumption frequency described by the portion size of a bowl, a glass or a serving for one-time intake was categorized into five response options from the lowest to the highest frequency as mentioned previously [15].

Demographic (age, gender, education level, income and marital status) and lifestyle variables (smoking, drinking, sleep quality and physical activity) were recorded using a self-administered questionnaire. Physical activity was assessed by self-reporting intensity (light, moderate and heavy or intense), duration (hours) and frequency (per week) in the last two weeks. For sleep quality, participants filled the questions regarding sleep quality and average daily sleep duration in the last month. Sleep quality had five response options (difficulty to fall asleep, difficulty maintaining sleep, feeling of non-restorative sleep, use of sedatives or sleeping pills and no problem to sleep well), and sleep duration had six response options (≤ 4 hours, 4-< 6 hours, 6-< 7 hours, 7-< 8 hours, 8-< 9 hours and > 9 hours). We defined sleep quality as ‘well’ if the participants had ≥ 7 hours of sleep duration with sleep quality of “no problem to sleep well” and as ‘not well’ if otherwise. For physical activity, the detailed examples of different intensities were described in the self-administered questionnaire. The metabolic equivalent task (MET) for different intensities of physical activity was determined according to previous study [16]. The MET expressed as hours per week was calculated by multiplying the corresponding MET coefficient by duration and frequency of physical activity.

Statistical analysis

The statistical analysis was performed by SAS 9.4 (SAS Institute Inc., USA). Continuous (non-normal distributed) and categorical variables were presented as median (interquartile range, IQR) and number (percentage), respectively. The characteristics of study subjects with or without MetS were compared using Mann-Whitney or chi-square test for continuous or categorical data, respectively. The multivariable linier regression [β and 95% confidence interval (CI)] and logistic regression (odds ratio (OR) and 95% CI) were used to examine the association of dietary pattern scores with the risk of MetS, components of MetS and their related biomarkers. Moreover, a subgroup analysis based on impaired kidney function categories was used for sensitivity analysis.

Dietary patterns were identified by PCA and RRR methods using PROC FACTOR and PROC PLS, respectively. For PCA method, the orthogonal varimax rotation was used and we decided to retain only one from two factors for the comparison. For RRR method, six response variables (waist circumference, TG, HDL-C, systolic BP, diastolic BP and FBG) associated with MetS were used to generate the MetS-specific dietary pattern (Fig. 1). As six response variables were included in the MetS-specific dietary pattern, six factors were generated by RRR method. However, we only retained the first factor that explained the largest percentage (2.4%) of variation in the response variables. The absolute factor loading values ≥ 0.20 for each food group were the cutoff point to derive the dietary patterns in both PCA and RRR methods. Dietary pattern scores for each individual were calculated by summing observed intake of food groups weighted by their respective factor loading. For further analysis, dietary pattern scores were divided into quartiles and two adjustment models were performed: model 1 adjusted for age and gender and model 2 adjusted for model 1 variables and education level, income, marital status, smoking, drinking, sleep quality and physical activity. A P-value < 0.05 was considered statistically significant.

Results

The characteristics of the participants with or without MetS are presented in Table 1. The prevalence of MetS was 27.3% (n = 6,976) and 63.9% (n = 4,457) of participants were male. Participants with MetS were likely to be older and have lower kidney function (eGFR 72.0 ± 12.0 vs. 75.9 ± 9.6 mL/min/1.73 m^2, P < 0.001, data not shown), less MET, elevated BMI, higher waist-to-hip ratio and worse values for each component of MetS compared with those without MetS. The prevalence of each component of MetS was 24.6% for central obesity, 29.7% for elevated TG, 14.9% for reduced HDL-C, 42.4% for elevated blood pressure and 58.0% for elevated FBG (data not shown). Participants with or without MetS statistically differed in the distribution of gender, education level, income, marital status, smoking and drinking. The prevalence of chronic diseases such as type 2 diabetes, hypertension and cardiovascular disease was higher in participants with MetS. Moreover, after adjusting for age, gender, education level, income, marital status, smoking, drinking, sleep quality and physical activity in model 2, participants with MetS had an increased risk of having eGFR < 60 mL/min/1.73 m^2 (OR = 1.64, 95% CI: 1.48, 1.82, $P < 0.001$, data not shown).

Dietary pattern analysis

Pearson's correlation coefficients between food groups and both PCA- and RRR-derived dietary patterns are shown in Fig. 2. For the purpose of comparison, we only considered the first extraction pattern in both PCA and RRR methods because the first extraction pattern explained the most variations in predictors, food groups in PCA-derived dietary pattern or response variables in RRR-derived dietary pattern. The first dietary pattern derived by PCA method was characterized by frequent intake of deep fried foods, preserved or processed foods, dipping sauce, meat, sugary drinks, organ meats, jam or honey, fried rice or flour products, instant noodles and eggs. The pattern derived by RRR method seemed to have similar characteristics (high intakes in processed foods, organ meats, dipping sauce, meat, fried rice or flour products, rice or flour products, eggs, instant noodles and deep fried foods, but low intakes in fruits and bread) with PCA-derived dietary pattern. As expected, the percentage variation explained by food groups or predictors was higher in PCA-derived dietary pattern compared with that in RRR-derived dietary pattern (13.8% vs. 6.9%). The RRR-derived dietary pattern explained 2.4% of the cumulative variation in six response variables and mainly driven by the explained variation in waist circumference (5.8%) and TG (2.4%).

Association between dietary patterns and metabolic syndrome

The association between PCA- or RRR-derived dietary pattern scores and MetS are presented in Table 2. The number of the participants with MetS increased across the increasing quartiles of RRR-derived dietary pattern scores. However, the number of the participants with MetS was greater in quartile 1 (Q1) and quartile 4 (Q4) of PCA-derived dietary pattern scores. Compared with the participants in the reference group (Q1), those in higher quartiles (Q3 and Q4) of PCA- or RRR-derived dietary pattern scores had 1.11-1.38 or 1.31-1.70 times higher odds ratios of having MetS, respectively, after adjustment for potential confounders in model 2. The association between PCA- or RRR-derived dietary pattern scores and components of MetS is illustrated in Tables 3 and 4. Participants in Q4 of PCA-derived dietary pattern scores were significantly associated with 1.64 (95% CI: 1.46, 1.85), 1.82 (95% CI: 1.58, 2.10), 1.25 (95% CI: 1.15, 1.36) and 1.19 (95% CI: 1.10, 1.29) times increased risk of having high waist circumference in men and women, elevated TG and elevated FBG, respectively, compared with those in Q1 (Table 3). Compared with the participants in Q1, those in Q4 of RRR-derived dietary pattern scores had 1.93 (95% CI: 1.71, 2.17), 2.17 (95% CI: 1.88, 2.51), 1.45 (95% CI: 1.33, 1.58) and 1.35 (95% CI: 1.24, 1.46) times higher odds ratios of having high waist circumference in men and women, elevated TG and elevated FBG, respectively

(Table 4). Moreover, the association of RRR-derived dietary pattern scores with elevated systolic or diastolic BP (OR = 1.30 for both) and lower HDL-C in women (OR = 1.32; 95% CI: 1.13, 1.54) was statistically significant. However, the correlations of PCA-derived dietary pattern scores with elevated BP and lower HDL-C in women were not significant. After adjustment for potential confounders, PCA-derived dietary pattern scores had a linear association with all anthropometric data, biochemical parameters and blood pressure except diastolic BP (Additional file 1: Table S1). As expected, RRR-derived dietary pattern scores had stronger linear association with all anthropometric data, biochemical parameters and blood pressure compared with PCA-derived dietary pattern scores. Moreover, a subgroup analysis shown a consistent results that RRR-derived dietary pattern had stronger association with risk of MetS compared with PCA-derived dietary pattern regardless of impaired kidney function categories (Additional file 2: Table S2).

Discussion

Our data supported a potential association between dietary patterns and the prevalence of MetS among middle-aged and elderly adults with impaired kidney function using two different methods to derive dietary patterns. Both PCA and RRR methods produced similar dietary patterns. The dietary pattern derived by PCA method reflected dietary behavior, and the dietary pattern identified by RRR method is more likely to have a diet-disease association. The similar dietary pattern was obtained from these two methods indicating RRR-derived dietary pattern also reflects the eating behavior of the population [13]. In addition, the RRR-derived dietary pattern was more strongly associated with response variables than the PCA-derived dietary pattern. Consistent with our findings, previous studies also observed the same results in the association between dietary patterns and cardiovascular risk factors [17, 18] or all-cause mortality [19] among middle-aged and/or elderly adults. In addition, the RRR-derived dietary pattern had a stronger correlation with markers of subclinical atherosclerosis compared with the PCA-derived dietary pattern among multi-ethnic middle-aged and elderly adults in the United States [20]. The Growth, Exercise and Nutrition Epidemiological Study in preSchoolers (GENESIS) study also revealed that the RRR-derived dietary pattern showed a significant association with childhood obesity among Greek preschool children, but the PCA-derived dietary pattern did not have any correlation [21].

The main advantage of using RRR method to establish the dietary pattern is to incorporate the prior knowledge with better explanation of response variables rather than only revealing the general eating pattern in population [18]. Therefore, in most studies, RRR-derived dietary patterns were associated with disease of interest, but not necessarily reflected real-world dietary pattern [13]. In the present study, participants with high adherence to a RRR-derived dietary pattern had higher OR of having MetS compared with those with high adherence to a PCA-derived dietary pattern. Moreover, the linear regression analysis showed β coefficients corresponding to RRR method were stronger than corresponding to PCA method. Since RRR method explicitly derives the predictors which explain the maximum of response variables, the dietary pattern identified by RRR is more likely to be closely associated with health outcomes compared with that derived by PCA [19, 22]. This argument was supported by the finding of Naja et al. [23], and the data showed that the dietary pattern derived by RRR was correlated with a higher

OR of elevated BP than that derived by PCA among Lebanese adult men. This finding could be attributed to the fact that the RRR-derived dietary pattern explained more variation in response variables than the PCA-derived dietary pattern [23].

Consistent with previous studies [13, 20, 24], we used components of MetS as response variables in RRR method. In our study, RRR-derived dietary pattern was characterized by high intakes of preserved or processed foods, deep fried foods, meat and sugary drinks but low intakes of fruits and bread, which was similar to Western or unhealthy dietary pattern found in previous studies [7, 22, 25–27]. Indeed, participants with high adherence to this dietary pattern had a positive association with the prevalence of MetS. Although the lower but significant correlations of PCA-derived dietary pattern with components of MetS compared with that of RRR-derived dietary pattern, the similar results were found regarding the association between PCA- or RRR-derived dietary pattern and components of MetS. In the present study, both PCA- and RRR-derived dietary patterns showed significant correlations with all metabolic components, but PCA-derived dietary pattern was not associated with diastolic BP.

Several possible mechanisms may explain the linear effect of unhealthy dietary pattern and the components of MetS. The food components of this dietary pattern such as preserved or processed foods, deep fried foods, meat and sugary drinks plausibly contribute to an increased risk of MetS. This dietary pattern was often accompanied by high intakes of total fat, saturated fat and simple sugar which may stimulate the production and secretion of certain pro-inflammatory cytokines and further increase systemic inflammation [20, 24, 28]. Chronic inflammation was associated with insulin resistance, dyslipidemia and elevated BP [23, 28]. Participants with higher adherence to a Western diet tended to have higher prevalence of hypertension, which may be partially correlated with high intakes of fat and protein from animal food sources in this particular dietary pattern [29, 30]. The International Study on Macro/Micronutrients and Blood Pressure (INTERMAP) study also reported a significant linear association between total protein intake and blood pressure [31]. Additionally, high consumption of red meat dietary pattern could be correlated with deposition of iron, particularly heme-iron. Subjects in the MetS group had an elevated iron overload than those in the age-matched control group [32]. Therefore, high iron contents in red meat might be related to an increased prevalence of MetS [32–35]. A recent meta-analysis study indicated that adherence to a posteriori meat/Western dietary pattern characterized by high intakes of meat, processed foods and fast foods significantly increased risk of MetS by 19% [27]. Similarly, other studies found that meat/Western dietary pattern was associated with an increased risk of MetS by 16% [25] to 28% [26].

The major strength of our study was the use of different approaches to derive dietary patterns and comparison of these two results. The similar dietary patterns obtained from PCA and RRR methods might indicate dietary behavior, which was assumed to be on the causal pathway from dietary pattern to the disease of interest. Furthermore, we had a large study population that could describe the dietary pattern in a greater scale. However, several limitations in the present study should be considered. First, the limitation of the study was the cross-sectional design, which made it difficult to have causal inference. Secondly, even though many possible confounding factors had been controlled in the analysis, we were not able to control for other factors such as family history of diabetes, hypertension and cardiovascular disease. These unmeasured factors may have introduced residual confounding. Lastly, although the questionnaire in this study had been validated for Taiwanese population, dietary intake was assessed using self-administered SQ-FFQ and under-reporting may occur.

Conclusion

In summary, both PCA and RRR methods obtain a similar dietary pattern which is associated with components of MetS among middle-aged and elderly adults with impaired kidney function. This similarity allows to assess the likeness between real eating behavior and MetS-related dietary patterns. Even though both dietary patterns have a linear association with components of MetS, RRR method shows stronger statistical correlations. Therefore, RRR method may be more suitable to evaluate dietary information for designing and realizing dietary guidelines. Further research is needed to confirm the association between RRR-derived dietary pattern and other disease outcomes in combination with prospective measurements.

Abbreviations

BMI: body mass index, BP: blood pressure, eGFR: estimated glomerular filtration rate, FBG: fasting blood glucose, HDL-C: high density lipoprotein cholesterol, LDL-C: low density lipoprotein cholesterol, MET: metabolic equivalent task, MetS: metabolic syndrome, PCA: principal component analysis, RRR: reduced rank regression, SQ-FFQ: food frequency questionnaire, TC: total cholesterol, TG: triglycerides.

Declarations

Ethics approval and consent to participate

The study was approved by the Taipei Medical University-Joint Institutional Review Board (TMU-JIRB) no. 201802006. All the participants signed a written informed consent authorized by Mei Jau Health Institute.

Consent for publication

The data provided by Mei Jau Health Institute to the researchers did not include any personal information, and all participants were adults. Not applicable.

Availability of data and materials

The data that support the findings of this study are available from Mei Jau (MJ) Health Institute, but restricted for research use only. The data are not publicly available. Data are available from the authors upon reasonable request and with permission of MJ Health Institute.

Competing interests

The authors declare no conflict of interest.

Funding

This research received no external funding.

Authors' contributions

ALK and JCJC conceived and designed the study; CYH, HAL and HHY managed and retrieved the data; ALK and AS analyzed the data and performed the statistical analysis; ALK, RP and JCJC wrote the manuscript. All authors have read and approved the final version of manuscript.

Acknowledgements

The authors thank to Mei Jau Health Institute for collecting and providing their database available for this study.

References

1. Arai H, Yamamoto A, Matsuzawa Y, Saito Y, Yamada N, Oikawa S, et al. Prevalence of the metabolic syndrome in elderly and middle-aged Japanese. J Clin Gerontol. 2010;1:42-7.
2. Alberti KGMM, Zimmet P, Shaw J. Metabolic syndrome-a new world-wide definition. A Consensus Statement from the International Diabetes Federation. Diabet Med. 2006;23:469-80.
3. Thomas G, Sehgal AR, Kashyap SR, Srinivas TR, Kirwan JP, Navaneethan SD. Metabolic syndrome and kidney disease: a systematic review and meta-analysis. Am Soc Nephrol. 2011;6:2364-73.
4. Tsangalis G, Papaconstantinou S, Kosmadakis G, Valis D, Zerefos N. Prevalence of the metabolic syndrome in hemodialysis. Int J Artif Organs. 2007;30:118-23.
5. AlShelleh S, AlAwwa I, Oweis A, AlRyalat SA, Al-Essa M, Saeed I, et al. Prevalence of metabolic syndrome in dialysis and transplant patients. Diabetes Metab Syndr Obes. 2019;12:575-79.
6. Newby P, Tucker KL. Empirically derived eating patterns using factor or cluster analysis: a review. Nutr Rev. 2004;62:177-203.
7. Hu FB. Dietary pattern analysis: a new direction in nutritional epidemiology. Curr Opin Lipidol. 2002;13:3-9.
8. Lutsey PL, Steffen LM, Stevens J. Dietary intake and the development of the metabolic syndrome: the Atherosclerosis Risk in Communities study. Circulation. 2008;117:754-61.
9. Panagiotakos DB, Pitsavos C, Skoumas Y, Stefanadis C. The association between food patterns and the metabolic syndrome using principal components analysis: The ATTICA Study. J Am Diet Assoc. 2007;107:979-87.
10. Reedy J, Wirfält E, Flood A, Mitrou PN, Krebs-Smith SM, Kipnis V, et al. Comparing 3 dietary pattern methods-cluster analysis, factor analysis, and index analysis-with colorectal cancer risk: the NIH-AARP diet and health study. Epidemiol. 2009;171:479-87.

11. Frank L, Jannasch F, Kröger J, Bedu-Addo G, Mockenhaupt F, Schulze M, et al. A dietary pattern derived by reduced rank regression is associated with type 2 diabetes in an urban Ghanaian population. Nutrients. 2015;7:5497-514.
12. Batis C, Mendez MA, Gordon-Larsen P, Sotres-Alvarez D, Adair L, Popkin B. Using both principal component analysis and reduced rank regression to study dietary patterns and diabetes in Chinese adults. Public Health Nutr. 2016;19:195-203.
13. Barbaresko J, Siegert S, Koch M, Aits I, Lieb W, Nikolaus S, et al. Comparison of two exploratory dietary patterns in association with the metabolic syndrome in a Northern German population. Br J Nutr. 2014;112:1364-72.
14. Grundy SM, Cleeman JI, Daniels SR, Donato KA, Eckel RH, Franklin BA, et al. Diagnosis and management of the metabolic syndrome: an American Heart Association/National Heart, Lung, and Blood Institute Scientific Statement. Circulation. 2005;112:2735-52.
15. Muga MA, Owili PO, Hsu CY, Rau HH, Chao JCJ. Association between dietary patterns and cardiovascular risk factors among middle-aged and elderly adults in Taiwan: a population-based study from 2003 to 2012. PLoS 2016;11:e0157745.
16. Jette M, Sidney K & Blumchen G. Metabolic equivalents (METS) in exercise testing, exercise prescription, and evaluation of functional capacity. Clin Cardiol. 1990;13:555-65.
17. Sauvageot N, Leite S, Alkerwi A, Sisanni L, Zannad F, Saverio S, et al. Association of empirically derived dietary patterns with cardiovascular risk factors: a comparison of PCA and RRR methods. PLoS 2016;11:e0161298.
18. Centritto F, Iacoviello L, di Giuseppe R, De Curtis A, Costanzo S, Zito F, et al. Dietary patterns, cardiovascular risk factors and C-reactive protein in a healthy Italian population. Nutr Metab Cardiovasc Dis. 2009;19:697-706.
19. Hoffmann K, Boeing H, Boffetta P, Nagel G, Orfanos P, Ferrari P, et al. Comparison of two statistical approaches to predict all-cause mortality by dietary patterns in German elderly subjects. Br J Nutr. 2005;93:709-16.
20. Nettleton JA, Steffen LM, Schulze MB, Jenny NS, Barr RG, Bertoni AG, et al. Associations between markers of subclinical atherosclerosis and dietary patterns derived by principal components analysis and reduced rank regression in the Multi-Ethnic Study of Atherosclerosis (MESA). Am J Clin Nutr. 2007;85:1615-25.
21. Manios Y, Kourlaba G, Grammatikaki E, Androutsos O, Ioannou E, Roma-Giannikou E. Comparison of two methods for identifying dietary patterns associated with obesity in preschool children: the GENESIS study. Eur J Clin Nutr. 2010;64:1407-14.
22. Wolters M, Joslowski G, Plachta-Danielzik S, Standl M, Müller M, Ahrens W, et al. Dietary patterns in primary school are of prospective relevance for the development of body composition in two German pediatric p Nutrients. 2018;10:1442.
23. Naja F, Itani L, Hwalla N, Sibai AM, Kharroubi SA. Identification of dietary patterns associated with elevated blood pressure among Lebanese men: a comparison of principal component analysis with

reduced rank regression and partial least square methods. PLoS 2019;14:e0220942.

24. Vujkovic M, Steegers EA, Looman CW, Ocké MC, van der Spek PJ, Steegers-Theunissen RP. The maternal Mediterranean dietary pattern is associated with a reduced risk of spina bifida in the offspring. Int J Gynaecol Obstet. 2009;116:408-15.
25. Shab-Bidar S, Golzarand M, Hajimohammadi M, Mansouri S. A posteriori dietary patterns and metabolic syndrome in adults: a systematic review and meta-analysis of observational studies. Public Health Nutr. 2018;21:1681-92.
26. Rodríguez-Monforte M, Sánchez E, Barrio F, Costa B, Flores-Mateo G. Metabolic syndrome and dietary patterns: a systematic review and meta-analysis of observational studies. Eur J Clin Nutr. 2017;56:925-47.
27. Fabiani R, Naldini G, Chiavarini MJN. Dietary patterns and metabolic syndrome in adult subjects: a systematic review and meta-a Nutrients. 2019;11:2056.
28. Deng FE, Shivappa N, Tang Y, Mann JR, Hebert JR. Association between diet-related inflammation, all-cause, all-cancer, and cardiovascular disease mortality, with special focus on prediabetics: findings from NHANES III. Eur J Clin Nutr. 2017;56:1085-93.
29. Nikniaz L, Nikniaz Z, Sadeghi-Bazargani H, Abdollahi HM, Farhangi MA. Association between major dietary patterns and metabolic syndrome components: a population-based study from north-west of Iran. Int J Diabetes Dev C 2019;39:721-9.
30. Sabour H, Norouzi-Javidan A, Soltani Z, Mousavifar SA, Latifi S, Emami-Razavi SH, et al. The correlation between dietary fat intake and blood pressure among people with spinal cord injury. Iran J Neurol. 2016;15:121-7.
31. Elliott P, Stamler J, Dyer AR, Appel L, Dennis B, Kesteloot H, et al. Association between protein intake and blood pressure: the INTERMAP Study. JAMA Intern Med. 2006;166:79-87.
32. Bozzini C, Girelli D, Olivieri O, Martinelli N, Bassi A, De Matteis G, et al. Prevalence of body iron excess in the metabolic syndrome. Diabetes Care. 2005;28:2061-3.
33. Woo HD, Shin A, Kim JJPO. Dietary patterns of Korean adults and the prevalence of metabolic syndrome: a cross-sectional study. PLoS 2014;9:e111593.
34. Sun L, Franco OH, Hu FB, Cai L, Yu Z, Li H, et al. Ferritin concentrations, metabolic syndrome, and type 2 diabetes in middle-aged and elderly C J Clin Endocrinol Metab. 2008;93:4690-6.
35. Azadbakht L, Esmaillzadeh A. Red meat intake is associated with metabolic syndrome and the plasma C-reactive protein concentration in women. Nutr J. 2008;139:335-9.

Tables

Table 1 Characteristics of the participants by MetS status (n = 25,569) [a]

	All participants (n = 25,569)	Participants without MetS (n = 18,593)	Participants with MetS (n = 6,976)	P [b]
Age (years)	51.0 (14.0)	49.0 (13.0)	55.0 (16.0)	< 0.001
Sex, n (%)				< 0.001
Male	14311 (56.0)	9854 (53.0)	4457 (63.9)	
Female	11258 (44.0)	8739 (47.0)	2519 (36.1)	
Education level, n (%)				< 0.001
Below university	16733 (65.4)	11748 (63.2)	4985 (71.5)	
University or above	8836 (34.6)	6845 (36.8)	1991 (28.5)	
Income (NTD/year), n (%)				< 0.001
< 800,000	11620 (45.4)	8083 (43.5)	3537 (50.7)	
810,000-1.6 million	9407 (36.8)	7057 (37.9)	2350 (33.7)	
≥ 1.61 million	4542 (17.8)	3453 (18.6)	1089 (15.6)	
Marital status, n (%)				< 0.001
No	4050 (15.8)	2822 (15.2)	1228 (17.6)	
Yes	21519 (84.2)	15771 (84.8)	5748 (82.4)	
Smoking, n (%)				< 0.001
No	21243 (83.1)	15660 (84.2)	5583 (80.0)	
Yes	4326 (16.9)	2933 (15.8)	1393 (20.0)	
Drinking alcohol, n (%)				< 0.001
No	21175 (82.8)	15586 (83.8)	5589 (80.1)	
Yes	4394 (17.2)	3007 (16.2)	1387 (19.9)	
Sleep quality, n (%)				0.58
Not well	22413 (87.7)	16311 (87.7)	6102 (87.5)	
Well	3156 (12.3)	2282 (12.3)	874 (12.5)	
MET (hours per week)	5.8 (11.7)	5.9 (11.7)	5.8 (11.7)	0.012
BMI (kg/m^2)	23.8 (4.2)	23.0 (3.6)	26.6 (3.9)	< 0.001
Waist circumference (cm)	80.0 (13.0)	77.0 (12.0)	88.0 (11.0)	< 0.001
Waist-to-hip ratio	0.8 (0.1)	0.8 (0.1)	0.9 (0.1)	< 0.001
Blood pressure (mmHg)				
Systolic	121.0 (24.0)	117.0 (21.0)	134.0 (20.0)	< 0.001
Diastolic	73.0 (16.0)	71.0 (15.0)	80.0 (15.0)	< 0.001
Biomarkers (mmol/L)				
TG	1.2 (0.9)	1.0 (0.7)	1.9 (1.1)	< 0.001
HDL-C	1.4 (0.5)	1.5 (0.5)	1.2 (0.4)	< 0.001
LDL-C	3.1 (1.0)	3.1 (1.0)	3.0 (1.1)	< 0.001
TC	5.2 (1.2)	5.2 (1.1)	5.3 (1.2)	< 0.001
FBG	5.6 (0.7)	5.5 (0.6)	6.0 (0.9)	< 0.001
Creatinine (μmol/L)	91.1 (23.0)	89.3 (23.0)	94.6 (23.9)	< 0.001
eGFR (mL/min/1.73 m^2)	76.4 (13.5)	77.4 (12.7)	73.4 (15.6)	< 0.001

Urinary protein, *n* (%)				< 0.001
+1	24464 (95.7)	18133 (97.5)	6331 (90.8)	
+2	636 (2.5)	300 (1.6)	336 (4.8)	
≥ +3	469 (1.8)	160 (0.9)	309 (4.4)	
Prevalence of chronic diseases, *n* (%)				
Type 2 diabetes	2449 (9.6)	832 (4.5)	1617 (23.2)	< 0.001
Hypertension	7450 (29.1)	3220 (17.3)	4230 (60.6)	< 0.001
Cardiovascular disease	1519 (5.9)	749 (4.0)	770 (11.0)	< 0.001

MetS metabolic syndrome, NTD New Taiwan dollar, MET metabolic equivalent task, BMI body mass index, TG triglycerides, HDL-C high density lipoprotein cholesterol, LDL-C low density lipoprotein cholesterol, TC total cholesterol, FBG fasting blood glucose, eGFR estimated glomerular filtration rate.

[a] Continuous variables are presented as median (interquartile range). Categorical variables are presented as absolute frequency (percentage).

[b] The *P*-values were tested using Mann-Whitney test for continuous variables and chi-square test for categorical variables.

Table 2 Association of PCA- or RRR-derived dietary pattern with MetS across quartiles of dietary pattern scores [a]

	Quartiles (Q) of dietary pattern scores (*n* = 25,569)			
	Q1	Q2	Q3	Q4
	OR	OR (95% CI)	OR (95% CI)	OR (95% CI)
PCA-derived dietary pattern				
Total (*n*)	6418	6365	6392	6394
MetS (*n*)	1762	1652	1665	1897
Model 1	1	1.02 (0.94, 1.11)	1.11 (1.02, 1.20)	1.40 (1.29, 1.53)
Model 2	1	1.03 (0.95, 1.12)	1.11 (1.02, 1.21)	1.38 (1.27, 1.51)
RRR-derived dietary pattern				
Total (*n*)	6403	6332	6468	6366
MetS (*n*)	1495	1582	1793	2106
Model 1	1	1.11 (1.02, 1.21)	1.33 (1.22, 1.44)	1.78 (1.64, 1.93)
Model 2	1	1.09 (1.00, 1.19)	1.31 (1.20, 1.43)	1.70 (1.56, 1.86)

PCA principal component analysis, RRR reduced rank regression, MetS metabolic syndrome.

[a] Data are presented as odds ratios (ORs) and 95% confidence intervals (95% CIs). Model 1: adjusted for age and gender. Model 2: adjusted for age, gender, education level, income, marital status, smoking, drinking, sleep quality and physical activity.

Table 3 Association of PCA-derived dietary pattern with components of MetS across quartiles of dietary pattern scores [a]

	Quartiles (Q) of PCA-derived dietary pattern scores (n = 25,569)			
	Q1 (n = 6,418)	Q2 (n = 6,365)	Q3 (n = 6,392)	Q4 (n = 6,394)
	OR	OR (95% CI)	OR (95% CI)	OR (95% CI)
High waist circumference in men				
Model 1	1	1.07 (0.95, 1.20)	1.29 (1.15, 1.45)	1.72 (1.54, 1.93)
Model 2	1	1.06 (0.94, 1.20)	1.27 (1.12, 1.43)	1.64 (1.46, 1.85)
High waist circumference in women				
Model 1	1	1.07 (0.95, 1.22)	1.26 (1.11, 1.44)	1.78 (1.55, 2.04)
Model 2	1	1.08 (0.94, 1.22)	1.28 (1.12, 1.46)	1.82 (1.58, 2.10)
Elevated systolic BP				
Model 1	1	0.97 (0.90, 1.05)	0.99 (0.91, 1.07)	1.03 (0.95, 1.12)
Model 2	1	0.97 (0.89, 1.05)	0.98 (0.91, 1.06)	1.04 (0.96, 1.13)
Elevated diastolic BP				
Model 1	1	0.92 (0.84, 1.01)	0.95 (0.86, 1.04)	1.01 (0.92, 1.11)
Model 2	1	0.93 (0.85, 1.02)	0.95 (0.87, 1.05)	1.02 (0.93, 1.13)
Elevated TG				
Model 1	1	1.02 (0.94, 1.11)	1.12 (1.03, 1.21)	1.3 (1.20, 1.41)
Model 2	1	1.01 (0.93, 1.10)	1.10 (1.01, 1.19)	1.25 (1.15, 1.36)
Low HDL-C in men				
Model 1	1	0.99 (0.86, 1.15)	1.03 (0.89, 1.19)	1.06 (0.92, 1.22)
Model 2	1	0.96 (0.82, 1.12)	1.02 (0.88, 1.19)	1.03 (0.89, 1.19)
Low HDL-C in women				
Model 1	1	1.02 (0.90, 1.16)	0.91 (0.79, 1.05)	1.11 (0.96, 1.29)
Model 2	1	1.05 (0.92, 1.20)	0.90 (0.78, 1.05)	1.15 (0.98, 1.34)
Elevated FBG				
Model 1	1	1.06 (0.99, 1.14)	1.02 (0.95, 1.10)	1.21 (1.12, 1.30)
Model 2	1	1.06 (0.98, 1.14)	1.01 (0.93, 1.09)	1.19 (1.10, 1.29)

PCA principal component analysis, MetS metabolic syndrome, BP blood pressure, TG triglycerides, HDL-C high density lipoprotein cholesterol, FBG fasting blood glucose.

[a] The odds ratios across quartiles of dietary pattern scores were compared with the reference group (Q1). Components of metabolic syndrome were defined as follows: high waist circumference (≥ 90 cm in men or ≥ 80 cm in women), elevated systolic BP (≥ 130 mmHg), elevated diastolic BP (≥ 85 mmHg), elevated TG (≥ 1.70 mmol/L), low HDL-C (< 1.03 mmol/L in men or < 1.30 mmol/L in women) and elevated FBG (≥ 5.60 mmol/L). Model 1: adjusted for age and gender (except waist circumference and HDL-C). Model 2: adjusted for age, gender (except waist circumference and HDL-C),education level, income, marital status, smoking, drinking, sleep quality and physical activity.

Table 4 Association of RRR-derived dietary pattern with components of MetS across quartiles of dietary pattern scores [a]

	Quartiles (Q) of RRR-derived dietary pattern scores (n = 25,569)			
	Q1 (n = 6,403)	Q2 (n = 6,332)	Q3 (n = 6,468)	Q4 (n = 6,366)
	OR	OR (95% CI)	OR (95% CI)	OR (95% CI)
High waist circumference in men				
Model 1	1	1.17 (1.03, 1.32)	1.27 (1.13, 1.43)	2.00 (1.78, 2.24)
Model 2	1	1.18 (1.04, 1.35)	1.28 (1.13, 1.45)	1.93 (1.71, 2.17)
High waist circumference in women				
Model 1	1	1.09 (0.96, 1.24)	1.68 (1.48, 1.90)	2.20 (1.92, 2.53)
Model 2	1	1.06 (0.93, 1.21)	1.65 (1.45, 1.88)	2.17 (1.88, 2.51)
Elevated systolic BP				
Model 1	1	1.03 (0.96, 1.12)	1.14 (1.05, 1.23)	1.32 (1.22, 1.43)
Model 2	1	1.03 (0.95, 1.12)	1.13 (1.04, 1.22)	1.30 (1.20, 1.41)
Elevated diastolic BP				
Model 1	1	1.04 (0.95, 1.14)	1.10 (1.01, 1.21)	1.32 (1.21, 1.45)
Model 2	1	1.03 (0.94, 1.14)	1.10 (1.00, 1.21)	1.30 (1.18, 1.43)
Elevated TG				
Model 1	1	1.09 (1.01, 1.18)	1.28 (1.18, 1.38)	1.56 (1.44, 1.69)
Model 2	1	1.06 (0.97, 1.15)	1.23 (1.13, 1.34)	1.45 (1.33, 1.58)
Low HDL-C in men				
Model 1	1	0.96 (0.83, 1.11)	1.00 (0.87, 1.16)	1.06 (0.92, 1.21)
Model 2	1	0.94 (0.81, 1.10)	0.91 (0.85, 1.15)	1.04 (0.89, 1.20)
Low HDL-C in women				
Model 1	1	1.14 (0.99, 1.29)	1.14 (0.99, 1.30)	1.31 (1.13, 1.52)
Model 2	1	1.11 (0.97, 1.27)	1.13 (0.98, 1.30)	1.32 (1.13, 1.54)
Elevated FBG				
Model 1	1	1.12 (1.04, 1.20)	1.19 (1.10, 1.28)	1.37 (1.27, 1.48)
Model 2	1	1.12 (1.04, 1.21)	1.17 (1.09, 1.26)	1.35 (1.24, 1.46)

RRR reduced rank regression, MetS metabolic syndrome, BP blood pressure, TG triglycerides, HDL-C high density lipoprotein cholesterol, FBG fasting blood glucose.

[a] The odds ratios across quartiles of dietary pattern scores were compared with the reference group (Q1). Components of metabolic syndrome were defined as follows: high waist circumference (≥ 90 cm in men or ≥ 80 cm in women), elevated systolic BP (≥ 130 mmHg), elevated diastolic BP (≥ 85 mmHg), elevated TG (≥ 1.70 mmol/L), low HDL-C (< 1.03 mmol/L in men or < 1.30 mmol/L in women) and elevated FBG (≥ 5.60 mmol/L). Model 1: adjusted for age and gender (except waist circumference and HDL-C). Model 2: adjusted for age, gender (except waist circumference and HDL-C),education level, income, marital status, smoking, drinking, sleep quality and physical activity.

Figures

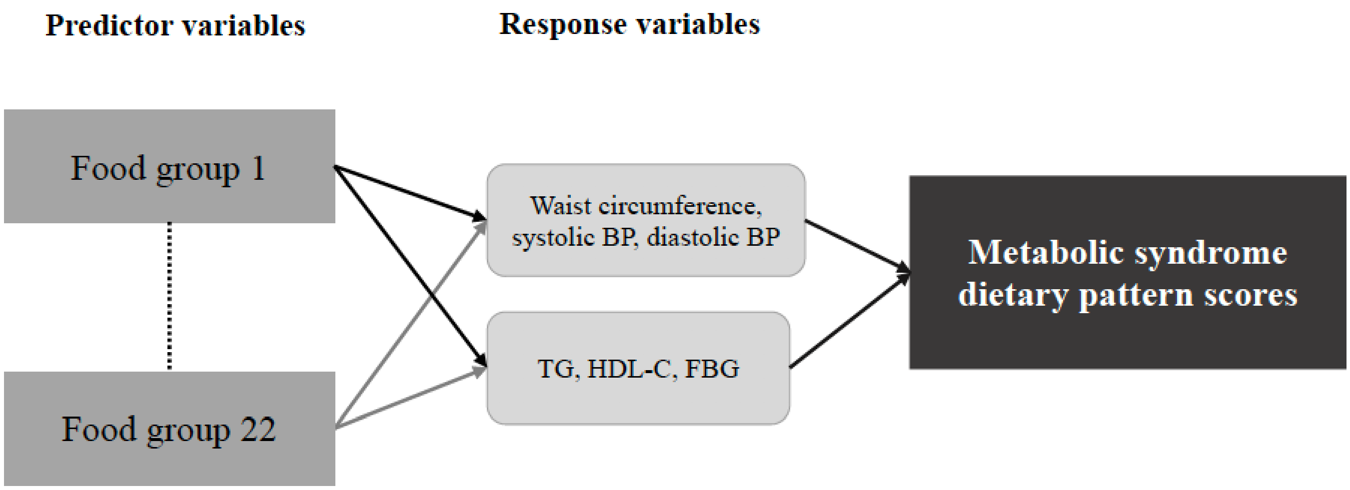

Figure 1

Scheme of metabolic syndrome dietary pattern scores derived by reduced rank regression. BP blood pressure, TG triglycerides, HDL-C high density lipoprotein cholesterol, FBG fasting blood glucose.

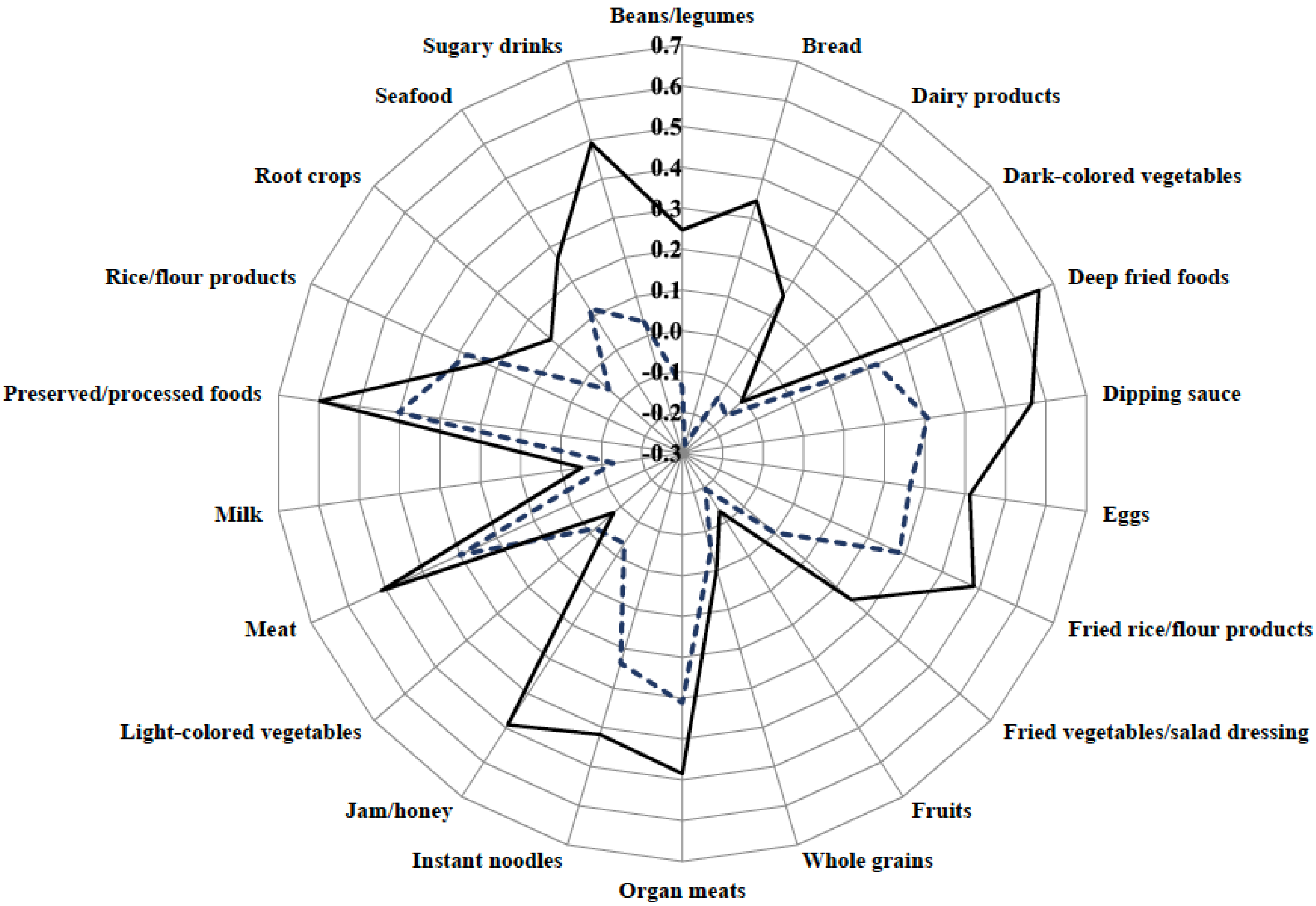

Figure 2

Radar chart of Pearson's correlation coefficients between food groups and two dietary patterns. The dietary patterns were derived by principal component analysis (—) and reduced rank regression (—).

Supplementary Files

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- Additionalfile2TableS2.docx
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