Nutrition 59 (2019) 108–115

Contents lists available at ScienceDirect

Nutrition

journal homepage: www.nutritionjrnl.com

Applied nutritional investigation

Meal-specific dietary patterns and their contribution to overall dietary patterns in the Japanese context: Findings from the 2012 National Health and Nutrition Survey, Japan

Kentaro Murakami Ph.D. [a,*], M. Barbara E. Livingstone Ph.D. [b], Satoshi Sasaki M.D., Ph.D. [c]

[a] *Interfaculty Initiative in Information Studies, University of Tokyo, Tokyo, Japan*
[b] *Northern Ireland Centre for Food and Health, Ulster University, Coleraine, United Kingdom*
[c] *Department of Social and Preventive Epidemiology, School of Public Health, University of Tokyo, Tokyo, Japan*

ARTICLE INFO

Article History:
Received 13 February 2018
Received in revised form 25 June 2018
Accepted 19 July 2018

Keywords:
Breakfast
Lunch
Dinner
Dietary pattern
Nutrient intake
Japan

ABSTRACT

Objective: Most studies on dietary patterns have focused on the total daily intake of foods without differentiating intake at specific eating occasions. The aim of this study was to identify meal-specific (breakfast, lunch, and dinner) dietary patterns and examine their contribution to overall dietary patterns, using data from the 2012 National Health and Nutrition Survey, Japan.
Methods: Dietary intake was assessed with a 1-d weighed dietary record for 15 618 Japanese adults ≥20 y of age.
Results: Using principal component analysis based on daily consumption of 22 food groups, four overall dietary patterns were identified: vegetable/fruit/fish/pulse, bread/dairy, meat/fat, and noodle/seasoning patterns. Four meal-specific dietary patterns, which were independently identified in the same manner based on consumption at each eating occasion, were as follows:
- Breakfast: rice/vegetable/fish/pulse/seasoning, bread/dairy/fruit/sugar, meat/egg/fat, and tea/coffee patterns;
- Lunch: bread/dairy, noodle/seasoning, meat/fat, and vegetable/pulse/potato/sugar patterns; and
- Dinner: meat/vegetable/seasoning, noodle/alcoholic beverage, fish/sugar/alcoholic beverage, and other grains/fat patterns.

The major contributors to interindividual variation in the vegetable/fruit/fish/pulse overall dietary pattern included the rice/vegetable/fish/pulse/seasoning breakfast (28%), the vegetable/pulse/potato/sugar lunch (15%), and the fish/sugar/alcoholic beverage dinner (19%). For other overall dietary patterns, the major contributors were generally patterns with similar characteristics, namely the bread/dairy/fruit/sugar breakfast (33%) and the bread/dairy lunch (24%) for the bread/dairy overall dietary pattern; the meat/egg/fat breakfast (13%), the meat/fat lunch (33%), the meat/vegetable/seasoning dinner (28%), and the other grains/fat dinner (11%) for the meat/fat overall dietary pattern; and the noodle/seasoning lunch (51%) and the noodle/alcoholic beverage dinner (25%) for the noodle/seasoning overall dietary pattern.
Conclusion: Major meal-specific dietary patterns were identified in the Japanese context, which differentially contributed to major overall dietary patterns.

Introduction

Japanese dietary habits have long attracted interest from other countries, primarily because of their possible contribution to a low prevalence of coronary artery disease and long life expectancy [1,2]. Typical characteristics of the Japanese diet include high consumption of refined grains, soybean products, seaweeds, vegetables, fish, and green tea and low consumption of whole grains, nuts, processed meat, and soft drinks [3,4]. Nevertheless, studying single nutrients or foods in isolation may be inappropriate because such a study cannot inherently take into account the complicated

This work was supported in part by the Health and Labour Sciences Research Grant (no. H29-jyunkankitou-ippan-006) from the Ministry of Health, Labour and Welfare, Japan. The Ministry of Health, Labour and Welfare had no role in the design, analysis or writing of this article. KM designed the study, analyzed and interpreted the data, and wrote the manuscript. MBEL and SS helped in the writing of the manuscript. All authors read and approved the final manuscript. The authors have no conflicts of interest to declare.

* Corresponding author. Tel: +81 3 5841 7872; Fax: +81 3 5841 7873.
E-mail address: Kenmrkm@m.u-tokyo.ac.jp (K. Murakami).

https://doi.org/10.1016/j.nut.2018.07.110
0899-9007/

interactions and cumulative effects that occur among individual dietary components [5]. More recently, focus has shifted to overall diet and dietary patterns [6]. Dietary patterns are generally assessed using two main approaches. The first is the a priori approach, which relies on diet quality scores or indices based on dietary guidelines. However, research based on this approach in Japan has been hindered by the lack of an appropriate tool for assessing the Japanese diet [7]. The second is the a posteriori approach, which uses statistical techniques (e.g., principal component analysis). This approach has been applied to dietary data from representative population groups in a number of countries [8–19].

Despite the finding that people generally eat specific combinations of foods at mealtimes [20–22], most previous studies on dietary patterns have focused on the total daily intake of food with no differentiation of eating occasions. The study of meal-specific dietary patterns in addition to overall dietary patterns may be more insightful, given synergies and interactions during digestion and metabolism [23] and the potential importance of time of eating [24]. Moreover, an understanding of the patterns of food combinations at meals and their association with overall dietary patterns may be used to inform the development of culturally appropriate and meaningful public health policies and recommendations for healthy eating. In addition, because these patterns reflect how people actually eat, meal-specific dietary advice would likely be more practical. To our knowledge, only two studies (from Brazil [25] and China [26]) have identified meal-specific dietary patterns, but their associations with overall dietary patterns were not investigated. Because all foods are not always consumed proportionately for each meal in free-living settings, empirical evidence on the associations between meal-specific dietary patterns and overall dietary patterns is needed.

Therefore, the aim of the present cross-sectional study was to identify meal-specific dietary patterns to examine their contribution to overall dietary patterns using data from the 2012 National Health and Nutrition Survey, Japan (NHNSJ).

Materials and methods

Data source and analytical sample

The NHNSJ is an annual, nationwide, nutrition survey conducted since 1945 through local public health centers under the supervision of Japan's Ministry of Health, Labour and Welfare on the basis of the Health Promotion Law. The present cross-sectional study used data from the 2012 NHNSJ, with permission of the Ministry. The 2012 NHNSJ has been detailed elsewhere [4]. In brief, based on the population census, 475 of ~1 million census units were randomly sampled as survey areas. All non-institutionalized Japanese people ≥1 y of age living in survey areas (approximately N = 61 000) were asked to participate, with a total of 12 750 of 24 555 eligible households (52%) taking part. The survey was performed from October 25 to December 7, 2012.

The number of participants in the 2012 NHNSJ ≥20 y of age was 30 639, of whom 3913, 8593, and 14 44 had missing information on dietary intake, anthropometric measurements, and lifestyle variables, respectively (some with more than one missing variable). After exclusion of 246 lactating and 136 pregnant women, the final sample for the present analysis with complete information on the variables of interest was 15 618 male participants and non-lactating and non-pregnant female participants ≥20 y of age. The participants (N = 15 618) were somewhat different from those excluded from the analysis (n = 1032–15 021 depending on variables); those excluded were more likely to be male, younger, current smokers, physically inactive, and have lower mean energy intake (EI), body mass index (BMI), and waist circumference (WC; $P < 0.0001$ for all).

This survey was performed in accordance with guidelines in the Declaration of Helsinki. Verbal informed consent was provided by all individual participants. In accordance with the Statistics Act, the Ministry of Health, Labour, and Welfare anonymized individual-level data collected from the NHNSJ, and provided access to the data sets to the first author of this study. Consistent with ethical guidelines developed for epidemiologic research by the Ministry of Education, Culture, Sports, Science and Technology and the Ministry of Health, Labour and Welfare, this analysis did not require institutional review board approval.

Dietary assessment

Data on dietary intake were obtained using a 1-d weighted household dietary record, as detailed previously [4,22,27,28]. In brief, the main record keeper (in most cases the main household cook) was provided written and verbal instructions at home by trained fieldworkers, who were registered dietitians, on how to conduct the dietary record and its purpose. The main record keeper was required to record and weigh all foods and beverages (excluding drinking water) consumed by household members on the recording day, such that the dietary record comprised data for all household members. When foods from the same dish were shared among household members, the record keeper recorded approximate proportions of the food eaten by each member. When weighing could not be conducted, such as when eating out, the record keeper recorded as much information as possible, including consumed portion sizes and details of leftovers. To increase participation, the recording day could be freely selected by households, with Sundays, national holidays, and days with special events (e.g., wedding party or funeral) excluded. The trained fieldworker collected the diary within several days of completion—often the next weekday—and checked the completeness of recording. Additional information was recorded where necessary.

Using an NHNSJ study manual, trained fieldworkers converted the estimates of portion size measured using household measures into weights and coded all individual food items following the Standard Tables of Food Composition in Japan [29]. After collection, the dietary records were rechecked at the local center by trained fieldworkers who input the data using software specifically developed for the NHNSJ. These input data were compiled by trained investigators at the central office to create the overall dietary data set.

Estimated daily intake of foods, energy, and selected nutrients for individuals was calculated from the household food consumption record, and approximate proportions consumed by each household member were calculated for shared dishes or foods using the Standard Tables of Food Composition in Japan [29]. Nutrient intake values were energy adjusted with the density method (i.e., percentage of energy for energy-providing nutrients; amount per 4184 kJ of energy for foods and other nutrients).

Regarding the utility of this household dietary record for estimating dietary intake for individuals [30], dietary intake of young women (~20 y of age) estimated using this 1-d household dietary record by mothers (mean age, 49 y) were compared with that with a separate 1-d weighted dietary record by the young women themselves (n = 32). Mean differences in intake by the two methods for energy, protein, fat, and carbohydrate were 6.2%, 5.7%, 6.7%, and 6.3%, yielding Pearson correlation coefficients of 0.90, 0.89, 0.91, and 0.90, respectively. In addition, previous analyses based on the NHNSJ yielded mean ratios of EI to estimated energy requirement of 1.04 for children [31] and 0.98 for adults [32].

Identification of overall dietary patterns

Before dietary pattern analysis, each unique food item consumed by the participants (>1600 individual item codes) was recoded into 22 food groups (Supplementary Table 1). Food grouping was based on the similarity of nutrient profiles or culinary usage of the foods, mainly according to the Standard Tables of Food Composition in Japan [29] and the classification of food groups used in the NHNSJ [4].

To derive overall dietary patterns, principal component analysis was performed based on intake of the 22 food groups expressed as amount per day, using the PROC FACTOR procedure in SAS version 9.4 (SAS Institute Inc, Cary, NC, USA). The derived factors are linear combinations of the included variables that explain as much as possible of the variation in the original variables. The factors were rotated by orthogonal transformation (varimax rotation) to provide a simpler structure having greater interpretability. The number of retained factors was determined by evaluating the scree plot and the combination of food groups for the identified factors [33]. The proportion of variance explained by the respective factors was determined by dividing the sum of squares of the respective factor loadings by the number of variables (i.e., food groups). Factor loadings are correlation coefficients between individual food groups and dietary patterns. Food groups having absolute factor loadings of ≥0.30 were determined to have contributed to a factor [14,16,17,34]. Dietary patterns were described based on the food groups having the highest positive loadings per dietary pattern, and factor scores for each participant and for each dietary pattern were obtained by adding the standardized intake of each of the 22 food groups weighted by the factor loading for each pattern. These scores represent standardized variables with a mean of 0 and a standard deviation of 1.

Identification of meal-specific (breakfast, lunch, and dinner) dietary patterns

The food diary sheet was derived from a typical Japanese eating pattern, comprising breakfast, lunch, dinner, and snacks. These eating events were described in the diary (information on time of eating occasions was not collected). Meal types in the analysis were based on this classification. Using the same procedure to derive overall dietary patterns, meal-specific dietary patterns, namely breakfast, lunch, and dinner patterns, were independently derived based on the amount of 22 food groups consumed at each eating occasion. Because a large proportion of

Table 1
Factor loadings for overall dietary patterns (N= 15 618): The 2012 National Health and Nutrition Survey, Japan*

	Overall intake (g/d)		Factor 1 Vegetable, fruit, fish, and pulse pattern†	Factor 2 Bread and dairy pattern†	Factor 3 Meat and fat pattern†	Factor 4 Noodle and seasoning pattern†
	Mean	SD				
Rice	341.3	184.3	0.26	**−0.56**	0.16	**−0.42**
Bread	31.0	43.2	−0.15	**0.65**	0.17	−0.02
Noodles	64.6	106.7	−0.16	0.01	−0.02	**0.80**
Other grains	15.5	35.1	0.01	0.08	**0.33**	0.03
Potatoes	57.7	69.5	**0.40**	−0.02	0.13	−0.13
Sugar	8.5	10.4	**0.33**	**0.39**	0.15	−0.04
Pulses	67.0	79.1	**0.43**	−0.10	−0.14	0.08
Nuts	2.6	9.6	0.21	0.13	0.00	0.01
Vegetables	313.7	178.7	**0.68**	−0.02	0.13	0.06
Fruits	116.5	137.0	**0.48**	**0.39**	−0.21	0.02
Fish	80.9	75.2	**0.46**	−0.16	−0.18	−0.02
Meat	78.0	68.3	0.00	−0.14	**0.69**	0.01
Eggs	34.5	33.8	0.16	−0.10	**0.32**	−0.11
Dairy products	98.8	126.2	0.18	**0.50**	−0.07	−0.02
Fats and oils	9.5	9.1	−0.04	0.17	**0.72**	−0.03
Confectioneries	30.0	49.4	0.02	0.26	−0.03	−0.04
Fruit juice	5.9	38.7	−0.02	0.10	0.12	0.10
Vegetable juice	9.4	47.3	−0.02	0.13	0.03	0.02
Alcoholic beverages	121.4	274.4	0.06	**−0.32**	0.20	0.22
Soft drinks	45.8	125.7	−0.07	−0.03	0.23	0.08
Tea and coffee	533.8	405.8	0.22	0.19	0.07	−0.15
Seasonings	87.8	85.8	0.28	−0.12	0.17	**0.67**
Variability explained (%)	—	—	7.8	7.6	7.2	6.4

*Overall dietary patterns were identified using principal component analysis based on overall intakes of the 22 food groups (g/d). Absolute factor loading values ≥0.30 are presented in **bold**.
†Dietary patterns were named according to the food groups with the highest positive factor loadings per dietary pattern.

participants went without snacking (35%) compared with those who went without breakfast (4.5%), lunch (1.8%), or dinner (0.4%), snack patterns were not investigated in this study.

Assessment of other variables

Approximately 90% of the participants underwent anthropometric measurements by trained fieldworkers using standard methods. Body height (to the closest 0.1 cm) and weight (to the closest 0.1 kg) were measured with the participants barefoot and wearing light clothes. WC was measured at the level of the umbilicus (to the closest 0.5 cm) at end respiration with the participant standing erect, the arms at the side, and the feet held together. In a few cases, height, weight, and WC were measured at home by other household members or were self-reported. BMI was calculated as weight (kg) divided by height (m) squared (kg/m^2). Systolic and diastolic blood pressure (SBD and DBP, respectively) was measured by trained fieldworkers in the right arm with a standard mercury sphygmomanometer after the participant had been sitting quietly for at least 5 min. This measurement was followed by a second measurement 1 to 2 min later, and the mean of the two was used. Blood samples collected while not fasting were analyzed for serum total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), and glycated hemoglobin (HbA1c) concentrations by a commercial laboratory [4,35,36].

Following the NHNSJ report [4], six age categories were defined: 20 to 29, 30 to 39, 40 to 49, 50 to 59, 60 to 69, or ≥70 y. Information also was collected on smoking status (never, past, or current), and habitual exercise (no or yes). Dietary reporting status was evaluated based on the ratio of reported EI to basal metabolic rate (BMR) (Goldberg's cutoff) [37], as described elsewhere [27]. Briefly, BMR was estimated using sex-specific equations for Japanese adults based on age, body height, and weight [38,39]. Participants were evaluated as plausible, under-, or over-reporters of EI by whether their ratio was within, below, or >95% confidence limits for agreement between EI:BMR and physical activity level for a sedentary lifestyle (i.e., 1.55) [37]. From this, underreporters, plausible reporters, and overreporters were defined as having an EI:BMR of <0.87, 0.87 to 2.75, and >2.75, respectively.

Statistical analysis

All statistical analyses were performed using SAS statistical software version 9.4 (SAS Institute Inc). Differences in overall dietary pattern scores across categories of basic characteristics were examined based on the independent *t* test or analysis of variance followed by a Bonferroni post hoc test. Associations between overall dietary pattern scores and overall intake of energy and selected nutrients were examined using Pearson correlation coefficients. Associations of overall dietary pattern scores with metabolic risk factors were investigated by linear regression analyses, with adjustment for potential confounding factors including sex, age, smoking status, habitual exercise, dietary reporting status, and total energy intake (as well as BMI for analyses on SBP and DBP; TC, HDL-C, LDL-C, and HbA1c). Contributions of meal-specific dietary pattern scores to interindividual variation in overall dietary pattern scores were examined using linear regression analyses. All reported *P*-values are two-tailed, and $P < 0.05$ was considered statistically significant, except for the case of correlation coefficients, for which an absolute correlation ≥0.30 was considered significant.

Results

Overall dietary patterns

The present analysis included 15 618 adults (6552 men and 9066 women) with a mean age of 58.4 y (Standard deviation 16.4). The principal component analysis identified four overall dietary patterns: vegetable/fruit/fish/pulse, bread/dairy, meat/fat, and noodle/seasoning patterns (Table 1). Overall, the four dietary patterns accounted for 28.8% of the total variance in overall food group intake. Each of the overall dietary pattern scores differed significantly according to sex, age, smoking status, habitual exercise, and dietary reporting status (Supplementary Table 2). In relation to nutrient intake (Supplementary Table 3), the vegetable/fruit/fish/pulse pattern was positively correlated with intakes of energy, dietary fiber, folate, vitamin C, potassium, calcium, magnesium, and iron. The bread/dairy pattern showed positive correlations with saturated fatty acid (SFA) and calcium intakes. The meat/fat pattern was correlated positively with intakes of energy, fats, SFAs, monounsaturated fatty acids, and ω-6 polyunsaturated fatty acids and inversely with intakes of carbohydrate, calcium, and magnesium. There was a positive correlation between the noodle/seasoning pattern and sodium intake.

After adjustment for potential confounding factors, the vegetable/fruit/fish/pulse pattern showed inverse associations with WC, SBP, DBP, TC, and LDL-C (Supplementary Table 4). The bread/dairy pattern was associated inversely with BMI, WC, SBP, and DBP but positively with TC and LDL-C. Conversely, the remaining two

Table 2
Factor loadings for meal-specific (breakfast, lunch, and dinner) dietary patterns (N = 15 618): The 2012 National Health and Nutrition Survey, Japan[*]

	Breakfast[†]				Lunch[†]				Dinner[†]			
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 1	Factor 2	Factor 3	Factor 4	Factor 1	Factor 2	Factor 3	Factor 4
	Rice, vegetable, fish, pulse, and seasoning pattern	Bread, dairy, fruit, and sugar pattern	Meat, egg, and fat pattern	Tea and coffee pattern	Bread and dairy pattern	Noodle and seasoning pattern	Meat and fat pattern	Vegetable, pulse, potato, and sugar pattern	Meat, vegetable, and seasoning pattern	Noodle and alcoholic beverage pattern	Fish, sugar, and alcoholic beverage pattern	Other grains and fat pattern
Rice	**0.69**	−**0.40**	−0.01	0.13	−**0.45**	−**0.66**	0.15	0.12	0.13	−**0.68**	0.06	−0.16
Bread	−**0.58**	**0.47**	**0.33**	0.09	**0.74**	0.03	0.08	0.04	−0.06	0.10	0.04	**0.31**
Noodles	0.00	−0.12	0.12	−0.23	−0.18	**0.78**	−0.04	−0.24	0.05	**0.63**	−**0.32**	−0.03
Other grains	0.07	0.13	0.01	−0.22	0.05	0.07	0.29	0.05	0.22	0.07	0.01	**0.53**
Potatoes	**0.43**	0.11	0.16	−0.03	−0.09	−0.05	0.20	**0.44**	0.29	−0.23	0.25	0.07
Sugar	−0.07	**0.52**	0.16	0.17	0.25	−0.07	0.08	**0.47**	0.18	−0.10	**0.49**	−0.02
Pulses	**0.46**	0.02	−0.08	0.06	−0.14	0.01	−0.16	**0.50**	0.17	0.20	**0.31**	−**0.32**
Nuts	0.10	0.27	−0.10	0.02	0.04	−0.02	−0.04	0.24	0.04	0.04	**0.30**	0.08
Vegetables	**0.68**	0.15	0.25	0.02	−0.26	0.00	0.28	**0.57**	**0.58**	0.01	0.27	−0.22
Fruits	0.06	**0.64**	−0.11	−0.02	**0.34**	0.06	−0.15	**0.33**	−0.06	−0.07	0.15	0.11
Fish	**0.49**	0.00	−0.08	0.02	−**0.31**	−**0.30**	−0.23	**0.32**	−**0.29**	0.05	**0.68**	−0.01
Meat	0.12	−0.10	**0.63**	−0.23	−0.12	−0.09	**0.75**	0.02	**0.73**	−0.05	−0.26	0.06
Eggs	0.15	−0.16	**0.49**	0.11	−0.05	−0.29	0.26	−0.19	0.13	−0.09	0.13	0.25
Dairy products	−0.10	**0.60**	−0.02	−0.28	**0.62**	0.08	0.03	0.24	−0.07	−0.01	0.04	**0.30**
Fats and oils	−0.27	0.16	**0.69**	0.02	0.06	−0.13	**0.76**	−0.01	**0.39**	−0.06	−0.04	**0.58**
Confectioneries	−0.16	−0.07	−0.22	−0.21	0.29	−0.02	−0.12	−0.13	−0.10	0.10	0.10	0.28
Fruit juice	−0.01	0.11	0.02	−0.15	0.08	0.00	0.04	−0.03	−0.06	0.06	−0.07	0.08
Vegetable juice	−0.04	0.12	−0.03	−0.21	0.15	−0.04	−0.01	−0.06	−0.05	0.00	−0.02	0.19
Alcoholic beverages	0.09	−0.04	0.23	−0.29	−0.09	0.06	0.07	0.15	0.11	**0.46**	**0.36**	0.11
Soft drinks	−0.09	−0.06	−0.04	−**0.37**	0.10	−0.03	0.10	−0.14	−0.01	0.07	0.01	0.25
Tea and coffee	0.00	0.07	0.09	**0.70**	−0.04	−0.29	0.03	−0.03	0.00	−**0.32**	−0.04	−0.06
Seasonings	**0.54**	−0.01	0.13	−0.03	−**0.33**	**0.62**	0.18	0.09	**0.44**	**0.32**	0.10	−0.24
Variability explained (%)	10.9	7.6	6.8	5.2	8.2	8.0	7.3	6.8	7.2	6.5	6.3	6.1

[*]Meal-specific (breakfast, lunch, and dinner) dietary patterns were identified using principal component analysis based on intakes of the 22 food groups from each meal (g/d). Absolute factor loading values ≥0.30 are presented in **bold**.
[†]Meal-specific dietary patterns were named according to the food groups with the highest positive factor loadings per dietary pattern.

Table 3

Contributions of meal-specific (breakfast, lunch, and dinner) dietary pattern scores to interindividual variation in overall dietary pattern scores (N = 15 618): The 2012 National Health and Nutrition Survey, Japan*

	Overall diet†											
	Factor 1 Vegetable, fruit, fish, and pulse pattern			Factor 2 Bread and dairy pattern			Factor 3 Meat and fat pattern			Factor 4 Noodle and seasoning pattern		
	β‡	SE‡	Partial R^2	β‡	SE‡	Partial R^2	β‡	SE‡	Partial R^2	β‡	SE‡	Partial R^2
	Model R^2 0.84			Model R^2 0.74			Model R^2 0.89			Model R^2 0.84		
Breakfast†												
Factor 1: Rice, vegetable, fish, pulse, and seasoning pattern	0.43	0.003	0.28	−0.38	0.004	0.10	−0.06	0.003	0.02	0.04	0.003	0.00
Factor 2: Bread, dairy, fruit, and sugar pattern	0.20	0.003	0.09	0.57	0.004	0.33	0.00§	0.003	0.00	0.04	0.003	0.01
Factor 3: Meat, egg, and fat pattern	0.04	0.003	0.00	0.11	0.004	0.01	0.33	0.003	0.13	−0.01	0.003	0.00
Factor 4: Tea and coffee pattern	0.07	0.003	0.01	0.01‖	0.004	0.00	−0.02	0.003	0.00	−0.08	0.003	0.02
Lunch†												
Factor 1: Bread and dairy pattern	−0.14	0.003	0.02	0.49	0.004	0.24	−0.02	0.003	0.00	−0.15	0.003	0.03
Factor 2: Noodle and seasoning pattern	−0.08	0.003	0.01	0.11	0.004	0.01	−0.09	0.003	0.01	0.71	0.003	0.51
Factor 3: Meat and fat pattern	0.04	0.003	0.01	−0.02	0.004	0.00	0.53	0.003	0.33	0.00¶	0.003	0.00
Factor 4: Vegetable, pulse, potato, and sugar pattern	0.39	0.003	0.15	0.10	0.004	0.01	−0.03	0.003	0.00	−0.08	0.003	0.01
Dinner†												
Factor 1: Meat, vegetable, and seasoning pattern	0.23	0.003	0.05	−0.06	0.004	0.00	0.53	0.003	0.28	0.15	0.003	0.02
Factor 2: Noodle and alcoholic beverage pattern	−0.05	0.003	0.00	−0.03	0.004	0.00	−0.05	0.003	0.00	0.50	0.003	0.25
Factor 3: Fish, sugar, and alcoholic beverage pattern	0.44	0.003	0.19	−0.07	0.004	0.01	−0.08	0.003	0.01	−0.01	0.003	0.00
Factor 4: Other grains and fat pattern	−0.13	0.003	0.02	0.16	0.004	0.02	0.32	0.003	0.11	−0.07	0.003	0.01

$P < 0.0001$ for all values unless otherwise indicated.

*Meal-specific (breakfast, lunch, and dinner) dietary patterns were identified using principal component analysis based on intakes of the 22 food groups from each meal (g/d). Overall dietary patterns were identified using principal component analysis based on overall intakes of the 22 food groups (g/d). The dietary pattern scores represent standardized variables with mean 0 and SD 1.

†Meal-specific dietary patterns and overall dietary patterns were named according to the food groups with the highest positive factor loadings per dietary pattern.

‡Regression coefficients indicate the change of overall dietary pattern scores with a 1-point increase of meal-specific dietary pattern scores.

§$P = 0.33$.

‖$P = 0.03$.

¶$P = 0.85$.

dietary patterns (meat/fat and noodle/seasoning patterns) were positively associated with all metabolic risk factors examined, except for HbA1c for both and DBP for the former.

Meal-specific (breakfast, lunch, and dinner) dietary patterns

Breakfast, lunch, dinner, and snacks on average contributed to 23%, 30%, 40%, and 8% of total EI, respectively. The amounts of rice, vegetables, tea, and coffee consumed were large for all three main meals (Supplementary Table 5). Other food groups with large consumption included dairy products and fruits for breakfast; noodles for lunch; and alcoholic beverages, fish, and meat for dinner.

The principal component analysis identified four breakfast patterns:

1. rice/vegetable/fish/pulse/seasoning,
2. bread/dairy/fruit/sugar,
3. meat/egg/fat, and
4. tea/coffee patterns (Table 2).

Four patterns also were identified for lunch:

1. bread/dairy,
2. noodle/seasoning,
3. meat/fat, and
4. vegetable/pulse/potato/sugar patterns.

Four patterns were again identified for dinner:

1. meat/vegetable/seasoning,
2. noodle/alcoholic beverage
3. fish/sugar/alcoholic beverage, and
4. other grains/fat patterns.

Each of the four patterns for breakfast, lunch, and dinner accounted for 30.5%, 30.3%, and 26.1%, respectively, of the variance in food-group intake consumed at each eating occasion.

Contribution of meal-specific (breakfast, lunch, and dinner) dietary patterns to interindividual variation in overall dietary patterns

Although the correlations between each of the 12 meal-specific dietary pattern scores were generally weak (r, −0.05 to 0.19), 74% to 89% of interindividual variation in overall dietary pattern scores were explained by meal-specific dietary pattern scores (Table 3). The major and positive contributors to the vegetable/fruit/fish/pulse overall dietary pattern included the rice/vegetable/fish/pulse/seasoning breakfast (28%), vegetable/pulse/potato/sugar lunch (15%), and fish/sugar/alcoholic beverage dinner (19%). The corresponding meal-specific patterns for the bread/dairy overall dietary pattern were the bread/dairy/fruit/sugar breakfast (33%) and bread/dairy lunch (24%). For the meat/fat overall dietary pattern, the meat/egg/fat breakfast (13%), meat/fat lunch (33%), meat/vegetable/seasoning dinner (28%), and other grains/fat dinner (11%) contributed largely and positively. The noodle/seasoning lunch (51%) and noodle/alcoholic beverage dinner (25%) were major and positive contributors to the noodle/seasoning overall dietary pattern.

Discussion

To our knowledge, this is the first study to investigate meal-specific dietary patterns and their contribution to overall dietary patterns using data from a national nutrition survey in Japan. We identified four major dietary patterns for each meal (breakfast, lunch, and dinner). Each of the four meal-specific dietary patterns accounted for 26% to 31% of the variance in food intake at each eating occasion. Based on daily food intake, four major overall dietary patterns were also identified, which accounted for 29% of the variance. About 74% to 89% of interindividual variation in overall dietary pattern scores was explained by meal-specific dietary pattern scores, but major contributors were considerably different.

Despite large differences in dietary habits among countries, previous studies from various countries have consistently identified two major dietary patterns [8–19]: A healthy/prudent pattern (characterized by a high intake of fruit, vegetables, whole grains, fish and seafood, legumes, olive oil, nuts, seeds, and low-fat dairy products) and a Western/unhealthy pattern (characterized by a high intake of meat [mainly processed], refined grains, sweets, and soft drinks). The vegetable/fruits/fish/pulse overall dietary pattern identified in this study was similar to the former, whereas the meat/fat overall dietary pattern had some characteristics in common with the latter. In addition to these two patterns, the two other patterns (i.e., the bread/dairy and noodle/seasoning patterns) were similarly identified in previous Japanese studies [33,40–43]. This study, based on a national dietary survey, thus confirms major patterns of the Japanese diet.

Published systematic reviews and meta-analyses have generally concluded that a healthy/prudent'dietary pattern is associated with a favorable metabolic risk factor profile, whereas a Western/unhealthy dietary pattern shows associations in the opposite direction [44–46]. The present study consistently showed that the vegetable/fruits/fish/pulse overall dietary pattern was associated with favorable metabolic risk factors, whereas the meat/fat overall dietary pattern showed unfavorable associations. Although the bread/dairy overall dietary pattern was positively associated with TC and LDL-C, which may have been due to a higher intake of SFAs [47], it was nevertheless inversely associated with body fat measures and BP. In contrast, the noodle/seasoning overall dietary pattern was associated with adverse metabolic risk factor profiles. These findings may seem irrelevant at first glance, considering not only that there were virtually no correlations between these two dietary patterns and nutrient intakes but also that consumption of whole grains and low-fat dairy products is quite low in Japan [48]. However, these findings might be reasonable in terms of the timing of eating, given that the bread/dairy overall dietary pattern was explained mainly by breakfast and lunch patterns characterized by bread, whereas the noodle/seasoning overall dietary pattern was explained by lunch and dinner patterns characterized by noodles. Supporting this, several previous studies have suggested that increasing intake of carbohydrate or energy in the morning could be protective against the development of metabolic disorders [24].

This study identified four breakfast, four lunch, and four dinner dietary patterns. To our knowledge, only two studies have identified meal-specific dietary patterns. In a sample of the residents in Sao Paulo City, Brazil, three breakfast (healthy, traditional, and snack), five lunch (traditional, salad, sweetened juice, Western, and meats), and four dinner (coffee with milk and bread, transitional, traditional, and soups and fruits) dietary patterns were identified [25]. In a study conducted in central eastern China, two dietary patterns (traditional [wheat for breakfast and rice for lunch and dinner] and modern) were identified for each meal [26]. Thus, in contrast to similarities in overall dietary patterns, meal-specific dietary patterns appear to vary among populations (despite some similarities in naming). Nevertheless, these studies consistently indicate that although similar dietary patterns were seen in the three meals within each study, analysis of dietary patterns by meals allowed the identifications of specific characteristics of each meal.

In the present study, although some dietary patterns repeatedly appeared on more than one eating occasion (e.g., some combinations of bread/dairy and meat/fat), the correlations between each of the 12 meal-specific dietary patterns were generally weak. Of note, each of the meal-specific dietary patterns contributed primarily to only one of the overall dietary patterns (except for the tea/coffee breakfast pattern). In addition, none of the four overall dietary patterns could be explained by a single meal-specific dietary pattern. Taken together, this study clearly indicates that all meals are important for improving overall diet quality, and that dietary modifications may be achievable from every meal (but not from a single meal), taking into account various factors including feasibility and preference. This in turn has valuable implications for meal-based or meal-specific dietary guidelines or interventions, given that dietary patterns are associated with individual-level characteristics (such as age and sex).

Very recently, the relation between overall dietary patterns and food intake patterns at the meal level (breakfast, lunch, afternoon snack, and dinner) was investigated in 816 German adults [49]. Using 24-h dietary recall data, the study showed that dinner was the highest contributor to the formation of four overall dietary patterns identified (i.e., prudent, Western, traditional, and cereal and legumes patterns). This is somewhat different from the present findings that the contribution of breakfast and lunch was higher than that of dinner. The exact reason is unknown but may include differences in the study populations, dietary patterns and habits, and dietary assessment methods. In any case, both studies clearly showed that overall dietary patterns to some extent originate at the meal level, which in turn could lead to a better understanding of how principal component analysis-derived dietary patterns arise [49]. Because principal component analysis has been widely used to derived dietary patterns, this kind of basic information should be accumulated from various countries.

Several limitations of this study should be mentioned. First, although NHNSJ aims to represent a nationally representative sample of the non-institutionalized population of Japan, only 52% of the sampled households participated. Moreover, no information was available on the basic characteristics of households that refused to participate [4]. Furthermore, the exact response rate at the individual level is unknown. Thus, a degree of selection bias cannot be ruled out.

All self-reported dietary assessments can be affected by random and systematic measurement errors [50,51]. Considering the day-to-day variability in dietary intake among free-living individuals, the dietary patterns derived here from a 1-d weighted household dietary record would not likely represent usual patterns of individual respondents. Failure to adjust for day-to-day variability affects distributions of food intake, tending to extend the tails, which may result in the appearance of food group combinations, meal patterns, or both consumed with very small frequencies. To minimize this possibility, we used only 22 food groups that were very general. Moreover, days of the week for dietary assessment were not proportionately selected, and Sundays were intentionally excluded (in accordance with the survey protocol). This also likely produced a degree of bias in assessment of average dietary patterns. We do not have information on the day actually selected for dietary recording [4]. In addition, because the survey was conducted within the limited period of around 6 wk (October 25 to December 7, 2012), no consideration was made of possible seasonal variation, which might have introduced additional bias in the assessment of average dietary patterns. Moreover, misreporting of dietary intake is a serious problem associated with self-reported dietary assessment methods, particularly among overweight and obese individuals [50,51], although repeated analysis after the exclusion of EI under- and overreporters produced similar results (data not shown). Most importantly, although the use of this household dietary record to estimate dietary intake among individuals has been indicated among young women, but not men or women of other age groups [30], its actual validity in assessing dietary patterns remains unknown. It would have been preferable to assess usual dietary patterns with several days of dietary assessment, preferably covering all seasons and all days of the week, or using a validated dietary assessment questionnaire. The feasibility of this should be considered for the NHNSJ.

Principal component analysis is itself affected by a number of limitations, and the results obtained may be data specific. The present study was also hindered by analytical decisions that were at a number of points subjective or arbitrary. These included the number (and classification) of food groups, definition of eating occasions, form of the input variables, number of factors extracted as well as the rotation method employed, and the interpretation and naming of factors. Our process might have resulted in a degree of inconsistency, and both the results and process used to derive meal-specific and overall dietary patterns require careful interpretation.

Conclusion

Using data from a national nutrition survey in Japan, we identified four overall, four breakfast, four lunch, and four dinner dietary patterns, each of which accounted for >25% of the variance in food intake. Although a considerably large proportion (74–89%) of interindividual variation in each of the four overall dietary pattern scores was explained by the 12 meal-specific dietary pattern scores, major contributors differed considerably. These findings on patterns of food combinations at meals and their association with overall dietary patterns provide a scientific basis on which meal-specific or meal-based public health nutrition policies and recommendations can be developed.

Supplementary materials

Supplementary data related to this article can be found at doi:10.1016/j.nut.2018.07.110.

References

[1] Sasaki S. The value of the National Health and Nutrition Survey in Japan. Lancet 2011;378:1205–6.
[2] Ikeda N, Saito E, Kondo N, Inoue M, Ikeda S, Satoh T, et al. What has made the population of Japan healthy? Lancet 2011;378:1094–105.
[3] Micha R, Khatibzadeh S, Shi P, Andrews KG, Engell RE, Mozaffarian D. Global, regional and national consumption of major food groups in 1990 and 2010: a systematic analysis including 266 country-specific nutrition surveys worldwide. BMJ Open 2015;5:e008705.
[4] Ministry of Health, Labour and Welfare, Japan. The National Health and Nutrition Survey in Japan Available at: http://www.mhlw.go.jp/bunya/kenkou/eiyou/h24-houkoku.html; 2012 Accessed 20 December 2017 .
[5] Hu FB. Dietary pattern analysis: a new direction in nutritional epidemiology. Curr Opin Lipidol 2002;13:3–9.
[6] Kant AK. Dietary patterns and health outcomes. J Am Diet Assoc 2004;104:615–35.
[7] Kuriyama N, Murakami K, Livingstone MB, Okubo H, Kobayashi S, Suga H, et al. Development of a food-based diet quality score for Japanese: associations of the score with nutrient intakes in young, middle-aged, and older Japanese women. J Nutr Sci 2016;5:e41.
[8] Ax E, Warensjo Lemming E, Becker W, Andersson A, Lindroos AK, Cederholm T, et al. Dietary patterns in Swedish adults; results from a national dietary survey. Br J Nutr 2016;115:95–104.
[9] Beck KL, Jones B, Ullah I, McNaughton SA, Haslett SJ, Stonehouse W. Associations between dietary patterns, socio-demographic factors and anthropometric measurements in adult New Zealanders: an analysis of data from the 2008/09 New Zealand Adult Nutrition Survey. Eur J Nutr 2018;57:1421–33.

[10] Bell LK, Edwards S, Grieger JA. The relationship between dietary patterns and metabolic health in a representative sample of adult Australians. Nutrients 2015;7:6491–505.
[11] Heidemann C, Scheidt-Nave C, Richter A, Mensink GBM. Dietary patterns are associated with cardiometabolic risk factors in a representative study population of German adults. Br J Nutr 2011;106:1253–62.
[12] Hearty AP, Gibney MJ. Comparison of cluster and principal component analysis techniques to derive dietary patterns in Irish adults. Br J Nutr 2009;101:598–608.
[13] Kerver JM, Yang EJ, Bianchi L, Song WO. Dietary patterns associated with risk factors for cardiovascular disease in healthy US adults. Am J Clin Nutr 2003;78:1103–10.
[14] Gibson S, Ashwell M. Dietary patterns among British adults: comparability with dietary guidelines for salt/sodium, fat, saturated fat and sugars. Public Health Nutr 2011;14:1323–36.
[15] Bertin M, Touvier M, Dubuisson C, Dufour A, Havard S, Lafay L, et al. Dietary patterns of French adults: associations with demographic, socio-economic and behavioural factors. J Hum Nutr Diet 2016;29:241–54.
[16] Knudsen VK, Matthiessen J, Biltoft-Jensen A, Sorensen MR, Groth MV, Trolle E, et al. Identifying dietary patterns and associated health-related lifestyle factors in the adult Danish population. Eur J Clin Nutr 2014;68:736–40.
[17] Wang D, He Y, Li Y, Luan D, Yang X, Zhai F, et al. Dietary patterns and hypertension among Chinese adults: a nationally representative cross-sectional study. BMC Public Health 2011;11:925.
[18] Shin JY, Kim JM, Kim Y. Associations between dietary patterns and hypertension among Korean adults: the Korean National Health and Nutrition Examination Survey (2008-2010). Nutr Res Pract 2013;7:224–32.
[19] Htun NC, Suga H, Imai S, Shimizu W, Takimoto H. Food intake patterns and cardiovascular risk factors in Japanese adults: analyses from the 2012 National Health and nutrition survey, Japan. Nutr J 2017;16:61.
[20] Hearty AP, Gibney MJ. Analysis of meal patterns with the use of supervised data mining techniques—artificial neural networks and decision trees. Am J Clin Nutr 2008;88:1632–42.
[21] Woolhead C, Gibney MJ, Walsh MC, Brennan L, Gibney ER. A generic coding approach for the examination of meal patterns. Am J Clin Nutr 2015;102:316–23.
[22] Murakami K, Livingstone MB, Sasaki S. Establishment of a meal coding system for the characterization of meal-based dietary patterns in Japan. J Nutr 2017;147:2093–101.
[23] Jacobs DR Jr, LM Steffen. Nutrients, foods, and dietary patterns as exposures in research: a framework for food synergy. Am J Clin Nutr 2003;78:508. S−13 S.
[24] Almoosawi S, Vingeliene S, Karagounis LG, Pot GK. Chrono-nutrition: a review of current evidence from observational studies on global trends in time-of-day of energy intake and its association with obesity. Proc Nutr Soc 2016;75:487–500.
[25] de Oliveira Santos R, Fisberg RM, Lobo Marchioni DM, Troncoso Baltar V. Dietary patterns for meals of Brazilian adults. Br J Nutr 2015;114:822–8.
[26] Shi Z, Riley M, Taylor A, Noakes M. Meal-specific food patterns and the incidence of hyperglycemia in a Chinese adult population. Br J Nutr 2017;118:53–9.
[27] Murakami K, Livingstone MB, Okubo H, Sasaki S. Energy density of the diets of Japanese adults in relation to food and nutrient intake and general and abdominal obesity: a cross-sectional analysis from the 2012 National Health and Nutrition Survey, Japan. Br J Nutr 2017;117:161–9.
[28] Murakami K, Livingstone MB, Okubo H, Sasaki S. Higher dietary acid load is weakly associated with higher adiposity measures and blood pressure in Japanese adults: the National Health and Nutrition Survey. Nutr Res 2017;44:67–75.
[29] Science and Technology Agency. Standard tables of food composition in Japan. 5th rev and Enlarged Edition Tokyo, Japan: National Printing Bureau; 2005.
[30] Iwaoka F, Yoshiike N, Date C, Shimada T, Tanaka H. A validation study on a method to estimate nutrient intake by family members through a household-based food-weighing survey. J Nutr Sci Vitaminol 2001;47:222–7.
[31] Murakami K, Livingstone MB, Okubo H, Sasaki S. Younger and older ages and obesity are associated with energy intake underreporting but not overreporting in Japanese boys and girls aged 1-19 years: the National Health and Nutrition Survey. Nutr Res 2016;36:1153–61.
[32] Murakami K, Livingstone MB, Okubo H, Sasaki S. Prevalence and characteristics of misreporting of energy intake in Japanese adults: the 2012 National Health and Nutrition Survey. Asia Pac J Clin Nutr 2018;27:441–50.
[33] Okubo H, Murakami K, Sasaki S, Kim MK, Hirota N, Notsu A, et al. Relative validity of dietary patterns derived from a self-administered diet history questionnaire using factor analysis among Japanese adults. Public Health Nutr 2010;13:1080–9.
[34] Varraso R, Garcia-Aymerich J, Monier F, Le Moual N, De Batlle J, Miranda G, et al. Assessment of dietary patterns in nutritional epidemiology: principal component analysis compared with confirmatory factor analysis. Am J Clin Nutr 2012;96:1079–92.
[35] Ikeda N, Takimoto H, Imai S, Miyachi M, Nishi N. Data resource profile: the Japan National Health and Nutrition Survey (NHNS). Int J Epidemiol 2015;44:1842–9.
[36] Nakamura M, Kiyama M, Kitamura A, Ishikawa Y, Sato S, Noda H, et al. Revised system to evaluate measurement of blood chemistry data from the Japanese National Health and Nutrition Survey and Prefectural Health and Nutrition Surveys. J Epidemiol 2013;23:28–34.
[37] Black AE. Critical evaluation of energy intake using the Goldberg cut-off for energy intake:basal metabolic rate. A practical guide to its calculation, use and limitations. Int J Obes Relat Metab Disord 2000;24:1119–30.
[38] Ganpule AA, Tanaka S, Ishikawa-Takata K, Tabata I. Interindividual variability in sleeping metabolic rate in Japanese subjects. Eur J Clin Nutr 2007;61:1256–61.
[39] Miyake R, Tanaka S, Ohkawara K, Ishikawa-Takata K, Hikihara Y, Taguri E, et al. Validity of predictive equations for basal metabolic rate in Japanese adults. J Nutr Sci Vitaminol 2011;57:224–32.
[40] Shimazu T, Kuriyama S, Hozawa A, Ohmori K, Sato Y, Nakaya N, et al. Dietary patterns and cardiovascular disease mortality in Japan: a prospective cohort study. Int J Epidemiol 2007;36:600–9.
[41] Fujiwara A, Asakura K, Uechi K, Masayasu S, Sasaki S. Dietary patterns extracted from the current Japanese diet and their associations with sodium and potassium intakes estimated by repeated 24 h urine collection. Public Health Nutr 2016;19:2580–91.
[42] Maruyama K, Iso H, Date C, Kikuchi S, Watanabe Y, Wada Y, et al. Dietary patterns and risk of cardiovascular deaths among middle-aged Japanese: JACC study. Nutr Metab Cardiovasc Dis 2013;23:519–27.
[43] Akter S, Nanri A, Pham NM, Kurotani K, Mizoue T. Dietary patterns and metabolic syndrome in a Japanese working population. Nutr Metab 2013;10:30.
[44] Rodriguez-Monforte M, Sanchez E, Barrio F, Costa B, Flores-Mateo G. Metabolic syndrome and dietary patterns: a systematic review and meta-analysis of observational studies. Eur J Nutr 2017;56:925–47.
[45] Hosseini Z, Whiting SJ, Vatanparast H. Current evidence on the association of the metabolic syndrome and dietary patterns in a global perspective. Nutr Res Rev 2016;29:152–62.
[46] Rezagholizadeh F, Djafarian K, Khosravi S, Shab-Bidar S. A posteriori healthy dietary patterns may decrease the risk of central obesity: findings from a systematic review and meta-analysis. Nutr Res 2017;41:1–13.
[47] Mensink RP, Zock PL, Kester AD, Katan MB. Effects of dietary fatty acids and carbohydrates on the ratio of serum total to HDL cholesterol and on serum lipids and apolipoproteins: a meta-analysis of 60 controlled trials. Am J Clin Nutr 2003;77:1146–55.
[48] Okubo H, Sasaki S, Murakami K, Yokoyama T, Hirota N, Notsu A, et al. Designing optimal food intake patterns to achieve nutritional goals for Japanese adults through the use of linear programming optimization models. Nutr J 2015;14:57.
[49] Schwedhelm C, Iqbal K, Knuppel S, Schwingshackl L, Boeing H. Contribution to the understanding of how principal component analysis-derived dietary patterns emerge from habitual data on food consumption. Am J Clin Nutr 2018;107:227–35.
[50] Livingstone MB, Black AE. Markers of the validity of reported energy intake. J Nutr 2003;133:895. S−920 S.
[51] Murakami K, Livingstone MB. Prevalence and characteristics of misreporting of energy intake in US adults: NHANES 2003-2012. Br J Nutr 2015;114:1294–303.