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ORIGINAL RESEARCH

Association of Meal and Snack Patterns With Mortality of All-Cause, Cardiovascular Disease, and Cancer: The US National Health and Nutrition Examination Survey, 2003 to 2014

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BACKGROUND: Although accumulating evidence has demonstrated that consumption time of energy and macronutrients plays an important role in maintaining health, the association between consumption time of different foods and cardiovascular disease, cancer, and all-cause mortalities is still largely unknown.

METHODS AND RESULTS: A noninstitutionalized household population of the US 21 503 participants from National Health and Nutrition Examination Survey was included. Meal patterns and snack patterns throughout a whole day were measured using 24-hour dietary recall. Principal component analysis was performed to establish dietary patterns. Cox proportional hazards models were used to evaluate the association between dietary patterns across meals and cardiovascular disease (CVD), cancer, and all-cause mortalities. During the 149 875 person-years of follow-up, 2192 deaths including 676 deaths because of CVD and 476 because of cancer were documented. After adjusting for potential confounders, participants consuming fruit-lunch had lower mortality risks of all-cause (hazard ratio [HR], 0.82; 95% CI, 0.72–0.92) and CVD (HR, 0.66; 95% CI, 0.49–0.87); whereas participants who consumed Western-lunch were more likely to die because of CVD (HR, 1.44; 95% CI, 1.10–1.89). Participants who consumed vegetable-dinner had lower mortality risks of all-cause, CVD, and cancer ($HR_{all\text{-}cause}$, 0.69; 95% CI, 0.60–0.78; HR_{CVD}, 0.77; 95% CI, 0.61–0.95; HR_{cancer}, 0.63; 95% CI, 0.48–0.83). For the snack patterns, participants who consumed fruit-snack after breakfast had lower mortality risks of all-cause and cancer ($HR_{all\text{-}cause}$, 0.78; 95% CI, 0.66–0.93; HR_{cancer}, 0.55; 95% CI, 0.39–0.78), and participants who consumed dairy-snack after dinner had lower risks of all-cause and CVD mortalities ($HR_{all\text{-}cause}$, 0.82; 95% CI, 0.72–0.94; HR_{CVD}, 0.67; 95% CI, 0.52–0.87). Participants who consumed a starchy-snack after main meals had greater mortality risks of all-cause ($HR_{after\text{-}breakfast}$, 1.50; 95% CI, 1.24–1.82; $HR_{after\text{-}lunch}$, 1.52; 95% CI, 1.27–1.81; $HR_{after\text{-}dinner}$, 1.50; 95% CI, 1.25–1.80) and CVD ($HR_{after\text{-}breakfast}$, 1.55; 95% CI, 1.08–2.24; $HR_{after\text{-}lunch}$, 1.44; 95% CI, 1.03–2.02; $HR_{after\text{-}dinner}$, 1.57; 95% CI, 1.10–2.23).

CONCLUSIONS: Fruit-snack after breakfast, fruit-lunch, vegetable-dinner, and dairy-snack after dinner was associated with lower mortality risks of CVD, cancer, and all-cause; whereas Western-lunch and starchy-snack after main meals had greater CVD and all-cause mortalities.

Key Words: consumption-time ■ dietary-patterns ■ mortality ■ NHANES

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CLINICAL PERSPECTIVE

What Is New?

- This study firstly investigated the association of meal and snack patterns across a day with cancer, cardiovascular disease, and all-cause mortality.
- Meal patterns of fruit-lunch and vegetable-dinner, and snack patterns of fruit after breakfast and dairy products after dinner were associated with decreased risks of cancer, cardiovascular disease, and all-cause mortality.
- Western lunch and starchy snack pattern after main meals were associated with elevated cardiovascular disease and all-cause mortality risk.

What Are the Clinical Implications?

- The present study emphasized that the content, amount, and the time of food intake are equally critical for maintaining health.
- The right time of intake is essential for regulating the body's metabolism and preventing the process of cancer and cardiovascular disease.
- Therefore, timing of meals needs to be taken into consideration for dietary recommendations to improve health.

Nonstandard Abbreviations and Acronyms

NHANES	National Health and Nutrition Examination Survey
PCA	principal component analysis
PLS-DA	Partial Least Squares Discriminant Analysis
VIP	variable importance for the projection

Chrono-nutrition, as an emerging field of nutritional research, aims to understand how meal times impact health.[1–4] The concept of chrono-nutrition emphasizes that, in addition to the quantity and quality of food, consumption time of diet is also critical for the well-being of an organism.[4] Accumulating animal and human studies have shown that high energy intake at dinner is associated with dyslipidemia and hyperglycemia,[5–8] whereas high energy intake at breakfast or prolonged time-restricted energy intake throughout the night have beneficial effects on body weight, glucose, lipid control, and long-term survival.[8–13] Although these studies suggest that intakes of energy and macronutrients at different time periods impact health differently, it is still largely unknown whether and how the consumption time of different foods may impact health.

Furthermore, compared with examining a single food, an examination of dietary pattern parallel more closely resembles the real world, in which nutrients and foods are consumed in combination, and their joint effects may best be investigated by considering the entire eating pattern.[14] Analyzing consumption time of dietary patterns across meals may therefore provide a comprehensive understanding of the health impact of chrono-nutrition. In this study, we hypothesized that a specific dietary pattern might differently affect health according to the time periods of consumption. In order to test this hypothesis, this study prospectively assessed the association of meal and snack patterns throughout a whole day with cardiovascular disease (CVD), cancer, and all-cause mortalities in the noninstitutionalized household population of the United States using data from the National Health and Nutrition Examination Survey (NHANES).

METHODS

All data and materials have been made publicly available at the National Health and Nutrition Examination Survey, which can be accessed at https://wwwn.cdc.gov/nchs/nhanes/Default.aspx.

Reproducible Research Statement

Data in this study can be downloaded at https://www.cdc.gov/nchs/nhanes/index.htm?CDC_AA_refVal=https%3A%2F%2Fwww.cdc.gov%2Fnchs%2Fnhanes.htm.

Study Population

NHANES is a stratified, multistage study (from counties or small groups of contiguous counties to individuals within a household) using a nationally representative sample of the noninstitutionalized household population of the United States. The detailed information of NHANES has been described elsewhere.[15] Briefly, adults (age ≥30 years) who participated in NHANES from 2003 to 2014 were selected in this study. After exclusion of participants who were dead within the 2 years after the baseline survey, and who had missing information on any dietary intake and/or mortality, and total energy intake ≥5000 or ≤500 kcal/d, 21 503 participants including 10 542 men and 10 961 women were included in this study. The institutional review board approval of the National Center for Health Statistics and written informed consent for each participant were obtained before data collection.

Dietary Assessment

Food intakes for 2 nonconsecutive days were collected through 24-hour dietary recall interviews. The first 24-hour dietary recall was conducted in person and the second 24-hour dietary recall was conducted 3 to 10 days afterwards via telephone. Dietary energy intake was estimated using the United States Department of Agriculture's Food and Nutrient Database for Dietary Studies. Dietary supplement use was obtained from a dietary supplement questionnaire. Based on the MyPyramid Equivalents Database 2.0 for USDA Survey Foods, the dietary components of the NHANES were integrated into 26 MyPyramid major food groups. Based on the twice 24-hour dietary recall, the mean values for the intakes of the 26 major food groups were calculated. These major food groups were then split into breakfast, snack between breakfast and lunch, lunch, snack between lunch and dinner, dinner, and snack after dinner based on the consumption times.[16]

Main Exposure

The exposure variables of this study were dietary patterns derived from food groups across meals. For the main meals, Western breakfast, starchy breakfast, and fruit breakfast were identified as main dietary patterns at breakfast; Western lunch, vegetable lunch, and fruit lunch were identified as main dietary patterns at lunch; Western dinner, vegetable dinner, and fruit dinner were identified as main dietary patterns at dinner. For the snacks, grain snack, starchy snack, fruit snack, and dairy snack were identified as main snack patterns after main meals.

Main Outcomes

The outcome variable was mortality status, which was determined by the National Death Index by December 31, 2015. The National Death Index is a highly reliable and widely used resource for death identification. The *International Classification of Diseases, Tenth Revision* (*ICD-10*) was used to determine disease-specific death. Death because of CVD was defined as *ICD-10* codes I00–I09, I11, I13, I20–I51, or I60–I69. Death because of cancer was defined as *ICD-10* codes I19–I43. In total, 2192 deaths, including 676 deaths because of CVD and 476 deaths because of cancer, were documented.

Covariates

Nondietary data included age (years), sex (men/women), race/ethnicity (Mexican American/Other Hispanic/Non-Hispanic White/Non-Hispanic Black/Other Race), education level (<9th grade, 9th–11th grade, high school graduate, general equivalency diploma or equivalent, some college or Associate in Arts degree, or college graduate or above), annual household income (<\$20 000, \$20 000–\$45 000, \$45 000–\$75 000, or >\$100 000), body mass index (kg/m^2), disease histories of hypertension, dyslipidemia, and diabetes mellitus (yes/no). Dietary measurements included total energy (kcal/d), percentage of energy provided by snacks (%), the timing of energy restriction (hours), dietary information collected at working day (yes/no), total dietary fat (g/d), protein (g/d), carbohydrate (g/d), breakfast skipping (yes/no), lunch skipping (yes/no), dietary supplement use (yes/no), and overall diet quality. Diet quality was calculated by the Alternative Healthy Eating Index.[17] The timing of energy restriction was calculated by 24 hours minus length of the ingestion period.

Statistical Analysis

The analyses (except principal component analysis [PCA] and partial least squares discriminant analysis [PLS-DA]) incorporated sample weights, stratification, clustering, and domains to account for the complex survey design according to the NHANES analytic guidelines. Demographic characteristics, dietary nutrients intake, and anthropometric measurements were presented as mean (SD) for continuous variables and number (percentage) for categorical variables. General linear models adjusting for age and χ^2 tests were used to compare baseline characteristics by mortality status, and they were also used to compare the differences for the food groups by dietary patterns. The PCA and Cox proportional hazards model were performed in the R-project 4.0.2 using "Ade4" package and "Survival" package, respectively. The PLS-DA was performed in SIMCA-P 13.0. The 2-sided P<0.05 was considered to be statistically significant.

Dietary Pattern Analysis

PCA, as a classical method of dietary pattern analysis, was performed to establish dietary patterns across meals, which has been described elsewhere.[14] Briefly, before the PCA analysis, the 26 major food groups across meals were adjusted for age, sex, and energy intake using the residual approach, respectively. The components loadings were rotated with varimax rotation to maintain uncorrelated principal components and enhance interpretability. Scree plot with parallel analysis (eigenvalue >1) was used to screen the principal components, and the top 3 principal components (dietary patterns) with a relative high variance interpretation were selected (Figure S1A through S1F). A principal component score of each dietary pattern was calculated based on weighted combination of observed variable (each food group). In the regression analysis of each dietary pattern, the coefficient of observed variable refers to the contribution of individual major food group in the specific dietary pattern. Each participant in this study received PCA scores. The positive value of the principal component score represents that participants in this dietary pattern are more likely to eat this food, and vice versa. For each dietary pattern by meals and snacks, the participants were categorized into quartiles based on the principal component scores of their diet. The participants in the highest quartile were the most adherent to this dietary pattern, whereas the lowest quartile meant the participants were not in this dietary pattern.

The PLS-DA was performed to validate the main meal and snack patterns established in the PCA, and identify the important food groups in the main meal and snack patterns. The participants in the highest quartile of each dietary pattern were selected, and the meal and snack patterns were set as dependent variables. Permutation test was conducted to validate the accuracy of the PLS-DA model. Furthermore, the variable importance for the projection (VIP) was then calculated to assess the influence of food groups on the classification of each dietary pattern and explanatory power, which were selected with the VIP>1 and P<0.05.

Cox Proportional Hazards Models

Cox proportional hazards models were developed to evaluate the association between dietary patterns across meals and CVD, cancer, and all-cause mortalities. Survival time was months between NHANES interview date and death or census date (December 31, 2015). We also controlled for a series of potential confounders, which were age, sex, ethnicity, education, income, smoking, drinking, exercise, body mass index, disease histories of hypertension, dyslipidemia, diabetes mellitus, cholesterol, as well as nutrient supplement use, total intake of daily energy, percentage of energy provided by snacks, fat, carbohydrate, protein, breakfast skipping, lunch skipping, the timing of energy restriction, dietary information collected at working day, and overall diet quality. Moreover, when we analyzed 1 dietary pattern in 1 meal, we also controlled other dietary patterns across meals to account for the whole-day dietary intake.

Sensitivity Analysis

Three sets of sensitivity analyses were performed in this study. In set 1, the participants who had follow-up time <3 years or died within 3 years of follow-up were excluded for evaluating whether the severe illness would influence these results. In set 2, we additionally adjusted for the behavior of diet control when establishing the meal and snack patterns in the PCA for evaluating whether the behavior of diet control would influence these meal and snack patterns, and further examined the association of the meal and snack patterns with cancer, CVD, and all-cause mortalities. In set 3, we also examined whether the diet quality could interact with the main meal and snack patterns. To achieve this, the study population was stratified by the mean value of Alternative Healthy Eating Index, and the association of meal and snack patterns with mortality outcomes was examined in the context of low and high quality, respectively.

RESULTS

Baseline Characteristics

The demographic and nutritional characteristics in terms of survival status are presented in Table. Participants who died of CVD or cancer were more likely to be older, male, non-Hispanic White individuals, lower education level and family income, and had higher frequency of dietary supplements use, higher prevalence of hypertension, diabetes mellitus, dyslipidemia, and lower energy intake and diet quality (P<0.05).

Meal Patterns at Breakfast, Lunch, and Dinner

The variable plots for the PCAs in terms of meal patterns are presented in Figure S2A through S2C. As indicated by the weights of the food groups in the main meal patterns, Western breakfast was characterized as relative high coefficients of refined grain, legumes, added sugars, solid fats, and red meat; starchy breakfast was characterized as relative high coefficients of white potato and other starchy food; and fruit breakfast was characterized as relatively high coefficients of fruits and whole grain (Figure 1A). Consistent with the results of food groups weights, the participants in the Western breakfast consumed the most servings of refined grain (2.892±1.842, oz/d), cheese (0.105±0.298, cup/d), cured meat (1.184±1.885, oz/d), red meat (0.345±1.015, oz/d), poultry (0.255±0.864, oz/d), legumes (0.330±1.031, oz/d), added sugars (5.364±5.314, tsp/d), and solid fats (12.915±11.320, g/d). Meanwhile, the participants in the starchy breakfast consumed the most servings of white potato (0.143±0.304, cup/d), other starchy vegetable (0.172±0.435, cup/d), milk (0.417±0.571, cup/d) and eggs (0.594±0.805, oz/d), and the participants in the fruit breakfast consumed the most servings of fruits (citrus, melons, and berries: 0.241±0.459, cup/d; fruit excluding citrus, melons, and berries: 0.865±0.619, cup/d), whole grain

Table. **Baseline Characteristics of Study Variables by Mortality Status**

Variables	Death from CVD or Cancer (N=1111)	Other Participants (N=20 392)	*P* Value	Total Sample
Age, y	70.5 (12.2)	53.7 (14.8)	<0.001	54.6 (15.2)
Men (%)	655 (59.0)	9887 (48.5)	<0.001	10 542 (49.0)
Non-Hispanic White people (%)	655 (59.0)	9547 (46.8)	<0.001	10 202 (47.4)
Current smoking (%)	233 (21.0)	4546 (22.3)	0.405	4779 (22.2)
Current drinking (%)	689 (62.0)	13 536 (66.4)	0.002	14 225 (66.2)
College graduate or above (%)	657 (59.1)	14 812 (72.6)	<0.001	15 469 (71.9)
>$100 000 annual household income (%)	26 (2.3)	2272 (11.1)	<0.001	2298 (10.7)
BMI, kg/m^2	28.5 (6.0)	29.3 (6.7)	<0.001	29.2 (6.6)
Regular exercise (%)	234 (21.1)	4379 (21.5)	0.522	4613 (21.5)
Dietary supplement use (%)	645 (58.1)	10 529 (51.7)	<0.001	11 174 (52.0)
Hypertension (%)	794 (71.5)	9643 (47.3)	<0.001	10 437 (48.5)
Diabetes mellitus (%)	348 (31.3)	3609 (17.7)	<0.011	3957 (18.4)
Dyslipidemia (%)	501 (45.1)	7525 (36.9)	<0.001	8026 (37.3)
Total energy intake, kcal/d	1753 (666)	2000 (769)	<0.001	1987 (766)
Total fat intake, g/d	66.3 (31.4)	74.8 (36.1)	<0.001	74.4 (35.9)
Total carbohydrate intake, g/d	214.1 (83.9)	245.1 (99.7)	<0.001	243.5 (99.1)
Total protein intake, g/d	69.9 (29.4)	78.9 (33.1)	<0.001	78.4 (33.0)
AHEI	48.7 (13.0)	52.4 (13.5)	<0.001	52.2 (13.5)
Breakfast skipping (%)	130 (11.7)	2644 (13.0)	0.119	2774 (12.9)

All data analyses conducted in the present study were based on weighted estimates with sample weights provided by the National Health and Nutrition Examination Survey. Continuous variables are presented as mean and SD. Categorical variables are presented as numbers and percentage. Hypertension was defined by a self-reported diagnosis, the systolic blood pressure ≥90 mm Hg, or the diastolic blood pressure ≥140 mm Hg. Dyslipidemia was defined as serum triglyceride ≥2.26 mmol/L, or serum cholesterol ≥6.22 mmol/L, or low-density lipoprotein cholesterol ≥4.14 mmol/L. Diabetes mellitus was defined by a self-reported diagnosis, a hemoglobin A1c level ≥6.5%, or a fasting plasma glucose level ≥7.0 mmol/L. AHEI indicates Alternative Healthy Eating Index; BMI, body mass index; and CVD, cardiovascular disease.

(0.571±0.771, oz/d), yogurt (0.031±0.134, cup/d), and nuts (0.112±0.454, oz/d) (all *P*<0.05) (Table S1).

At lunch (Figure 1B), Western lunch was characterized as relative high coefficients of refined grain, solid fats, cheese, added sugars, and cured meat; vegetable lunch was characterized as relative high coefficients of total vegetable, red and orange vegetable, tomato and dark vegetable; fruit lunch was characterized as relative high coefficients of fruits and yogurt. Similarly, the participants in the Western lunch consumed the most servings of refined grain (3.736±2.127, oz/d), cheese (0.425±0.632, cup/d), cured meat (3.057±2.958, oz/d), eggs (0.153±0.452, oz/d), legumes (0.551±1.484, oz/d), added sugars (5.743±6.328, tsp/d), and solid fats (17.003±14.640, g/d). The participants in the vegetable lunch consumed the most servings of total vegetables (1.333±0.760, cup/d), dark vegetables (0.150±0.338, cup/d), red and orange vegetables (0.447±0.448, cup/d), tomato (0.310±0.327, cup/d), other vegetable (0.590±0.545, cup/d), and other starchy vegetable (0.203±0.410, cup/d). The participants in the fruit lunch consumed the most servings of whole grain (0.214±0.496, oz/d), fruits (citrus, melons, and berries: 0.170±0.491, cup/d; fruit excluding citrus, melons, and berries: 0.551±0.567, cup/d), yogurt (0.026±0.121, cup/d), and nuts (0.171±0.732, oz/d) (all the *P*<0.05) (Table S2).

At dinner (Figure 1C), Western dinner was characterized as relative high coefficients of refined grain, cheese, solid fats, added sugars, and eggs; vegetable dinner was characterized as relative high coefficients of total vegetable, red and orange vegetable, tomato, and dark vegetable; fruit dinner was characterized as relative high coefficients of fruits and yogurt. Similarly, the participants in the Western dinner consumed the most servings of refined grain (4.382±2.273, oz/d), cheese (0.618±0.734, cup/d), cured meat (3.256±2.844, oz/d), red meat (1.086±1.596, oz/d), eggs (0.134±0.307, oz/d), solid fats (23.196±16.238, g/d), and added sugars (5.642±6.602, tsp/d). The participants in the vegetable dinner consumed the most servings of dark vegetable (0.163±0.343, cup/d), red and orange vegetable (0.592±0.472, cup/d), tomato (0.421±0.357, cup/d), other vegetable (0.722±0.703, cup/d), other starchy vegetable (0.309±0.527, cup/d), and legumes (0.458±1.186, oz/d). The participants in the fruit dinner consumed the most servings of fruits (citrus, melons, and berries: 0.184±0.448, cup/d; fruit excluding

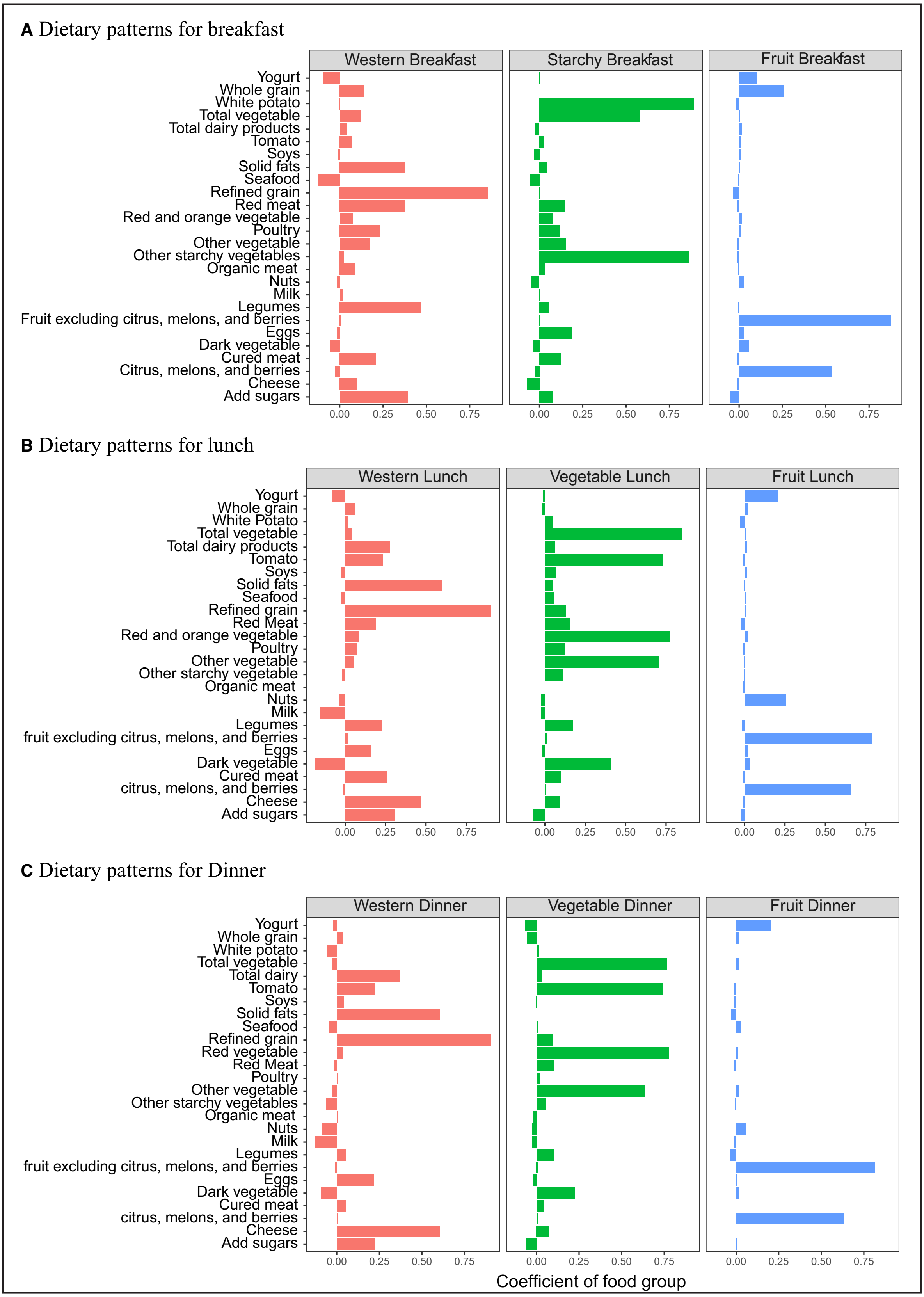

Figure 1. The coefficient of each food group in the meal patterns at breakfast (A), lunch (B), and dinner (C) in the total sample with adjustment for age, sex, and total daily energy intake (N=21 503).

citrus, melons, and berries: 0.489±0.538, cup/d), milk (0.195±0.391, cup/d), yogurt (0.016±0.084, cup/d), and nuts (0.122±0.498, oz/d) (all the $P<0.05$) (Table S3).

Snack Patterns After Breakfast, Lunch, and Dinner

The variable plots for the PCAs in terms of snack patterns are presented in Figure S2D and S2E. As indicated by the weights of food groups after breakfast (Figure 2A), grain snack was characterized as relative high coefficients of refined grain, whole grain, added sugars, cheese, and eggs; starchy snack was characterized as relative high coefficients of white potato and other starchy food; fruit snack was characterized as high intake of fruits. Also, the participants in the grain snack consumed the most servings of refined grain (0.667±1.141, oz/d), whole grain (0.110±0.371, oz/d), cheese (0.039±0.238, cup/d), eggs (0.034±0.200, oz/d), and added sugars (4.131±5.547, tsp/d), and the participants in the starchy snack consumed the most servings of white potato (0.025±0.144, cup/d) and other starchy foods (0.026±0.163, cup/d). Meanwhile, the participants in the fruit snack consumed the most servings of fruits (citrus, melons, and berries: 0.084±0.277, cup/d; fruit excluding citrus, melons, and berries: 0.389±0.598, cup/d) (all the $P<0.05$) (Table S4). In the snacks after lunch (Figure 2B), grain snack was characterized as relative high coefficients of refined grain, added sugars, eggs, and whole grain; starchy snack was characterized as relative high coefficients of white potato and other starchy food; dairy snack was characterized as relative high coefficients of total dairy products, milk, and cheese. Similarly, the participants in the grain snack consumed the most servings of refined grain (1.269±1.345, oz/d), whole grain (0.186±0.495, oz/d), eggs (0.046±0.193, oz/d), and added sugars (5.918±6.621, tsp/d), and the participants in the starchy snack consumed the most servings of white potato (0.087±0.272, cup/d) and other starchy food (0.094±0.316, cup/d). Meanwhile, the participants in the dairy snack consumed the most servings of total dairy products (0.392±0.542, cup/d), milk (0.212±0.399, cup/d), and cheese (0.146±0.411) (all the $P<0.05$) (Table S5).

In the snacks after dinner (Figure 2C), starchy snack was characterized as relative high coefficients of white potato and other starchy products; grain snack was characterized as relative high coefficients of refined grain and whole grain; dairy snack was characterized as high intake of total dairy products, milk, and cheese. Similarly, the participants in the grain snack consumed the most servings of refined grain (1.241±1.424, oz/d) and added sugars (8.215±6.952, tsp/d), and the participants in the starchy snack consumed the most servings of white potato (0.081±0.232, cup/d) and other starchy products (0.090±0.294, cup/d). Meanwhile, the participants in the dairy snack consumed the most servings of total dairy products (0.693±0.587, cup/d), cheese (0.130±0.365, cup/d), whole grain (0.135±0.412, oz/d), and milk (0.523±0.553, cup/d) (all the $P<0.05$) (Table S6).

Validation of Meal and Snack Patterns Using PLS-DA

The PLS-DA was performed to validate the meal and snack patterns established in the PCA. The scatterplots showed that main meal and each snack pattern could be separated, which were further validated through permutation tests (Figure S3A through S3F). The VIP in dietary patterns of each time period are presented in Tables S7 and S8.

At breakfast, in the refined group, solid fats and add sugars were identified as the main food groups in the Western breakfast; white potato and other starchy food were identified as the main food groups in the starchy breakfast, and fruits were identified as the main food groups in the fruit breakfast (all the VIP >1 and $P<0.05$). At lunch, refined grain and solid fats were identified as the main food groups in the Western lunch; total vegetable, red and orange vegetable, tomato, and dark vegetable were identified as the main food groups in the vegetable lunch; fruits excluding citrus, melons, and berries was selected as the main food groups in the fruit lunch (all the VIP >1 and $P<0.05$). At dinner, refined grain, solid fats, and cheese were identified as the main food groups in the Western dinner; total vegetable, red and orange vegetable, and tomato were identified as the main food groups in the vegetable dinner; fruits excluding citrus, melons, and berries were identified as the main food group in the fruit dinner (all the VIP >1 and $P<0.05$).

For the snack patterns, the refined grain, added sugars, and whole grain were identified as the main food groups in the grain snack after breakfast; fruits were identified as the main food groups in the fruit snack after breakfast (all the VIP >1 and $P<0.05$). The refined grain and added sugars were identified as the main food groups in the grain snack after lunch; the total dairy products, milk, and cheese were identified as the main food groups in the dairy snack after lunch (all the VIP >1 and $P<0.05$). The refined grain was identified as the main food group in the grain snack after dinner; total dairy products and milk were was identified as the main food groups in the dairy snack after dinner (all the VIP >1 and $P<0.05$).

Cox Proportional Hazards Models

The association of main meal patterns at breakfast, lunch, and dinner with all-cause, CVD, and cancer mortalities are presented in Figure 3. As indicated

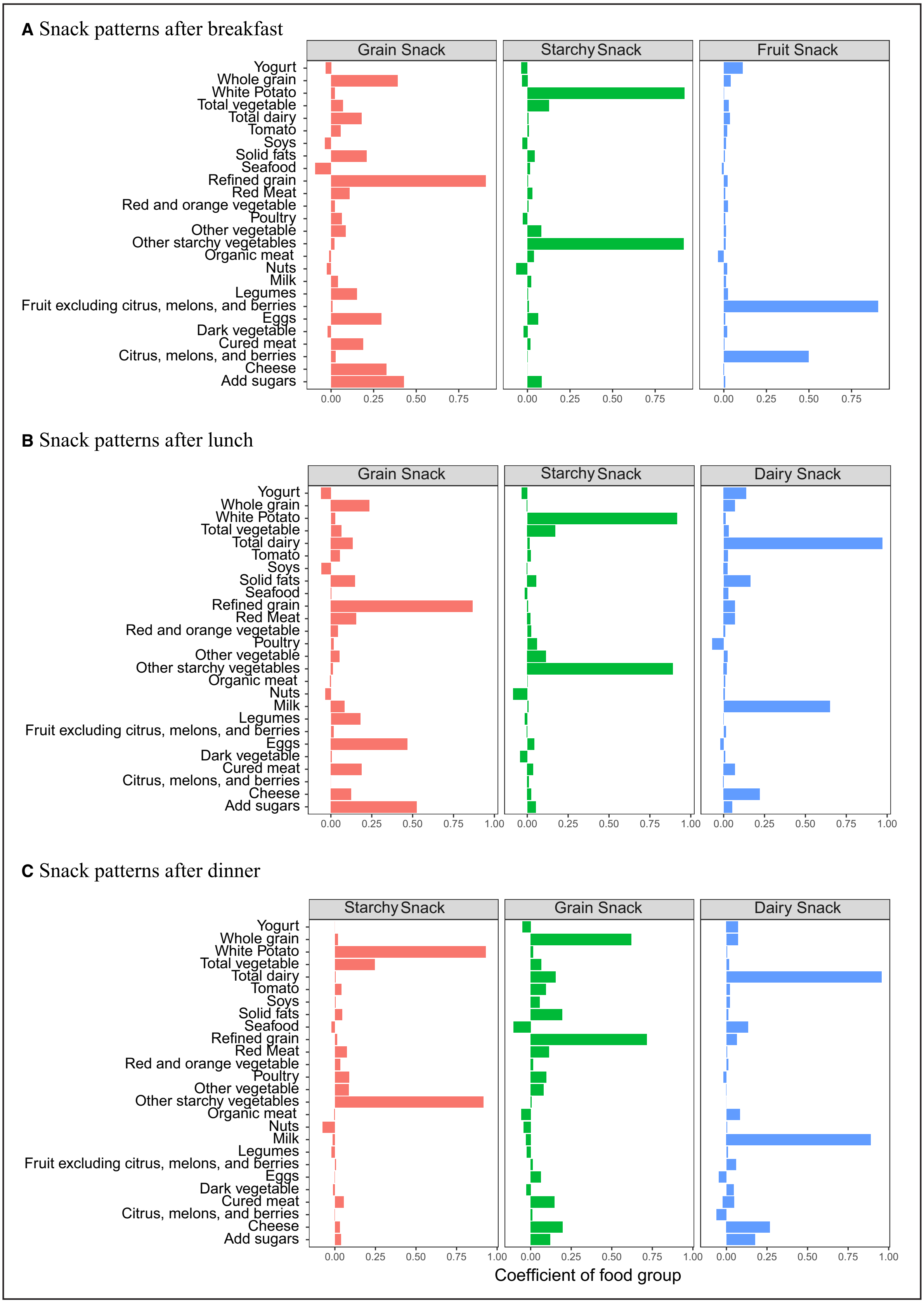

Figure 2. The coefficient of each food group in the snack patterns after breakfast (A), lunch (B), and dinner (C) in the total sample with adjustment for age, sex, and total daily energy intake (N=21 503).

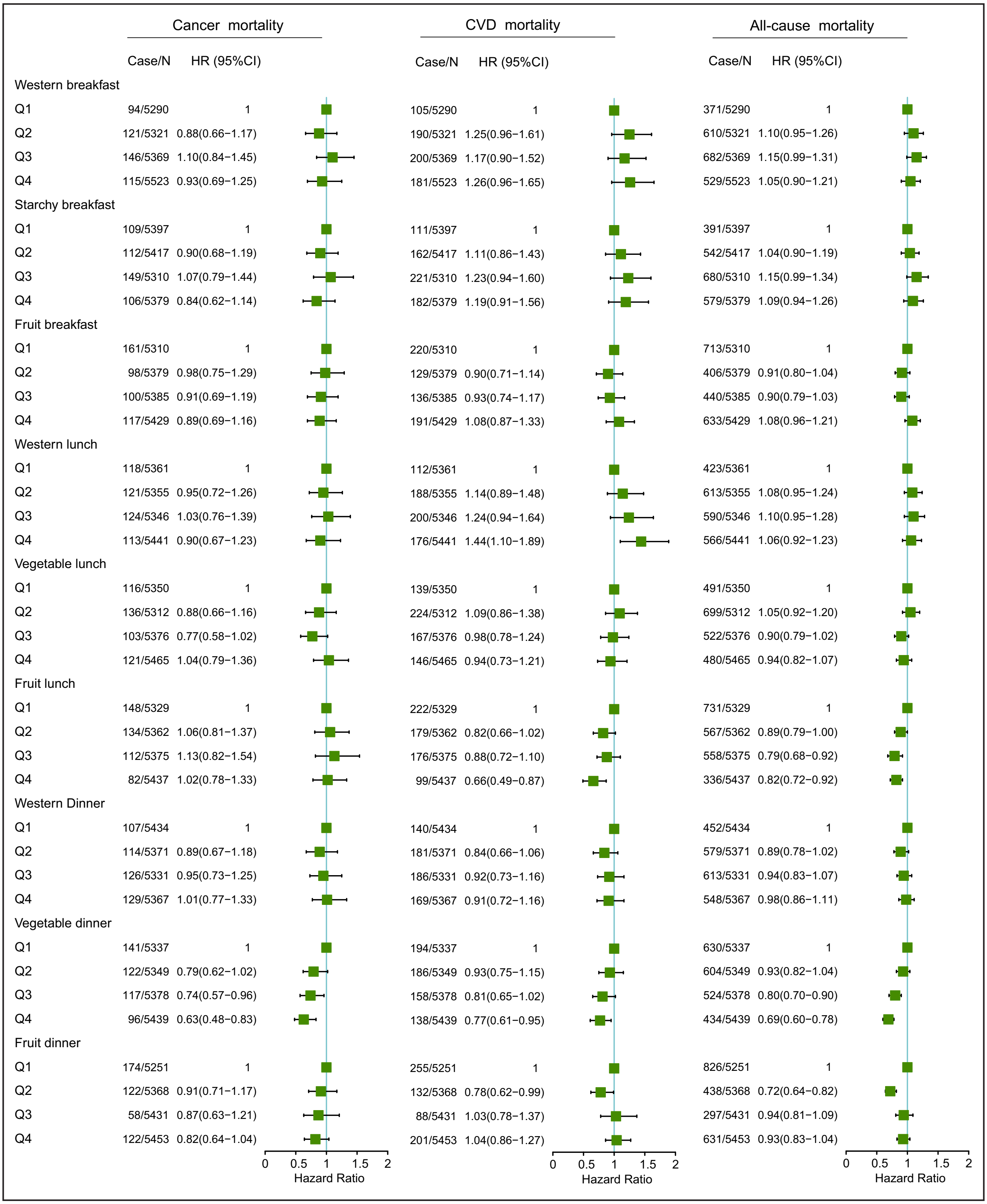

Figure 3. Adjusted HRs for dietary patterns at breakfast, lunch, and dinner and cancer, CVD, and all-cause mortality.
Adjustments included age, sex, ethnicity, income, education, exercise, smoking, alcohol intake, BMI, diabetes mellitus, hypertension, dyslipidemia, nutrient supplement use, total intake of energy, percentage of energy provided by snacks, fat, protein, cholesterol, breakfast skipping, lunch skipping, hours of restricted eating, dietary information collected at working day or weekend, and AHEI. AHEI indicates Alternative Healthy Eating Index; BMI, body mass index; Case/N, number of case subjects/total; CVD, cardiovascular disease; HRs, hazard ratios; and Q, quartile.

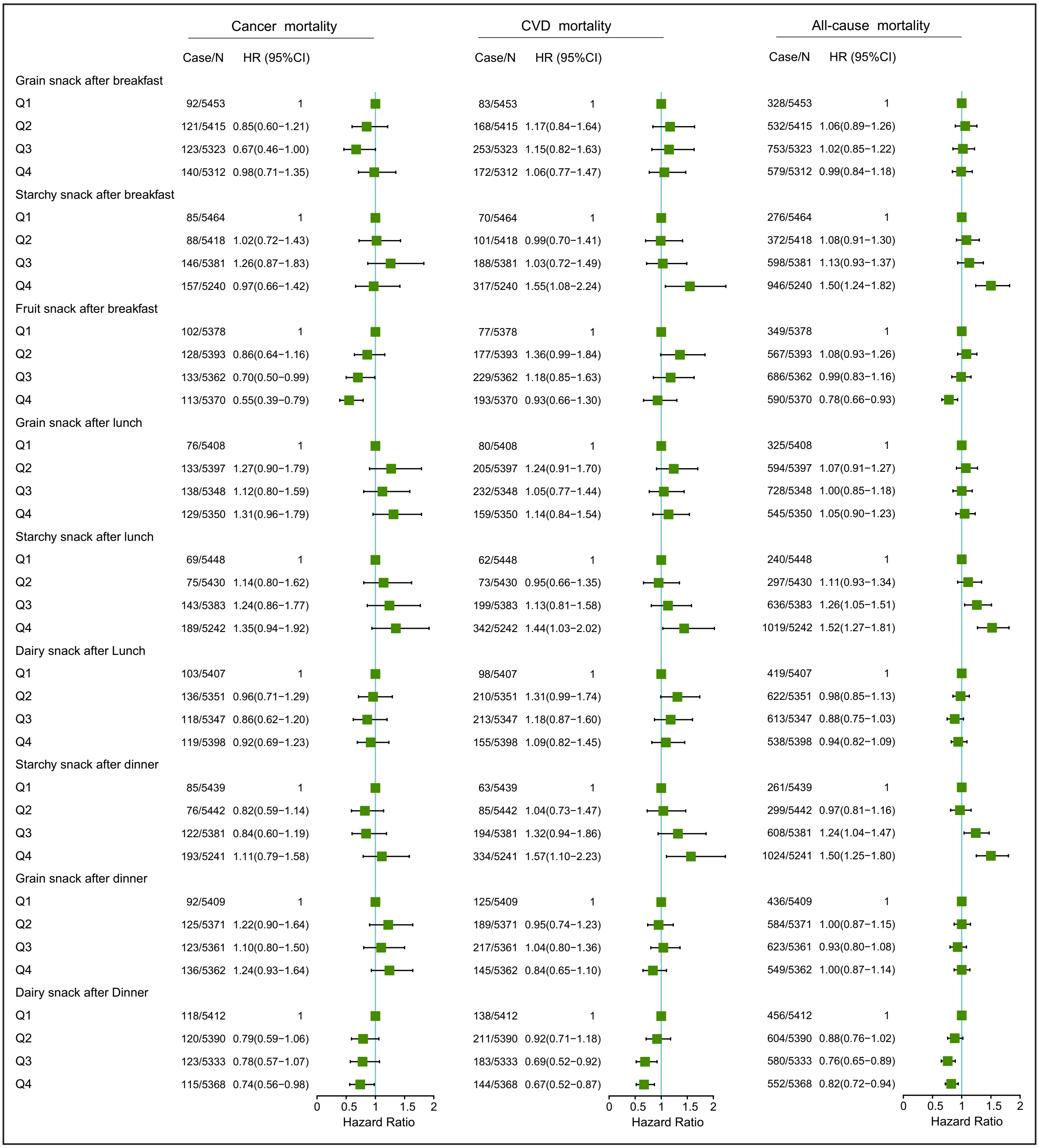

Figure 4. Adjusted HRs for snack patterns after breakfast, lunch, and dinner and cancer, CVD, and all-cause mortality. Adjustments included age, sex, ethnicity, income, education, exercise, smoking, alcohol intake, BMI, diabetes mellitus, hypertension, dyslipidemia, nutrient supplement use, total intake of energy, percentage of energy provided by snacks, fat, protein, cholesterol, breakfast skipping, lunch skipping, hours of restricted eating, dietary information collected at working day or weekend, and AHEI. AHEI, Alternative Healthy Eating Index; BMI, body mass index; Case/N, number of case subjects/total; CVD, cardiovascular disease; HRs, hazard ratios; and Q, quartile.

by hazard ratio (HR) and 95% CI, compared with the participants who were not in the meal patterns (Q1), participants who consumed the Western lunch (Q4) were more likely to die because of CVD (HR, 1.44; 95% CI, 1.10–1.89); whereas participants who consumed the fruit lunch pattern had lower mortality risks of all-cause (HR, 0.82; 95% CI, 0.72–0.92) and CVD (HR, 0.66; 95% CI, 0.49–0.87). At dinner, compared with the participants who were not in the dietary pattern (Q1), participants who consumed the vegetable dinner (Q4) had lower mortality risks of all-cause (HR, 0.69; 95% CI, 0.60–0.78), CVD (HR, 0.77; 95% CI, 0.61–0.95), and cancer (HR, 0.63; 95% CI, 0.48–0.83).

The association of snack patterns after breakfast, lunch, and dinner with all-cause, CVD, and cancer mortality are presented in Figure 4. After breakfast, compared with the participants who were not in the snack patterns (Q1), participants who consumed the fruit snack pattern (Q4) had lower mortality risks of all-cause (HR, 0.78; 95% CI, 0.66–0.93) and cancer (HR, 0.55; 95% CI, 0.39–0.78), and participants who consumed the starchy snack pattern (Q4) were more likely to die from all-cause (HR, 1.50; 95% CI, 1.24–1.82) and CVD (HR, 1.55; 95% CI, 1.08–2.24). Similarly, participants who consumed the starchy snack pattern (Q4) after lunch were more likely to die from all-cause (HR, 1.52; 95% CI, 1.27–1.81) and CVD (HR, 1.44; 95% CI, 1.03–2.02). After dinner, participants who consumed the starchy snack pattern (Q4) were more likely to die from all-cause (HR, 1.50; 95% CI, 1.25–1.80) and CVD (HR, 1.57; 95% CI, 1.10–2.23), whereas participants who consumed the dairy snack pattern (Q4) had lower mortality risks of all-cause (HR, 0.82; 95% CI, 0.72–0.94), CVD (HR, 0.67; 95% CI, 0.52–0.87), and cancer (HR, 0.74; 95% CI, 0.56–0.98).

Sensitivity Analysis

After exclusion of the participants who had follow-up time of <3 years or died within 3 years of follow-up, the association of meal and snack patterns with mortality outcomes was decreased, but still significant (Tables S9 and S10), indicating that the severe illness did not influence the above association. The second set of sensitivity analysis showed that after additional adjustment for the behavior of diet control, although the coefficients of each food group were varied, the representative food group (the highest coefficients) in each meal and snack pattern did not changing significantly (Figures S4 and S5), indicating that these meal and snack patterns were relatively robust, and the association of meal and snack patterns with mortality outcomes was still significant (Tables S11 and S12). The third set of sensitivity analysis showed that the association between main meal patterns and mortality outcomes was more obvious in the participants with low diet quality than with high diet quality. In the context of low diet quality, starchy breakfast was associated with higher mortality risks of CVD and all-cause, and the Western lunch was associated with CVD mortality. Meanwhile, the vegetable dinner was associated lower mortality risks of cancer, CVD, and all-cause (Table S13). In contrast, fruit lunch was associated with lower risk of CVD mortality, and the vegetable dinner was associated with lower all-cause mortality (Table S14); whereas no other significant association between main meal patterns and mortality outcomes was observed in the context of high diet quality (Table S14). For the snack patterns, in the context of low diet quality, grain snack and fruit snack after breakfast were associated with lower cancer mortality, and dairy snack after dinner was associated with lower mortality risks of CVD and all-cause (Table S15). In the context of high diet quality, starchy snack after lunch was associated with higher mortality risks of CVD and all-cause, and dairy snack after lunch was associated with higher risk of CVD mortality; whereas dairy snack after dinner was associated with lower mortality risks of cancer, CVD, and all-cause (Table S16).

DISCUSSION

To the best of our knowledge, this was the first study to examine the association of meal and snack patterns across a day with cancer, CVD, and all-cause mortalities. For main meals, this study found that meal patterns of fruit lunch and vegetable dinner were associated with decreased mortality risks of cancer, CVD, and all-cause, whereas Western lunch was associated with elevated mortality risks of CVD and all-cause. For snack patterns, this study found that snack patterns of fruit after breakfast and dairy products after dinner were associated with decreased mortality risks of cancer, CVD, and all-cause; whereas the starchy snack pattern after main meals was associated with elevated mortality risks of CVD and all-cause.

Although many studies reported the association of increased vegetable intake or vegetable dietary pattern with decreased cancer, CVD, and all-cause mortality,[18–20] it is still largely unknown whether vegetable intake at various times would impact health. Therefore, the most important finding of this study was that higher intake of vegetables at dinner was significantly associated with lower risks of cancer, CVD, and all-cause mortalities, whereas vegetables consumed at lunch did not have these beneficial effects. Moreover, the association between a vegetable dinner pattern and mortality outcomes was independent of a series of traditional dietary risk factors, in particular, overall diet quality (including total vegetable consumption) and breakfast skipping. The circadian pattern of metabolism and gut microbiota are likely the possible mechanisms underpinning the results of this study. First, when the total daily energy intake was held constant, vegetable dinner is frequently associated with lower energy intake in the evening. The recent randomized controlled trial and observational study have documented the beneficial effects of low energy intake at dinner on cardiometabolic health and long-term survival.[11,13] Animal studies also demonstrated that high energy consumption at dinner was tightly related to the disrupted clock gene and fat accumulation, and reduced energy intake at dinner could restore clock gene expression, leading to decreased glucose, blood lipid levels, and body weight.[21,22] On the other hand, gut microbes and their metabolites also have circadian patterns.[23] The abundance of bacteria that use dietary fiber from vegetables to generate short-chain fatty acids is frequently highest at night, and it gradually decreases in the daytime,[24] suggesting that high intake of vegetables at dinner can produce more short-chain fatty acids, which is more compatible with the circadian pattern of these bacteria. Short-chain fatty acids, as important metabolites of gut microbes, in addition to their beneficial effects on cardiometabolic health and cancer, have been reported in previous studies.[25,26]

Another key finding of this study is that Western lunch, characterized as high intakes of refined grain, cheese, cured meat, and red meat at lunch, was associated with elevated CVD and all-cause mortalities. The Western lunch typically contains high energy, total fat, and low-quality carbohydrate. A previous randomized controlled trial has reported that participants who consumed a high fat or carbohydrate meal at lunch were drowsier and sleepy,[27] which might increase duration of daytime napping through stimulating secretion of cholecystokinin and various gut peptides,[28,29] and disruption of the circadian pattern of serotonin. The association of lengthy napping in the afternoon with high CVD and all-cause mortality has been reported in previous studies, which may support the findings in this study.[30] Further, Western dietary pattern is associated with chronic, low-grade inflammation.[31] It has been reported that pro-inflammation cytokines in the blood also had an internal circadian pattern; they are usually highest at 4:00 AM with a gradual decrease during the daytime, and lowest in the afternoon.[32,33] A previous animal study has demonstrated that the later saturated fat was consumed, the more likely they disrupted the internal circadian pattern of pro-inflammation cytokines, resulting in the chronic, low-grade inflammation status; whereas consumption of anti-inflammatory food at the same time could restore the circadian pattern.[34] Consistent with the evidence, this study demonstrated that fruit lunch pattern and fruit snack pattern after breakfast were associated with low mortality risks of cancer, CVD, and all-cause.

Moreover, this study also found that higher intake of dairy products after dinner was associated with lower mortality risks of CVD and all-cause, whereas dairy products consumed after lunch was not. Currently, the association of dairy products consumption with CVD and all-cause mortalities was inconsistent,[35,36] and no study has examined the consumption time of dairy products. The beneficial effect of dairy products after dinner reported in this study could be explained by improved sleep quality. There is growing evidence that sleep quality is associated with all-cause and CVD mortalities.[37,38] Dairy products included high levels of tryptophan, which is the precursor of serotonin and melatonin.[39] In the evening, the synthesis of serotonin and melatonin was activated,[40] and higher dairy products after dinner might provide more tryptophan to synthesize serotonin and melatonin, which is more compatible with the circadian pattern of serotonin and melatonin for maintaining higher sleep quality. The observational studies and randomized controlled trial also found that dairy products consumption in the evening could improve sleep quality, especially for elderly people,[41,42] partially supporting the findings in this study. Further, results of this study also showed that participants with starchy snack pattern after breakfast, lunch, and dinner were more likely to die from CVD and all-cause mortalities. It seemed that consumption time did not modify the health impact of starchy snacks. Starchy snacks after main meals was usually fried potato crisps with high energy density, which provide energy similar to a main meal. It has been reported that higher consumption of fried potato was associated with elevated mortality in the previous study,[43] and the recent randomized controlled trial also demonstrated that high frequency of meals across a day could disrupt the expression of circadian genes, resulting in hyperglycemia and insulin resistance, partially supporting the above results.[44]

In addition, this study also observed that the association between main meal patterns and mortality outcomes was more obvious in the participants with low diet quality than high diet quality, suggesting that the intake timing for the main meal patterns was more important for the participants in the low diet quality than in the high diet quality; also, participants in the low diet quality might greatly decrease their mortality risks of cancer and CVD by changing their intake timing for the main meal patterns. Further, this study also observed that the positive association of starchy snack and dairy snack after lunch with mortalities of CVD and all-cause, and the negative association of dairy snack after dinner with mortalities of cancer, CVD, and all-cause, suggested that although participants had relatively high diet quality, they also should focus on their consumption time of snacks for decreasing the mortality risks of cancer and CVD.

Strengths and Limitations

This study has several strengths. First, this was the first study to examine the association of meal and snack patterns across a day with cancer, CVD, and all-cause mortality using high-quality dietary data from a well-designed population-based study (NHANES), which strengthens the understanding of the impact of consumption time for different foods on health. Second, the association result in this study was relatively robust with adjustment for a variety of important dietary confounders. These findings also emphasize that not only nutritional values but also timing of meals need to be taken into consideration for dietary recommendations to improve health. We also recognize that this study has certain limitations. First, although the self-reported 24-hour dietary recall is the most valid and commonly used instrument to capture diet information in observational studies, it is subject to measurement error because of day-to-day variations in food intake. Second, we had the opportunity to control a series of potential confounders, but this study still was observational in nature, and other unmeasured confounding factors cannot be ruled out. Third, we only used 2 dietary measurements in 2 weeks to predict long-term survival status in the general population, who may change dietary habits over time. Fourth, we recognized that the complex study design is a limitation in PCA, and the meal and snack patterns established in our study probably could not generalized to the noninstitutionalized household population of the United States. Therefore, future research is needed to evaluate the longitudinal effect of dietary patterns across meals on mortality outcomes. Fourth, this study only included American participants, which is likely to limit the generalizability of our findings to other ethnic populations. Last, although the NHANES documented the mortality status determined by the *ICD-10*, it did not make public the details of the cause of death. Therefore, this study cannot examine the association of main meal and snack patterns with details of the cause of death. Future study including this information is warranted to provide more comprehensive evidence for the health impacts of the timing of dietary patterns.

IMPLICATION AND CONCLUSIONS

Nutritional recommendation is a critical element for maintaining public health. Nutritional guidelines and intervention strategies should integrate and emphasize the importance of optimal consumption times for foods in a day. Based on the findings in this study, the optimal consumption time for fruit was likely in the daytime, and the optimal consumption time for vegetables was at dinner. The dairy products could be consumed as a snack after dinner. This information is of importance in providing nutritional recommendations for the public.

In conclusion, higher intake of fruit at lunch, and higher intake of vegetables and dairy products in the evening were associated with lower mortality risks of CVD, cancer, and all-cause; whereas higher intake of refined grain, cheese, added sugars, and cured meat at lunch, and higher intake of potato and starchy foods after main meals were associated with greater CVD and all-cause mortalities.

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Author contributions: W. Jiang, Wei, and Han conceived the study design. Xu, X. Wang, and Y. Li did the statistical analysis. Huang, G. Li, Y. Wang, and Sun repeated and validated the statistical analysis. Han, Sun, and X. Jiang wrote the manuscript. All authors provided critical revisions of the draft and approved the submitted draft. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted. Han is the guarantor.

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Disclosures

The authors declared that there were no conflict of interest.

Supplementary Material

Tables S1–S16
Figures S1–S5

REFERENCES

1. 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. DOI: 10.1017/S0029665116000306.
2. Challet E. The circadian regulation of food intake. *Nat Rev Endocrinol*. 2019;15:393–405. DOI: 10.1038/s41574-019-0210-x.
3. Henry CJ, Kaur B, Quek RYC. Chrononutrition in the management of diabetes. *Nutr Diabetes*. 2020;10:6. DOI: 10.1038/s41387-020-0109-6.
4. Asher G, Sassone-Corsi P. Time for food: the intimate interplay between nutrition, metabolism, and the circadian clock. *Cell*. 2015;161:84–92. DOI: 10.1016/j.cell.2015.03.015.

5. Morgan LM, Shi JW, Hampton SM, Frost G. Effect of meal timing and glycaemic index on glucose control and insulin secretion in healthy volunteers. *Br J Nutr*. 2012;108:1286–1291. DOI: 10.1017/S0007114511006507.
6. Loboda A, Kraft WK, Fine B, Joseph J, Nebozhyn M, Zhang C, He Y, Yang X, Wright C, Morris M, et al. Diurnal variation of the human adipose transcriptome and the link to metabolic disease. *BMC Med Genomics*. 2009;2:7. DOI: 10.1186/1755-8794-2-7.
7. Mekary RA, Giovannucci E, Willett WC, van Dam RM, Hu FB. Eating patterns and type 2 diabetes risk in men: breakfast omission, eating frequency, and snacking. *Am J Clin Nutr*. 2012;95:1182–1189. DOI: 10.3945/ajcn.111.028209.
8. Fuse Y, Hirao A, Kuroda H, Otsuka M, Tahara Y, Shibata S. Differential roles of breakfast only (one meal per day) and a bigger breakfast with a small dinner (two meals per day) in mice fed a high-fat diet with regard to induced obesity and lipid metabolism. *J Circadian Rhythms*. 2012;10:4. DOI: 10.1186/1740-3391-10-4.
9. Wu T, Sun L, ZhuGe F, Guo X, Zhao Z, Tang R, Chen Q, Chen L, Kato H, Fu Z. Differential roles of breakfast and supper in rats of a daily three-meal schedule upon circadian regulation and physiology. *Chronobiol Int*. 2011;28:890–903. DOI: 10.3109/07420528.2011.622599.
10. Sherman H, Genzer Y, Cohen R, Chapnik N, Madar Z, Froy O. Timed high-fat diet resets circadian metabolism and prevents obesity. *FASEB J*. 2012;26:3493–3502. DOI: 10.1096/fj.12-208868.
11. Jakubowicz D, Wainstein J, Ahrén B, Bar-Dayan Y, Landau Z, Rabinovitz HR, Froy O. High-energy breakfast with low-energy dinner decreases overall daily hyperglycaemia in type 2 diabetic patients: a randomised clinical trial. *Diabetologia*. 2015;58:912–919. DOI: 10.1007/s00125-015-3524-9.
12. Sutton EF, Beyl R, Early KS, Cefalu WT, Ravussin E, Peterson CM. Early time-restricted feeding improves insulin sensitivity, blood pressure, and oxidative stress even without weight loss in men with prediabetes. *Cell Metab*. 2018;27:1212–1221.e3. DOI: 10.1016/j.cmet.2018.04.010.
13. Han T, Gao J, Wang L, Li C, Qi L, Sun C, Li Y. The association of energy and macronutrient intake at dinner versus breakfast with disease-specific and all-cause mortality among people with diabetes: the U.S. National Health and Nutrition Examination Survey, 2003–2014. *Diabetes Care*. 2020;43:1442–1448. DOI: 10.2337/dc19-2289.
14. Hu FB. Dietary pattern analysis: a new direction in nutritional epidemiology. *Curr Opin Lipidol*. 2002;13:3–9. DOI: 10.1097/00041433-200202000-00002.
15. Shan Z, Rehm CD, Rogers G, Ruan M, Wang DD, Hu FB, Mozaffarian D, Zhang FF, Bhupathiraju SN. Trends in dietary carbohydrate, protein, and fat intake and diet quality among US adults, 1999–2016. *JAMA*. 2019;322:1178–1187. DOI: 10.1001/jama.2019.13771.
16. Kant AK, Graubard BI. 40-year trends in meal and snack eating behaviors of American adults. *J Acad Nutr Diet*. 2015;115:50–63. DOI: 10.1016/j.jand.2014.06.354.
17. Wang DD, Leung CW, Li Y, Ding EL, Chiuve SE, Hu FB, Willett WC. Trends in dietary quality among adults in the United States, 1999 through 2010. *JAMA Intern Med*. 2014;174:1587–1595. DOI: 10.1001/jamainternmed.2014.3422.
18. Aune D, Giovannucci E, Boffetta P, Fadnes LT, Keum N, Norat T, Greenwood DC, Riboli E, Vatten LJ, Tonstad S. Fruit and vegetable intake and the risk of cardiovascular disease, total cancer and all-cause mortality-a systematic review and dose-response meta-analysis of prospective studies. *Int J Epidemiol*. 2017;46:1029–1056. DOI: 10.1093/ije/dyw319.
19. He FJ, Nowson CA, Lucas M, MacGregor GA. Increased consumption of fruit and vegetables is related to a reduced risk of coronary heart disease: meta-analysis of cohort studies. *J Hum Hypertens*. 2007;21:717–728. DOI: 10.1038/sj.jhh.1002212.
20. Steffen LM, Jacobs DR Jr, Stevens J, Shahar E, Carithers T, Folsom AR. Associations of whole-grain, refined-grain, and fruit and vegetable consumption with risks of all-cause mortality and incident coronary artery disease and ischemic stroke: the Atherosclerosis Risk in Communities (ARIC) Study. *Am J Clin Nutr*. 2003;78:383–390. DOI: 10.1093/ajcn/78.3.383.
21. Kohsaka A, Laposky AD, Ramsey KM, Estrada C, Joshu C, Kobayashi Y, Turek FW, Bass J. High-fat diet disrupts behavioral and molecular circadian rhythms in mice. *Cell Metab*. 2007;6:414–421. DOI: 10.1016/j.cmet.2007.09.006.
22. Hatori M, Vollmers C, Zarrinpar A, DiTacchio L, Bushong E, Gill S, Leblanc M, Chaix A, Joens M, Fitzpatrick J, et al. Time-restricted feeding without reducing caloric intake prevents metabolic diseases in mice fed a high-fat diet. *Cell Metab*. 2012;15:848–860. DOI: 10.1016/j.cmet.2012.04.019.
23. Zarrinpar A, Chaix A, Yooseph S, Panda S. Diet and feeding pattern affect the diurnal dynamics of the gut microbiome. *Cell Metab*. 2014;20:1006–1017. DOI: 10.1016/j.cmet.2014.11.008.
24. Tahara Y, Yamazaki M, Sukigara H, Motohashi H, Sasaki H, Miyakawa H, Haraguchi A, Ikeda Y, Fukuda S, Shibata S. Gut microbiota-derived short chain fatty acids induce circadian clock entrainment in mouse peripheral tissue. *Sci Rep*. 2018;8:1395. DOI: 10.1038/s41598-018-19836-7.
25. Tang WH, Kitai T, Hazen SL. Gut microbiota in cardiovascular health and disease. *Circ Res*. 2017;120:1183–1196. DOI: 10.1161/CIRCRESAHA.117.309715.
26. Sivaprakasam S, Prasad PD, Singh N. Benefits of short-chain fatty acids and their receptors in inflammation and carcinogenesis. *Pharmacol Ther*. 2016;164:144–151. DOI: 10.1016/j.pharmthera.2016.04.007.
27. Lloyd HM, Green MW, Rogers PJ. Mood and cognitive performance effects of isocaloric lunches differing in fat and carbohydrate content. *Physiol Behav*. 1994;56:51–57. DOI: 10.1016/0031-9384(94)90260-7.
28. Stacher G, Bauer H, Steinringer H. Cholecystokinin decreases appetite and activation evoked by stimuli arising from the preparation of a meal in man. *Physiol Behav*. 1979;23:325–331. DOI: 10.1016/0031-9384(79)90374-3.
29. Bruck D, Armstrong S, Coleman G. Sleepiness after glucose in narcolepsy. *J Sleep Res*. 1994;3:171–179. DOI: 10.1111/j.1365-2869.1994.tb00125.x.
30. Yamada T, Hara K, Shojima N, Yamauchi T, Kadowaki T. Daytime napping and the risk of cardiovascular disease and all-cause mortality: a prospective study and dose-response meta-analysis. *Sleep*. 2015;38:1945–1953. DOI: 10.5665/sleep.5246.
31. Barbaresko J, Koch M, Schulze MB, Nöthlings U. Dietary pattern analysis and biomarkers of low-grade inflammation: a systematic literature review. *Nutr Rev*. 2013;71:511–527. DOI: 10.1111/nure.12035.
32. Gudewill S, Pollmächer T, Vedder H, Schreiber W, Fassbender K, Holsboer F. Nocturnal plasma levels of cytokines in healthy men. *Eur Arch Psychiatry Clin Neurosci*. 1992;242:53–56. DOI: 10.1007/BF02190343.
33. Cutolo M, Seriolo B, Craviotto C, Pizzorni C, Sulli A. Circadian rhythms in RA. *Ann Rheum Dis*. 2003;62:593–596. DOI: 10.1136/ard.62.7.593.
34. Kim SM, Neuendorff N, Chapkin RS, Earnest DJ. Role of inflammatory signaling in the differential effects of saturated and poly-unsaturated fatty acids on peripheral circadian clocks. *EBioMedicine*. 2016;7:100–111. DOI: 10.1016/j.ebiom.2016.03.037.
35. Farvid MS, Malekshah AF, Pourshams A, Poustchi H, Sepanlou SG, Sharafkhah M, Khoshnia M, Farvid M, Abnet CC, Kamangar F, et al. Dairy food intake and all-cause, cardiovascular disease, and cancer mortality: the Golestan cohort study. *Am J Epidemiol*. 2017;185:697–711. DOI: 10.1093/aje/kww139.
36. van Aerde MA, Soedamah-Muthu SS, Geleijnse JM, Snijder MB, Nijpels G, Stehouwer CD, Dekker JM. Dairy intake in relation to cardiovascular disease mortality and all-cause mortality: the Hoorn Study. *Eur J Nutr*. 2013;52:609–616. DOI: 10.1007/s00394-012-0363-z.
37. Garfield V, Joshi R, Garcia-Hernandez J, Tillin T, Chaturvedi N. The relationship between sleep quality and all-cause, CVD and cancer mortality: the Southall and Brent REvisited study (SABRE). *Sleep Med*. 2019;60:230–235. DOI: 10.1016/j.sleep.2019.03.012.
38. Kabat GC, Xue X, Kamensky V, Zaslavsky O, Stone KL, Johnson KC, Wassertheil-Smoller S, Shadyab AH, Luo J, Hale L, et al. The association of sleep duration and quality with all-cause and cause-specific mortality in the Women's Health Initiative. *Sleep Med*. 2018;50:48–54. DOI: 10.1016/j.sleep.2018.05.015.
39. Nongonierma AB, FitzGerald RJ. Milk proteins as a source of tryptophan-containing bioactive peptides. *Food Funct*. 2015;6:2115–2127. DOI: 10.1039/C5FO00407A.
40. Cipolla-Neto J, Amaral FGD. Melatonin as a hormone: new physiological and clinical insights. *Endocr Rev*. 2018;39:990–1028. DOI: 10.1210/er.2018-00084.
41. Valtonen M, Niskanen L, Kangas AP, Koskinen T. Effect of melatonin-rich night-time milk on sleep and activity in elderly institutionalized subjects. *Nord J Psychiatry*. 2005;59:217–221. DOI: 10.1080/08039480510023034.

42. Yamamura S, Morishima H, Kumano-go T, Suganuma N, Matsumoto H, Adachi H, Sigedo Y, Mikami A, Kai T, Masuyama A, et al. The effect of *Lactobacillus helveticus* fermented milk on sleep and health perception in elderly subjects. *Eur J Clin Nutr*. 2009;63:100–105. DOI: 10.1038/sj.ejcn.1602898.
43. Veronese N, Stubbs B, Noale M, Solmi M, Vaona A, Demurtas J, Nicetto D, Crepaldi G, Schofield P, Koyanagi AI, et al. Fried potato consumption is associated with elevated mortality: an 8-y longitudinal cohort study. *Am J Clin Nutr*. 2017;106:162–167. DOI: 10.3945/ajcn.117.154872.
44. Jakubowicz D, Landau Z, Tsameret S, Wainstein J, Raz I, Ahren BO, Chapnik N, Barnea M, Ganz T, Menaged M, et al. Reduction in glycated hemoglobin and daily insulin dose alongside circadian clock upregulation in patients with type 2 diabetes consuming a three-meal diet: a randomized clinical trial. *Diabetes Care*. 2019;42:2171–2180. DOI: 10.2337/dc19-1142.

SUPPPLEMENTAL MATERIAL

Table S1. The differences for the food groups across meal patterns at breakfast.

Food groups	Western Breakfast	Starchy Breakfast	Fruit Breakfast	*P*-values
Refined grain (oz/d)	2.892±1.842	1.233±1.477	1.194±1.379	$P<0.001$
Whole grain (oz/d)	0.543±0.923	0.470±0.751	0.571±0.771	$P<0.001$
Total vegetable (cup/d)	0.200±0.411	0.315±0.593	0.120±0.335	$P<0.001$
Dark vegetable (cup /d)	0.006±0.043	0.005±0.044	0.008±0.077	$P=0.006$
Red and orange vegetable (cup/d)	0.060±0.171	0.058±0.183	0.138±0.160	$P<0.001$
Tomato (cup/d)	0.044±0.123	0.037±0.112	0.027±0.118	$P<0.001$
Other vegetable (cup/d)	0.084±0.217	0.092±0.350	0.038±0.149	$P<0.001$
White potato (cup/d)	0.043±0.153	0.143±0.304	0.032±0.147	$P<0.001$
Other starchy vegetable (cup/d)	0.063±0.237	0.172±0.435	0.038±0.193	$P<0.001$
Fruit excluding citrus, melons and berries (cup/d)	0.262±0.492	0.319±0.546	0.865±0.619	$P<0.001$
Citrus, melons and berries (cup/d)	0.062±0.221	0.050±0.190	0.241±0.459	$P<0.001$
Total Dairy products (cup/d)	0.457±0.579	0.485±0.595	0.472±0.530	$P<0.001$
Milk (cup/d)	0.342±0.495	0.417±0.571	0.371±0.477	$P<0.001$
Cheese (cup/d)	0.105±0.298	0.053±0.176	0.064±0.214	$P<0.001$
Yogurt (cup/d)	0.006±0.050	0.012±0.080	0.031±0.134	$P<0.001$
Cured meat (oz/d)	1.184±1.885	0.985±1.705	0.621±1.478	$P<0.001$
Seafood (oz/d)	0.034±0.283	0.044±0.369	0.042±0.387	$P=0.080$

Red meat (oz/d)	0.345±1.015	0.263±0.918	0.088±0.487	$P<0.001$
Poultry (oz/d)	0.255±0.864	0.190±0.724	0.089±0.506	$P<0.001$
Organic meat (oz/d)	0.013±0.158	0.015±0.171	0.003±0.069	$P<0.001$
Eggs (oz/d)	0.363±0.629	0.594±0.805	0.354±0.633	$P<0.001$
Nuts (oz/d)	0.073±0.347	0.043±0.214	0.112±0.454	$P<0.001$
Legumes (oz/d)	0.330±1.031	0.165±0.731	0.080±0.526	$P<0.001$
Soys (oz/d)	0.010±0.106	0.006±0.068	0.017±0.126	$P<0.001$
Add sugars (tsp/d)	5.364±5.314	3.494±4.255	3.111±3.448	$P<0.001$
Solid fats (grams/d)	12.915±11.320	8.932±9.119	7.440±8.587	$P<0.001$

Adjustments included age, sex, and total intake of energy. Values are described as means±SD. 1 cup = 236.59 g; 1 oz = 28.35 g; 1 tablespoon =15 mL.

Table S2. The differences for the food groups across meal patterns at lunch.

Food groups	Western Lunch	Vegetable Lunch	Fruit Lunch	*P*-values
Refined grain (oz/d)	3.736±2.127	2.100±2.142	1.799±1.705	$P<0.001$
Whole grain (oz/d)	0.213±0.640	0.168±0.497	0.214±0.496	$P<0.001$
Total vegetable (cup/d)	0.603±0.616	1.333±0.760	0.615±0.685	$P<0.001$
Dark vegetable (cup /d)	0.021±0.093	0.150±0.338	0.067±0.221	$P<0.001$
Red and orange vegetable (cup/d)	0.186±0.303	0.447±0.448	0.167±0.291	$P<0.001$
Tomato (cup/d)	0.170±0.258	0.310±0.327	0.117±0.204	$P<0.001$
Other vegetable (cup/d)	0.249±0.339	0.590±0.545	0.240±0.367	$P<0.001$
White potato (cup/d)	0.111±0.264	0.135±0.303	0.115±0.273	$P<0.001$
Other starchy vegetable (cup/d)	0.130±0.314	0.203±0.410	0.153±0.360	$P<0.001$
Fruit excluding citrus, melons and berries (cup/d)	0.149±0.383	0.148±0.355	0.551±0.567	$P<0.001$
Citrus, melons and berries (cup/d)	0.034±0.168	0.050±0.341	0.170±0.491	$P<0.001$
Total Dairy products (cup/d)	0.488±0.651	0.363±0.573	0.363±0.512	$P<0.001$
Milk (cup/d)	0.054±0.151	0.086±0.273	0.120±0.305	$P<0.001$
Cheese (cup/d)	0.425±0.632	0.263±0.492	0.214±0.397	$P<0.001$
Yogurt (cup/d)	0.007±0.072	0.012±0.086	0.026±0.121	$P<0.001$
Cured meat (oz/d)	3.057±2.958	2.721±2.554	2.276±2.360	$P<0.001$
Seafood (oz/d)	0.231±1.054	0.355±1.144	0.303±1.011	$P<0.001$

Red meat (oz/d)	0.867±1.695	0.885±1.623	0.514±1.196	$P<0.001$
Poultry (oz/d)	0.748±1.498	0.851±1.450	0.611±1.240	$P<0.001$
Organic meat (oz/d)	0.013±0.235	0.007±0.115	0.013±0.253	$P=0.142$
Eggs (oz/d)	0.153±0.452	0.089±0.255	0.117±0.374	$P<0.001$
Nuts (oz/d)	0.078±0.545	0.085±0.547	0.171±0.732	$P<0.001$
Legumes (oz/d)	0.551±1.484	0.457±1.291	0.213±0.787	$P<0.001$
Soys (oz/d)	0.014±0.118	0.025±0.180	0.022±0.175	$P<0.001$
Add sugars (tsp/d)	5.743±6.328	3.385±4.655	3.790±4.774	$P<0.001$
Solid fats (grams/d)	17.003±14.640	10.289±11.444	9.694±11.066	$P<0.001$

Adjustments included age, sex, and total intake of energy. Values are described as means±SD. 1 cup = 236.59 g; 1 oz = 28.35 g; 1 tablespoon =15 mL.

Table S3. The differences for the food groups across meal patterns at dinner.

Food groups	Western Dinner	Vegetable Dinner	Fruit Dinner	*P*-values
Refined grain (oz/d)	4.382±2.273	2.474±2.246	2.156±4.898	$P<0.001$
Whole grain (oz/d)	0.168±0.58	0.132±0.444	0.187±0.526	$P<0.001$
Total vegetable (cup/d)	0.889±0.739	1.703±0.908	0.940±0.882	$P<0.001$
Dark vegetable (cup /d)	0.058±0.176	0.163±0.343	0.096±0.233	$P<0.001$
Red and orange vegetable (cup/d)	0.254±0.330	0.592±0.472	0.238±0.360	$P<0.001$
Tomato (cup/d)	0.245±0.312	0.421±0.357	0.158±0.251	$P<0.001$
Other vegetable (cup/d)	0.338±0.412	0.722±0.703	0.365±0.579	$P<0.001$
White potato (cup/d)	0.160±0.332	0.189±0.368	0.184±0.350	$P<0.001$
Other starchy vegetable (cup/d)	0.229±0.451	0.309±0.527	0.277±0.494	$P<0.001$
Fruit excluding citrus, melons and berries (cup/d)	0.124±0.356	0.132±0.345	0.489±0.538	$P<0.001$
Citrus, melons and berries (cup/d)	0.048±0.227	0.048±0.210	0.184±0.448	$P<0.001$
Total Dairy products (cup/d)	0.773±0.826	0.488±0.679	0.446±0.602	$P<0.001$
Milk (cup/d)	0.148±0.338	0.172±0.416	0.195±0.391	$P<0.001$
Cheese (cup/d)	0.618±0.734	0.309±0.528	0.232±0.448	$P<0.001$
Yogurt (cup/d)	0.005±0.044	0.004±0.037	0.016±0.084	$P<0.001$
Cured meat (oz/d)	3.256±2.844	3.199±2.525	2.944±2.557	$P<0.001$
Seafood (oz/d)	0.383±1.323	0.463±1.395	0.481±1.359	$P<0.001$

Red meat (oz/d)	1.086±1.596	1.303±1.785	0.998±1.658	$P<0.001$
Poultry (oz/d)	0.876±1.610	0.932±1.496	0.875±1.403	$P=0.034$
Organic meat (oz/d)	0.016±0.188	0.007±0.119	0.014±0.183	$P=0.015$
Eggs (oz/d)	0.134±0.307	0.101±0.249	0.111±0.275	$P<0.001$
Nuts (oz/d)	0.048±0.288	0.070±0.364	0.122±0.498	$P<0.001$
Legumes (oz/d)	0.396±1.117	0.458±1.186	0.278±0.838	$P<0.001$
Soys (oz/d)	0.032±0.248	0.024±0.188	0.023±0.166	$P=0.058$
Add sugars (tsp/d)	5.642±6.602	3.825±5.108	4.500±5.404	$P<0.001$
Solid fats (grams/d)	23.196±16.238	14.128±13.428	13.604±12.964	$P<0.001$

Adjustments included age, sex, and total intake of energy. Values are described as means±SD. 1 cup = 236.59 g; 1 oz = 28.35 g; 1 tablespoon =15 mL.

Table S4. The differences for the food groups across snack patterns after breakfast.

Food groups	Grain Snack	Starchy Snack	Fruit Snack	*P*-values
Refined grain (oz/d)	0.667±1.141	0.131±0.588	0.214±0.675	$P<0.001$
Whole grain (oz/d)	0.110±0.371	0.006±0.083	0.068±0.329	$P<0.001$
Total vegetable (cup/d)	0.031±0.155	0.050±0.227	0.023±0.157	$P<0.001$
Dark vegetable (cup /d)	0.001±0.025	0.001±0.016	0.001±0.028	$P=0.903$
Red and orange vegetable (cup/d)	0.009±0.080	0.006±0.066	0.010±0.101	$P=0.578$
Tomato (cup/d)	0.009±0.077	0.005±0.060	0.006±0.080	$P=0.227$
Other vegetable (cup/d)	0.009±0.071	0.014±0.116	0.006±0.055	$P<0.001$
White potato (cup/d)	0.010±0.085	0.025±0.144	0.006±0.070	$P<0.001$
Other starchy vegetable (cup/d)	0.010±0.088	0.026±0.163	0.008±0.107	$P<0.001$
Fruit excluding citrus, melons and berries (cup/d)	0.105±0.333	0.082±0.305	0.389±0.598	$P<0.001$
Citrus, melons and berries (cup/d)	0.038±0.196	0.023±0.147	0.084±0.277	$P<0.001$
Total Dairy products (cup/d)	0.124±0.366	0.059±0.253	0.067±0.267	$P<0.001$
Milk (cup/d)	0.077±0.252	0.047±0.217	0.044±0.211	$P<0.001$
Cheese (cup/d)	0.039±0.238	0.009±0.106	0.012±0.090	$P<0.001$
Yogurt (cup/d)	0.006±0.055	0.001±0.024	0.008±0.060	$P<0.001$
Cured meat (oz/d)	0.160±0.782	0.054±0.462	0.091±0.642	$P<0.001$
Seafood (oz/d)	0.005±0.087	0.007±0.179	0.001±0.036	$P=0.002$
Red meat (oz/d)	0.026±0.251	0.021±0.268	0.018±0.258	$P=0.016$
Poultry (oz/d)	0.021±0.251	0.004±0.068	0.027±0.311	$P=0.002$
Organic meat (oz/d)	0.002±0.092	0.002±0.093	0.001±0.001	$P=0.174$
Eggs (oz/d)	0.034±0.200	0.023±0.193	0.021±0.187	$P=0.003$
Nuts (oz/d)	0.090±0.421	0.014±0.183	0.095±0.532	$P<0.001$

Legumes (oz/d)	0.014±0.218	0.003±0.067	0.015±0.226	*P*=0.313
Soys (oz/d)	0.007±0.062	0.001±0.022	0.011±0.112	*P*＜0.001
Add sugars (tsp/d)	4.131±5.547	2.343±5.108	1.218±3.057	*P*＜0.001
Solid fats (grams/d)	4.727±7.752	1.499±4.912	1.493±4.333	*P*＜0.001

Adjustments included age, sex, and total intake of energy. Values are described as means±SD. 1 cup = 236.59 g; 1 oz = 28.35 g; 1 tablespoon =15 mL.

Table S5. The differences for the food groups across snack patterns after lunch.

Food groups	Grain Snack	Starchy Snack	Dairy Snack	*P*-values
Refined grain (oz/d)	1.269±1.345	0.297±0.796	0.496±1.015	*P*＜0.001
Whole grain (oz/d)	0.186±0.495	0.049±0.271	0.094±0.362	*P*＜0.001
Total vegetable (cup/d)	0.087±0.242	0.164±0.403	0.070±0.247	*P*＜0.001
Dark vegetable (cup /d)	0.003±0.043	0.001±0.020	0.003±0.049	*P*=0.082
Red and orange vegetable (cup/d)	0.025±0.118	0.026±0.160	0.019±0.103	*P*＜0.001
Tomato (cup/d)	0.018±0.083	0.015±0.095	0.015±0.078	*P*=0.045
Other vegetable (cup/d)	0.026±0.112	0.042±0.218	0.020±0.137	*P*＜0.001
White potato (cup/d)	0.030±0.143	0.087±0.272	0.025±0.142	*P*＜0.001
Other starchy vegetable (cup/d)	0.030±0.147	0.094±0.316	0.028±0.160	*P*＜0.001
Fruit excluding citrus, melons and berries (cup/d)	0.183±0.434	0.180±0.458	0.177±0.419	*P*=0.152
Citrus, melons and berries (cup/d)	0.042±0.213	0.055±0.346	0.044±0.206	*P*=0.001
Total Dairy products (cup/d)	0.186±0.389	0.105±0.326	0.392±0.542	*P*＜0.001
Milk (cup/d)	0.100±0.256	0.075±0.273	0.212±0.399	*P*＜0.001
Cheese (cup/d)	0.079±0.292	0.027±0.172	0.146±0.411	*P*＜0.001
Yogurt (cup/d)	0.003±0.036	0.002±0.026	0.027±0.117	*P*＜0.001
Cured meat (oz/d)	0.363±1.346	0.169±0.815	0.270±1.060	*P*=0.001
Seafood (oz/d)	0.026±0.292	0.012±0.195	0.031±0.420	*P*=0.110
Red meat (oz/d)	0.080±0.496	0.023±0.215	0.060±0.420	*P*＜0.001
Poultry (oz/d)	0.050±0.373	0.072±0.523	0.020±0.200	*P*＜0.001
Organic meat (oz/d)	0.001±0.030	0.001±0.030	0.001±0.054	*P*=0.584
Eggs (oz/d)	0.046±0.193	0.018±0.143	0.014±0.080	*P*＜0.001
Nuts (oz/d)	0.194±0.676	0.056±0.359	0.225±0.801	*P*＜0.001

Legumes (oz/d)	0.044±0.387	0.009±0.152	0.018±0.228	*P*＜0.001
Soys (oz/d)	0.004±0.042	0.005±0.068	0.008±0.090	*P*=0.006
Add sugars (tsp/d)	5.918±6.621	2.897±5.513	3.280±4.620	*P*＜0.001
Solid fats (grams/d)	8.441±10.092	2.994±6.518	7.217±9.947	*P*＜0.001

Adjustments included age, sex, and total intake of energy. Values are described as means±SD. 1 cup = 236.59 g; 1 oz = 28.35 g; 1 tablespoon =15 mL.

Table S6. The differences for the food groups across snack patterns after dinner.

Food groups	Grain Snack	Starchy Snack	Dairy Snack	*P*-values
Refined grain (oz/d)	1.241±1.424	0.308±0.831	0.646±1.020	$P < 0.001$
Whole grain (oz/d)	0.077±0.266	0.090±0.357	0.135±0.412	$P < 0.001$
Total vegetable (cup/d)	0.077±0.233	0.139±0.363	0.062±0.246	$P < 0.001$
Dark vegetable (cup /d)	0.003±0.050	0.002±0.041	0.005±0.066	P=0.257
Red and orange vegetable (cup/d)	0.023±0.111	0.015±0.091	0.017±0.107	P=0.004
Tomato (cup/d)	0.015±0.075	0.011±0.068	0.013±0.078	P=0.003
Other vegetable (cup/d)	0.021±0.100	0.030±0.182	0.015±0.100	$P < 0.001$
White potato (cup/d)	0.030±0.139	0.081±0.232	0.023±0.123	$P < 0.001$
Other starchy vegetable (cup/d)	0.029±0.142	0.090±0.294	0.025±0.165	$P < 0.001$
Fruit excluding citrus, melons and berries (cup/d)	0.138±0.363	0.131±0.351	0.154±0.380	P=0.062
Citrus, melons and berries (cup/d)	0.052±0.330	0.054±0.306	0.045±0.234	P=0.264
Total Dairy products (cup/d)	0.307±0.450	0.161±0.363	0.693±0.587	$P < 0.001$
Milk (cup/d)	0.245±0.408	0.112±0.283	0.523±0.553	$P < 0.001$
Cheese (cup/d)	0.044±0.179	0.027±0.196	0.130±0.365	$P < 0.001$
Yogurt (cup/d)	0.012±0.083	0.019±0.106	0.032±0.129	$P < 0.001$
Cured meat (oz/d)	0.321±1.183	0.195±0.887	0.231±1.059	$P < 0.001$
Seafood (oz/d)	0.056±0.510	0.013±0.204	0.008±0.166	$P < 0.001$
Red meat (oz/d)	0.071±0.432	0.041±0.321	0.044±0.348	$P < 0.001$
Poultry (oz/d)	0.033±0.270	0.077±0.511	0.033±0.324	$P < 0.001$
Organic meat (oz/d)	0.001±0.020	0.006±0.252	0.007±0.258	P=0.015
Eggs (oz/d)	0.063±0.194	0.013±0.070	0.021±0.079	$P < 0.001$

Nuts (oz/d)	0.200±0.803	0.060±0.429	0.227±0.977	$P < 0.001$
Legumes (oz/d)	0.016±0.217	0.004±0.078	0.010±0.156	$P=0.027$
Soys (oz/d)	0.002±0.021	0.004±0.052	0.005±0.055	$P=0.004$
Add sugars (tsp/d)	8.215±6.952	2.891±4.957	5.317±5.909	$P < 0.001$
Solid fats (grams/d)	11.912±11.045	4.418±7.989	11.175±10.707	$P < 0.001$

Adjustments included age, sex, and total intake of energy. Values are described as means±SD. 1 cup = 236.59 g; 1 oz = 28.35 g; 1 tablespoon =15 mL.

Table S7. VIP values of the food groups across meals patterns.

Meal patterns	Food group	VIP	*P*-value	Dietary Pattern
Breakfast	Refined grain (oz/d)	2.42	*P*<0.001	western breakfast
	Fruit excluding citrus, melons and berries (cup/d)	2.20	*P*<0.001	fruit breakfast
	White potato (cup/d)	1.52	*P*<0.001	starchy breakfast
	Citrus, melons and berries (cup/d)	1.32	*P*<0.001	fruit breakfast
	Other starchy vegetable (cup/d)	1.28	*P*<0.001	starchy breakfast
	Add sugars (tsp/d)	1.16	*P*<0.001	western breakfast
	Solid fats (grams/d)	1.16	*P*<0.001	western breakfast
	Total vegetable (cup/d)	2.08	*P*<0.001	vegetable lunch
	Refined grain (oz/d)	1.94	*P*<0.001	western lunch

Lunch	Fruit excluding citrus, melons and berries (cup/d)	1.87	*P*<0.001	fruit lunch
	Red and orange vegetable (cup/d)	1.59	*P*<0.001	vegetable lunch
	Tomato (cup/d)	1.37	*P*<0.001	vegetable lunch
	Solid fats (grams/d)	1.26	*P*<0.001	western lunch
	Dark vegetable (cup/d)	1.03	*P*<0.001	vegetable lunch
Dinner	Refined grain (oz/d)	1.96	*P*<0.001	western dinner
	Total vegetable (cup/d)	1.93	*P*<0.001	vegetable dinner
	Red and orange vegetable (cup/d)	1.84	*P*<0.001	vegetable dinner
	Fruit excluding citrus, melons and berries (cup/d)	1.76	*P*<0.001	Fruit dinner
	Tomato (cup/d)	1.60	*P*<0.001	vegetable dinner
	Solid fats (grams/d)	1.40	*P*<0.001	western dinner

Cheese (cup/d)	1.31	*P*<0.001	western dinner

VIP values were measured based on the PLS-DA models. *P*-values were adjusted by age, sex, and total intake of energy. 1 cup = 236.59 g; 1 oz = 28.35 g; 1 tablespoon =15 mL.

Table S8. VIP values of the food groups across snacks patterns.

Snacks patterns	Food group	VIP	*P*-value	Dietary Pattern
Snack patterns after breakfast	Fruit excluding citrus, melons and berries (cup/d)	2.77	*P*<0.001	fruit snack
	Refined grain (oz/d)	2.02	*P*<0.001	grain snack
	Add sugars (tsp/d)	1.85	*P*<0.001	grain snack
	Whole grain (oz/d)	1.11	*P*<0.001	grain snack
	Citrus, melons and berries (cup/d)	1.08	*P*<0.001	fruit snack
Snack patterns after lunch	Refined grain (oz/d)	2.48	*P*<0.001	grain snack
	Total Dairy products (cup/d)	2.15	*P*<0.001	dairy snack
	Add sugars (tsp/d)	1.57	*P*<0.001	grain snack
	Milk (cup/d)	1.51	*P*<0.001	dairy snack
	Cheese (cup/d)	1.23	*P*<0.001	dairy snack
	Total Dairy	2.40	*P*<0.001	dairy snack

Snack patterns after dinner	products (cup/d)			
	Milk (cup/d)	2.05	*P*<0.001	dairy snack
	Refined grain (oz/d)	2.02	*P*<0.001	grain snack

VIP values were measured based on the PLS-DA models. *P*-values were adjusted by age, sex, and total intake of energy. 1 cup = 236.59 g; 1 oz = 28.35 g; 1 tablespoon =15 mL.

Table S9. Adjusted HRs for meal patterns at breakfast, lunch and dinner and cancer, CVD and all-cause mortality after excluding the participants who had follow-up time of less than three years or died within three years of follow-up.

	Cancer mortality		CVD mortality		All-cause mortality	
	Case/N	HR (95%CI)	Case/N	HR (95%CI)	Case/N	HR (95%CI)
Western breakfast						
Q1	71/4665	1	88/4665	1	290/4665	1
Q2	101/4768	0.97(0.70-1.34)	155/4768	1.22(0.92-1.62)	505/4768	1.14(0.98-1.33)
Q3	125/4842	1.26(0.93-1.71)	174/4842	1.21(0.91-1.60)	584/4842	1.22(1.05-1.42)
Q4	95/4928	1.01(0.72-1.41)	151/4928	1.23(0.92-1.65)	438/4928	1.07(0.91-1.26)
P for trend		0.196		0.495		0.042
Starchy breakfast						
Q1	93/4826	1	96/4826	1	325/4826	1
Q2	89/4862	0.85(0.62-1.15)	132/4862	1.07(0.81-1.41)	443/4862	1.01(0.87-1.17)
Q3	122/4737	1.05(0.75-1.45)	186/4737	1.18(0.88-1.58)	563/4737	1.13(0.96-1.32)
Q4	88/4778	0.83(0.59-1.16)	154/4778	1.20(0.90-1.60)	486/4778	1.10(0.93-1.29)
P for trend		0.264		0.586		0.314
Fruit breakfast						
Q1	135/4715	1	175/4715	1	582/4715	1
Q2	82/4792	0.94(0.70-1.26)	112/4792	0.93(0.72-1.21)	338/4792	0.89(0.77-1.04)
Q3	76/4809	0.81(0.60-1.10)	117/4809	0.95(0.74-1.22)	361/4809	0.88(0.76-1.01)
Q4	99/4887	0.89(0.68-1.18)	164/4887	1.11(0.89-1.40)	536/4887	1.08(0.95-1.23)
P for trend		0.264		0.496		0.010

Western lunch						
Q1	100/4795	1	99/4795	1	367/4795	1
Q2	98/4765	0.94(0.69-1.27)	158/4765	1.11(0.85-1.47)	493/4765	1.02(0.88-1.18)
Q3	100/4797	0.99(0.71-1.38)	165/4797	1.17(0.87-1.59)	490/4797	1.07(0.91-1.26)
Q4	94/4846	0.91(0.65-1.27)	146/4846	1.39(1.04-1.87)	467/4846	1.02(0.87-1.20)
P for trend		0.911		0.115		0.825
Vegetable lunch						
Q1	91/4854	1	119/4854	1	400/4854	1
Q2	119/4750	0.87(0.64-1.18)	193/4750	1.04(0.80-1.34)	597/4750	1.03(0.89-1.19)
Q3	81/4784	0.76(0.55-1.04)	130/4794	0.89(0.69-1.15)	416/4784	0.88(0.76-1.02)
Q4	101/4815	1.09(0.80-1.47)	126/4815	0.92(0.70-1.21)	404/4815	0.97(0.83-1.12)
P for trend		0.105		0.621		0.143
Fruit lunch						
Q1	116/4695	1	185/4695	1	606/4695	1
Q2	114/4791	1.17(0.88-1.56)	150/4791	0.92(0.73-1.17)	474/4791	0.90(0.82-1.10)
Q3	69/4880	1.13(0.79-1.60)	83/4880	0.83(0.65-1.05)	275/4880	0.84(0.73-0.96)
Q4	93/4837	1.10(0.83-1.48)	150/4837	0.68(0.50-0.92)	462/4837	0.77(0.65-0.91)
P for trend		0.741		0.083		0.011
Western Dinner						
Q1	85/4835	1	114/4835	1	373/4835	1
Q2	95/4825	0.96(0.71-1.31)	145/4825	0.78(0.60-1.01)	476/4825	0.88(0.77-1.02)
Q3	104/4779	1.02(0.75-1.38)	166/4779	0.99(0.77-1.27)	518/4779	0.96(0.83-1.10)
Q4	108/4764	1.06(0.79-1.43)	143/4764	0.91(0.70-1.17)	450/4764	0.95(0.82-1.10)
P for trend		0.925		0.152		0.374
Vegetable dinner						
Q1	122/4763	1	167/4763	1	530/4763	1

Q2	93/4800	0.71(0.54-0.94)	147/4800	0.85(0.67-1.07)	485/4800	0.89(0.78-1.01)
Q3	99/4801	0.71(0.54-0.94)	139/4801	0.82(0.65-1.04)	443/4801	0.80(0.70-0.92)
Q4	78/4839	0.59(0.44-0.79)	115/4839	0.73(0.56-0.94)	359/4839	0.67(0.59-0.78)
P for trend		0.003		0.016		<0.001
Fruit dinner						
Q1	144/4607	1	212/4607	1	685/4607	1
Q2	101/4815	0.92(0.70-1.22)	115.4815	0.78(0.61-1.00)	365/4815	0.72(0.63-0.83)
Q3	51/4903	0.88(0.61-1.25)	78/4903	1.04(0.77-1.41)	253/4903	0.93(0.79-1.10)
Q4	96/4878	0.77(0.59-1.01)	163/4878	0.99(0.80-1.23)	514/4878	0.90(0.80-1.02)
P for trend		0.318		0.143		0.279

Adjustments included age, sex, ethnicity, income, education, exercise, smoking, alcohol intake, BMI, diabetes, hypertension, dyslipidemia, nutrient supplement use, total intake of energy, percentage of energy provided by snacks, fat, protein, cholesterol, breakfast skipping, lunch skipping, hours of restricted eating, dietary information collected at working day or week-end and AHEI.

Case/N, number of case subjects/total; Q, quartile;

Table S10. Adjusted HRs for snack patterns after breakfast, lunch and dinner and cancer, CVD and all-cause mortality after excluding the participants who had follow-up time of less than three years or died within three years of follow-up.

	Cancer mortality		CVD mortality		All-cause mortality	
	Case/N	HR (95%CI)	Case/N	HR (95%CI)	Case/N	HR (95%CI)
Grain snack after breakfast						
Q1	72/4873	1	74/4873	1	263/4873	1
Q2	102/4831	0.91(0.62-1.34)	144/4831	1.12(0.79-1.61)	445/4831	1.10(0.91-1.33)
Q3	100/4778	0.73(0.48-1.11)	210/4778	1.09(0.75-1.59)	634/4778	1.11(0.90-1.36)
Q4	118/4721	1.09(0.76-1.56)	140/4721	0.97(0.68-1.38)	475/4721	1.05(0.87-1.26)
P for trend		0.085		0.745		0.706
Starchy snack after breakfast						
Q1	70/4892	1	62/4892	1	225/4892	1
Q2	73/4845	1.04(0.71-1.51)	87/4845	0.94(0.65-1.36)	311/4845	1.11(0.91-1.35)
Q3	129/4811	1.36(0.90-2.04)	161/4811	0.98(0.66-1.46)	509/4811	1.15(0.93-1.43)
Q4	120/4655	0.87(0.57-1.32)	258/4655	1.46(0.99-2.17)	772/4655	1.50(1.21-1.86)
P for trend		0.576		0.007		<0.001
Fruit snack after breakfast						
Q1	85/4807	1	68/4807	1	281/4807	1
Q2	100/4840	0.79(0.57-1.11)	152/4840	1.36(0.98-1.87)	475/4840	1.12(0.95-1.34)

Q3	114/4793	0.74(0.51-1.07)	198/4793	1.14(0.80-1.61)	578/4793	1.05(0.87-1.26)
Q4	93/4763	0.58(0.39-0.85)	150/4763	0.81(0.56-1.16)	483/4763	0.82(0.68-0.99)
P for trend		0.003		0.035		0.003
Grain snack after lunch						
Q1	65/4838	1	67/4838	1	267/4838	1
Q2	109/4813	1.16(0.80-1.69)	184/4813	1.39(0.99-1.94)	496/4813	1.08(0.90-1.29)
Q3	110/4776	1.02(0.70-1.49)	185/4776	1.06(0.75-1.49)	595/4776	1.00(0.83-1.19)
Q4	108/4776	1.23(0.88-1.73)	132/4776	1.18(0.85-1.65)	459/4776	1.08(0.91-1.28)
P for trend		0.469		0.100		0.530
Starchy snack after Lunch						
Q1	55/4909	1	50/4909	1	198/4909	1
Q2	66/4831	1.26(0.86-1.84)	65/4831	1.04(0.71-1.52)	250/4831	1.13(0.93-1.38)
Q3	118/4811	1.25(0.85-1.86)	171/4811	1.18(0.81-1.71)	533/4811	1.26(1.04-1.54)
Q4	153/4652	1.43(0.96-2.11)	282/4652	1.57(1.08-2.27)	836/4652	1.55(1.28-1.89)
P for trend		0.116		0.001		<0.001
Dairy snack after lunch						
Q1	88/4828	1	79/4828	1	345/4828	1
Q2	112/4801	0.91(0.65-1.26)	180/4801	1.35(0.99-1.84)	523/4801	0.99(0.84-1.16)
Q3	97/4752	0.85(0.59-1.22)	176/4752	1.22(0.88-1.71)	502/4752	0.88(0.73-1.04)
Q4	95/4822	0.86(0.63-1.19)	133/4822	1.18(0.87-1.61)	447/4822	0.95(0.81-1.11)
P for trend		0.802		0.299		0.348
Starchy snack after dinner						

Q1	69/4897	1	52/4897	1	212/4897	1
Q2	61/4852	0.79(0.55-1.15)	77/4852	1.19(0.82-1.74)	251/4852	1.13(0.93-1.38)
Q3	106/4809	0.88(0.60-1.29)	160/4809	1.41(0.97-2.05)	509/4809	1.26(1.04-1.53)
Q4	156/4645	1.14(0.78-1.67)	279/4645	1.74(1.19-2.56)	845/4645	1.55(1.28-1.89)
P for trend		0.142		<0.001		<0.001
Grain snack after dinner						
Q1	73/4838	1	104/4838	1	357/4838	1
Q2	102/4765	1.20(0.86-1.68)	162/4765	1.03(0.78-1.36)	486/4765	1.02(0.87-1.18)
Q3	103/4804	1.18(0.83-1.67)	181/4804	1.10(0.83-1.47)	513/4804	0.94(0.80-1.10)
Q4	114/4796	1.31(0.96-1.78)	121.4796	0.87(0.66-1.15)	461/4796	1.02(0.88-1.18)
P for trend		0.409		0.342		0.592
Dairy snack after dinner						
Q1	98/4839	1	118/4839	1	373/4839	1
Q2	104/4789	0.84(0.61-1.16)	173/4789	0.88(0.67-1.16)	503/4789	0.89(0.76-1.04)
Q3	98/4736	0.77(0.55-1.09)	152/4736	0.69(0.51-0.94)	478/4736	0.78(0.65-0.92)
Q4	92/4839	0.73(0.54-0.99)	125/4839	0.69(0.52-0.92)	463/4839	0.80(0.73-0.98)
P for trend		0.050		0.001		0.010

Adjustments included age, sex, ethnicity, income, education, exercise, smoking, alcohol intake, BMI, diabetes, hypertension, dyslipidemia, nutrient supplement use, total intake of energy, percentage of energy provided by snacks, fat, protein, cholesterol, breakfast skipping, lunch skipping, hours of restricted eating, dietary information collected at working day or week-end and AHEI.

Case/N, number of case subjects/total; Q, quartile

Table S11. Adjusted HRs for meal patterns of diet control adjustment and cancer, CVD and all-cause mortality.

	Cancer mortality		CVD mortality		All-cause mortality	
	Case/N	HR (95%CI)	Case/N	HR (95%CI)	Case/N	HR (95%CI)
Western breakfast						
Q1	102/5376	1	103/5376	1	383/5376	1
Q2	116/5375	1.03(0.76-1.37)	200/5375	1.18(0.92-1.53)	625/5375	1.15(0.99-1.32)
Q3	149/5376	1.20(0.90-1.59)	199/5376	1.17(0.91-1.52)	677/5376	1.20(1.04-1.38)
Q4	109/5376	1.05(0.78-1.42)	174/5376	1.24(0.95-1.62)	507/5376	1.08(0.93-1.25)
P for trend		0.490		0.448		0.053
Starchy breakfast						
Q1	107/5375	1	109/5375	1	388/5375	1
Q2	121/5376	0.84(0.63-1.12)	172/5376	1.04(0.81-1.35)	553/5376	1.02(0.89-1.18)
Q3	143/5376	1.13(0.84-1.52)	213/5376	1.27(0.97-1.66)	679/5376	1.14(0.98-1.32)
Q4	105/5376	0.86(0.63-1.16)	182/5376	1.20(0.92-1.56)	572/5376	1.11(0.96-1.29)
P for trend		0.069		0.199		0.196
Fruit breakfast						
Q1	161/5375	1	231/5375	1	729/5375	1
Q2	99/5376	0.91(0.70-1.19)	119/5376	0.96(0.76-1.22)	398/5376	0.91(0.79-1.03)
Q3	99/5377	0.88(0.67-1.15)	136/5377	0.91(0.72-1.15)	440/5377	0.89(0.78-1.01)
Q4	117/5375	0.84(0.65-1.09)	190/5375	1.08(0.87-1.33)	625/5375	1.06(0.94-1.19)
P for trend		0.591		0.555		0.150
Western lunch						
Q1	117/5376	1	116/5376	1	435/5376	1

Q2	125/5376	0.90(0.68-1.18)	185/5376	1.22(0.94-1.57)	626/5376	1.09(0.95-1.25)
Q3	126/5375	0.97(0.72-1.31)	206/5375	1.31(0.99-1.74)	591/5375	1.12(0.96-1.29)
Q4	108/5376	0.89(0.65-1.20)	169/5376	1.45(1.10-1.91)	540/5376	1.11(0.95-1.28)
P for trend		0.799		0.073		0.495
Vegetable lunch						
Q1	116/5375	1	144/5375	1	493/5375	1
Q2	139/5377	0.79(0.59-1.05)	222/5377	1.03(0.80-1.31)	707/5377	0.95(0.84-1.09)
Q3	100/5376	0.76(0.58-1.01)	170/5376	0.93(0.73-1.18)	522/5376	0.86(0.76-1.00)
Q4	121/5375	0.97(0.74-1.27)	140/5375	0.90(0.70-1.16)	470/5375	0.88(0.77-1.01)
P for trend		0.127		0.714		0.089
Fruit lunch						
Q1	139/5376	1	210/5376	1	691/5376	1
Q2	133/5375	1.02(0.79-1.32)	189/5375	0.86(0.70-1.07)	576/5375	0.86(0.76-0.96)
Q3	91/5377	0.96(0.70-1.33)	98/5377	0.77(0.62-0.97)	361/5377	0.79(0.70-0.89)
Q4	113/5375	0.95(0.73-1.24)	179/5375	0.69(0.52-0.92)	564/5375	0.74(0.63-0.87)
P for trend		0.957		0.049		<0.001
Western Dinner						
Q1	105/5375	1	139/5375	1	449/5375	1
Q2	118/5376	0.84(0.64-1.11)	179/5376	0.85(0.67-1.08)	579/5376	0.90(0.79-1.02)
Q3	127/5377	0.95(0.72-1.24)	195/5377	0.89(0.70-1.13)	620/5377	0.96(0.84-1.09)
Q4	126/5375	1.03(0.79-1.35)	163/5375	0.94(0.74-1.19)	544/5375	0.98(0.86-1.12)
P for trend		0.464		0.571		0.356
Vegetable dinner						
Q1	149/5376	1	199/5376	1	644/5376	1
Q2	116/5375	0.90(0.70-1.16)	183/5375	0.97(0.78-1.20)	594/5375	0.98(0.87-1.10)
Q3	114/5377	0.80(0.62-1.04)	156/5377	0.82(0.65-1.02)	525/5377	0.80(0.71-0.91)

Q4	97/5375	0.65(0.50-0.86)	138/5375	0.76(0.60-0.97)	429/5375	0.70(0.61-0.80)
P for trend		0.001		0.015		<0.001
Fruit dinner						
Q1	181/5375	1	262/5375	1	856/5375	1
Q2	118/5376	0.94(0.73-1.21)	134/5376	0.81(0.65-1.00)	431/5376	0.72(0.64-0.82)
Q3	61/5376	0.80(0.57-1.12)	81/5376	1.02(0.78-1.34)	288/5376	0.92(0.79-1.07)
Q4	116/5376	0.86(0.67-1.09)	199/5376	1.01(0.83-1.23)	617/5376	0.93(0.83-1.04)
P for trend		0.474		0.526		0.658

Adjustments included age, sex, ethnicity, income, education, exercise, smoking, alcohol intake, BMI, diabetes, hypertension, dyslipidemia, nutrient supplement use, total intake of energy, percentage of energy provided by snacks, fat, protein, cholesterol, breakfast skipping, lunch skipping, hours of restricted eating, dietary information collected at working day or week-end and AHEI.

Case/N, number of case subjects/total; Q, quartile

Table S12. Adjusted HRs for snack patterns of diet control adjustment and cancer, CVD and all-cause mortality.

	Cancer mortality		CVD mortality		All-cause mortality	
	Case/N	HR (95%CI)	Case/N	HR (95%CI)	Case/N	HR (95%CI)
Grain snack after breakfast						
Q1	86/5376	1	79/5376	1	1	1
Q2	120/5375	1.04(0.73-1.47)	154/5375	0.98(0.70-1.37)	297/5376	1.12(0.94-1.33)
Q3	130/5377	0.82(0.56-1.21)	269/5377	1.22(0.85-1.75)	524/5375	1.12(0.92-1.36)
Q4	140/5375	1.06(0.76-1.49)	174/5375	1.14(0.81-1.60)	779/5377	1.09(0.91-1.29)
P for trend		0.255		0.409	592/5375	0.642
Starchy snack after breakfast						
Q1	88/5376	1	73/5376	1	286/5376	1
Q2	94/5375	0.92(0.66-1.28)	105/5375	1.22(0.89-1.68)	379/5375	1.03(0.87-1.23)
Q3	130/5376	0.82(0.57-1.19)	202/5376	1.59(1.17-2.17)	634/5376	1.03(0.86-1.25)
Q4	164/5376	0.82(0.56-1.19)	296/5376	1.63(1.22-2.19)	893/5376	1.18(0.97-1.43)
P for trend		0.719		0.001		0.183
Fruit snack after breakfast						
Q1	106/5375	1	79/5375	1	380/5375	1
Q2	127/5377	1.00(0.74-1.33)	185/5377	1.05(0.75-1.47)	556/5377	1.06(0.92-1.23)
Q3	129/5376	0.85(0.61-1.17)	237/5376	1.04(0.73-1.48)	701/5376	1.12(0.96-1.31)
Q4	114/5375	0.73(0.53-1.01)	175/5375	1.22(0.85-1.76)	555/5375	0.90(0.77-1.06)

P for trend		0.153		0.513		0.053
Grain snack after lunch						
Q1	79/5375	1	81/5375	1	325/5375	1
Q2	126/5376	1.19(0.85-1.68)	196/5376	1.14(0.83-1.56)	570/5376	1.00(0.85-1.19)
Q3	144/5377	1.09(0.77-1.53)	238/5377	0.97(0.71-1.33)	749/5377	0.98(0.83-1.15)
Q4	127/5375	1.22(0.89-1.66)	161/5375	1.04(0.77-1.40)	548/5375	1.01(0.87-1.18)
P for trend		0.545		0.601		0.969
Starchy snack after lunch						
Q1	73/5376	1	68/5376	1	251/5376	1
Q2	77/5376	1.01(0.71-1.42)	71/5376	0.79(0.55-1.12)	295/5376	1.02(0.85-1.22)
Q3	134/5376	1.09(0.77-1.56)	196/5376	1.02(0.73-1.42)	628/5376	1.19(0.99-1.43)
Q4	192/5375	1.15(0.80-1.64)	341/5376	1.25(0.90-1.74)	1018/5375	1.39(1.16-1.65)
P for trend		0.842		0.028		<0.001
Dairy snack after lunch						
Q1	102/5375	1	108/5375	1	429/5375	1
Q2	136/5376	1.02(0.76-1.38)	205/5376	1.15(0.88-1.52)	625/5376	0.98(0.85-1.14)
Q3	120/5376	0.92(0.66-1.28)	211/5376	1.02(0.76-1.37)	603/5376	0.85(0.73-1.00)
Q4	118/5376	0.96(0.72-1.28)	152/5376	0.94(0.72-1.24)	535/5376	0.92(0.80-1.06)
P for trend		0.889		0.386		0.103
Starchy snack after dinner						
Q1	79/5376	1	62/5376	1	254/5376	1
Q2	70/5376	0.83(0.59-1.18)	69/5376	0.88(0.62-1.27)	268/5376	0.89(0.75-1.07)

Q3	123/5375	1.00(0.71-1.40)	195/5375	1.41(1.01-1.96)	597/5375	1.22(1.03-1.46)
Q4	204/5376	1.27(0.90-1.81)	350/5376	1.69(1.20-2.39)	1073/5376	1.54(1.29-1.85)
P for trend				<0.001		<0.001
Grain snack after dinner						
Q1	96/5376	1	122/5376	1	413/5376	1
Q2	114/5375	1.05(0.77-1.43)	212/5375	1.00(0.76-1.32)	595/5375	0.99(0.86-1.16)
Q3	135/5377	1.10(0.81-1.49)	183/5377	0.98(0.72-1.32)	629/5377	0.95(0.82-1.10)
Q4	131/5375	1.13(0.85-1.51)	146/5375	0.79(0.60-1.04)	555/5375	0.98(0.85-1.13)
P for trend		0.842		0.169		0.736
Dairy snack after dinner						
Q1	117/5376	1	122/5376	1	452/5376	1
Q2	118/5375	0.77(0.57-1.05)	204/5375	0.86(0.67-1.12)	579/5375	0.81(0.70-0.94)
Q3	121/5376	0.71(0.54-0.94)	208/5376	0.75(0.58-0.97)	611/5376	0.73(0.62-0.86)
Q4	120/5376	0.66(0.48-0.92)	142/5376	0.70(0.54-0.92)	550/5376	0.79(0.69-0.91)
P for trend		0.022		0.039		0.001

Adjustments included age, sex, ethnicity, income, education, exercise, smoking, alcohol intake, BMI, diabetes, hypertension, dyslipidemia, nutrient supplement use, total intake of energy, percentage of energy provided by snacks, fat, protein, cholesterol, breakfast skipping, lunch skipping, hours of restricted eating, dietary information collected at working day or week-end and AHEI.

Case/N, number of case subjects/total; Q, quartile

Table S13. Adjusted HRs for dietary patterns at breakfast, lunch and dinner and cancer, CVD and all-cause mortality in the context of low-dietary quality.

	Cancer mortality		CVD mortality		All-cause mortality	
	Case/N	HR (95%CI)	Case/N	HR (95%CI)	Case/N	HR (95%CI)
Western breakfast						
Q1	49/2216	1	60/2216	1	206/2216	1
Q2	74/2912	0.92(0.63-1.36)	136/2912	1.17(0.85-1.61)	407/2912	1.09(0.91-1.30)
Q3	88/3017	1.04(0.72-1.51)	135/3017	1.05(0.76-1.45)	455/3017	1.09(0.91-1.30)
Q4	52/2760	0.73(0.48-1.11)	115/2760	1.16(0.83-1.62)	308/2760	0.91(0.75-1.10)
P for trend		0.253		0.681		0.857
Starchy breakfast						
Q1	27/1356	1	36/1356	1	120/1356	1
Q2	58/2452	0.93(0.58-1.50)	89/2452	1.16(0.77-1.73)	303/2452	1.15(0.92-1.44)
Q3	111/3777	1.18(0.74-1.89)	181/3777	1.57(1.06-2.33)	532/3777	1.26(1.01-1.57)
Q4	67/3320	0.87(0.53-1.42)	140/3320	1.54(1.03-2.29)	421/3320	1.26(1.01-1.58)
P for trend				0.020		0.032
Fruit breakfast						
Q1	77/2010	1	142/2010	1	427/2010	1
Q2	68/3206	0.90(0.63-1.29)	100/3206	0.91(0.68-1.20)	303/3206	0.88(0.75-1.03)
Q3	64/3250	0.93(0.64-1.33)	85/3250	0.80(0.60-1.08)	277/3250	0.82(0.70-0.97)
Q4	54/2439	0.77(0.53-1.12)	119/2439	1.05(0.81-1.36)	369/2439	1.03(0.88-1.20)
P for trend		0.581		0.308		0.412
Western lunch						
Q1	53/2335	1	56/2335	1	215/2335	1
Q2	79/3070	0.83(0.57-1.21)	135/3070	1.27(0.90-1.79)	423/3070	1.05(0.88-1.26)

Q3	70/2947	0.80(0.52-1.22)	134/2947	1.61(1.11-2.35)	373/2947	1.10(0.90-1.35)
Q4	61/2553	0.77(0.50-1.20)	121/2553	1.60(1.09-2.34)	365/2553	1.19(0.97-1.46)
P for trend		0.687		0.011		0.330
Vegetable lunch						
Q1	56/2278	1	86/2278	1	274/2278	1
Q2	91/3629	0.72(0.49-1.07)	161/3629	0.89(0.65-1.21)	518/3629	0.93(0.78-1.10)
Q3	61/2714	0.71(0.49-1.05)	122/2714	0.99(0.74-1.32)	345/2714	0.89(0.75-1.06)
Q4	55/2284	0.84(0.56-1.20)	77/2284	0.85(0.61-1.18)	239/2284	0.83(0.69-1.01)
P for trend		0.687		0.661		0.280
Fruit lunch						
Q1	53/1631	1	112/1631	1	357/1631	1
Q2	89/2937	1.08(0.75-1.56)	129/2937	0.75(0.57-1.00)	417/2937	0.85(0.72-0.99)
Q3	64/3831	0.93(0.59-1.45)	82/3831	0.77(0.54-1.08)	261/3831	0.69(0.57-0.84)
Q4	57/2506	0.92(0.62-1.38)	123/2506	1.00(0.76-1.32)	341/2506	0.74(0.63-0.87)
P for trend		0.786		0.105		<0.001
Western Dinner						
Q1	46/2011	1	70/2011	1	205/2011	1
Q2	71/3103	0.75(0.51-1.10)	130/3103	0.81(0.59-1.10)	388/3103	0.87(0.73-1.04)
Q3	79/3172	0.79(0.54-1.16)	138/3172	0.90(0.67-1.23)	437/3172	0.97(0.81-1.16)
Q4	67/2619	0.82(0.55-1.22)	108/2619	0.91(0.66-1.26)	346/2619	0.99(0.82-1.19)
P for trend		0.516		0.565		0.264
Vegetable dinner						
Q1	76/2560	1	129/2560	1	397/2560	1
Q2	84/3323	0.75(0.51-1.10)	138/3323	0.96(0.74-1.23)	429/3323	0.95(0.82-1.10)
Q3	68/2805	0.79(0.54-1.16)	107/2805	0.83(0.64-1.09)	327/2805	0.79(0.67-0.92)
Q4	35/2217	0.55(0.36-0.83)	72/2217	0.74(0.55-0.99)	223/2217	0.70(0.58-0.83)

P for trend		<0.001		0.038		<0.001
Fruit dinner						
Q1	78/1852	1	142/1852	1	446/1852	1
Q2	77/2837	0.82(0.58-1.15)	104/2837	0.78(0.59-1.02)	312/2837	0.69(0.59-0.81)
Q3	42/3638	0.69(0.45-1.08)	66/3638	1.07(0.76-1.49)	226/3638	0.92(0.77-1.11)
Q4	66/2578	0.84(0.59-1.20)	134/2578	1.08(0.84-1.39)	392/2578	0.95(0.82-1.10)
P for trend		0.430		0.270		0.250

Adjustments included age, sex, ethnicity, income, education, exercise, smoking, alcohol intake, BMI, diabetes, hypertension, dyslipidemia, nutrient supplement use, total intake of energy, percentage of energy provided by snacks, fat, protein, cholesterol, breakfast skipping, lunch skipping, hours of restricted eating, dietary information collected at working day or week-end and AHEI.

Case/N, number of case subjects/total; Q, quartile

Table S14. Adjusted HRs for dietary patterns at breakfast, lunch and dinner and cancer, CVD and all-cause mortality in the context of high-dietary quality.

	Cancer mortality		CVD mortality		All-cause mortality	
	Case/N	HR (95%CI)	Case/N	HR (95%CI)	Case/N	HR (95%CI)
Western breakfast						
Q1	45/3074	1	45/3074	1	165/3074	1
Q2	47/2409	1.04(0.68-1.60)	54/2409	0.92(0.61-1.39)	203/2409	1.04(0.84-1.30)
Q3	58/2352	1.26(0.84-1.89)	65/2352	1.13(0.76-1.67)	227/2352	1.16(0.94-1.44)
Q4	63/2763	1.42(0.95-2.13)	66/2763	1.21(0.81-1.81)	221/2763	1.23(0.99-1.52)
P for trend		0.285		0.519		0.193
Starchy breakfast						
Q1	82/4041	1	75/4041	1	271/4041	1
Q2	54/2965	0.77(0.53-1.12)	73/2965	1.03(0.73-1.47)	239/2965	0.93(0.77-1.12)
Q3	38/1533	1.03(0.67-1.59)	40/1533	1.04(0.67-1.61)	148/1533	1.03(0.82-1.29)
Q4	39/2059	0.83(0.56-1.25)	42/2059	0.83(0.55-1.24)	158/2059	0.95(0.77-1.17)
P for trend		0.411		0.710		0.750
Fruit breakfast						
Q1	84/3300	1	78/3300	1	286/3300	1
Q2	30/2173	0.95(0.61-1.47)	29/2173	1.05(0.68-1.64)	103/2173	0.97(0.77-1.23)
Q3	36/2135	0.79(0.52-1.18)	51/2135	1.11(0.76-1.61)	163/2135	0.99(0.80-1.21)
Q4	63/2990	0.92(0.64-1.31)	72/2990	1.09(0.77-1.54)	264/2990	1.08(0.90-1.29)
P for trend		0.720		0.951		0.770
Western lunch						
Q1	65/3026	1	56/3026	1	208/3026	1
Q2	42/2285	1.09(0.68-1.72)	53/2285	1.34(0.85-2.12)	190/2285	1.24(0.98-1.57)

Q3	54/2399	1.23(0.79-1.93)	66/2399	1.37(0.88-2.15)	217/2399	1.20(0.95-1.51)
Q4	52/2888	1.02(0.65-1.60)	55/2888	1.00(0.63-1.58)	201/2888	1.00(0.79-1.27)
P for trend		0.750		0.226		0.092
Vegetable lunch						
Q1	60/3072	1	53/3072	1	217/3072	1
Q2	45/1683	0.88(0.57-1.35)	63/1683	1.36(0.91-2.04)	181/1683	1.02(0.82-1.27)
Q3	42/2662	0.83(0.55-1.26)	45/2662	0.79(0.52-1.20)	177/2662	0.82(0.66-1.01)
Q4	66/3181	1.13(0.77-1.65)	69/3181	1.02(0.69-1.50)	241/3181	0.94(0.78-1.15)
P for trend		0.750		0.089		0.191
Fruit lunch						
Q1	95/3698	1	110/3698	1	374/3698	1
Q2	45/2425	1.05(0.71-1.56)	50/2425	0.91(0.63-1.32)	150/2425	0.87(0.71-1.07)
Q3	18/1606	1.02(0.59-1.76)	17/1606	0.66(0.38-1.17)	75/1606	0.94(0.72-1.24)
Q4	55/2869	1.00(0.70-1.42)	53/2869	0.70(0.49-0.98)	217/2869	0.86(0.72-1.03)
P for trend		0.994		0.155		0.350
Western Dinner						
Q1	61/3423	1	70/3423	1	247/3423	1
Q2	43/2268	0.86(0.57-1.29)	51/2268	0.83(0.57-1.21)	191/2268	0.92(0.75-1.12)
Q3	47/2159	0.99(0.67-1.46)	48/2159	0.70(0.48-1.04)	176/2159	0.84(0.69-1.03)
Q4	62/2748	1.18(0.82-1.70)	61/2748	0.92(0.64-1.31)	202/2748	0.95(0.78-1.15)
P for trend		0.493		0.336		0.401
Vegetable dinner						
Q1	65/2777	1	65/2777	1	233/2777	1
Q2	38/2026	0.88(0.58-1.33)	48/2026	1.03(0.70-1.52)	175/2026	1.07(0.88-1.31)
Q3	49/2573	0.74(0.50-1.09)	51/2573	0.71(0.48-1.04)	197/2573	0.79(0.65-0.96)
Q4	61/3222	0.72(0.50-1.04)	66/3222	0.73(0.50-1.04)	211/3222	0.68(0.56-0.83)

P for trend		0.278		0.107		<0.001
Fruit dinner						
Q1	96/3399	1	113/3399	1	380/3399	1
Q2	45/2531	1.22(0.83-1.78)	28/2531	0.67(0.43-1.04)	126/2531	0.87(0.70-1.09)
Q3	16/1793	0.80(0.46-1.39)	22/1793	1.08(0.66-1.75)	71/1793	0.93(0.71-1.21)
Q4	56/2875	0.82(0.58-1.16)	67/2875	0.85(0.61-1.17)	239/2875	0.89(0.75-1.06)
P for trend		0.238		0.245		0.484

Adjustments included age, sex, ethnicity, income, education, exercise, smoking, alcohol intake, BMI, diabetes, hypertension, dyslipidemia, nutrient supplement use, total intake of energy, percentage of energy provided by snacks, fat, protein, cholesterol, breakfast skipping, lunch skipping, hours of restricted eating, dietary information collected at working day or week-end and AHEI.

Case/N, number of case subjects/total; Q, quartile

Table S15. Adjusted HRs for snack patterns after breakfast, lunch and dinner and cancer, CVD and all-cause mortality in the context of low dietary quality.

	Cancer mortality		CVD mortality		All-cause mortality	
	Case/N	HR (95%CI)	Case/N	HR (95%CI)	Case/N	HR (95%CI)
Grain snack after breakfast						
Q1	21/751	1	18/751	1	64/751	1
Q2	47/2610	0.47(0.26-0.87)	66/2610	1.01(0.56-1.84)	228/2610	0.96(0.70-1.31)
Q3	102/4606	0.33(0.19-0.59)	231/4606	1.04(0.59-1.82)	674/4606	0.88(0.65-1.19)
Q4	93/2938	0.55(0.32-0.94)	131/2938	0.99(0.57-1.71)	410/2938	0.86(0.64-1.15)
P for trend		<0.001		0.986		0.635
Starchy snack after breakfast						
Q1	15/937	1	22/937	1	74/937	1
Q2	22/1814	1.45(0.71-2.92)	26/1814	0.82(0.44-1.50)	105/1814	0.96(0.69-1.33)
Q3	82/3780	1.63(0.90-2.97)	101/3780	0.75(0.44-1.29)	339/3780	0.87(0.65-1.17)
Q4	144/4374	1.90(0.99-3.55)	297/4374	1.47(0.88-2.43)	858/4374	1.40(1.06-1.86)
P for trend		0.231		0.001		<0.001
Fruit snack after breakfast						
Q1	32/1190	1	28/1190	1	108/1190	1
Q2	56/2739	0.67(0.41-1.11)	109/2739	1.36(0.86-2.16)	331/2739	1.10(0.86-1.41)
Q3	87/3558	0.69(0.42-1.12)	151/3558	1.06(0.67-1.69)	469/3558	0.99(0.77-1.26)
Q4	88/3418	0.52(0.31-0.86)	158/3418	0.81(0.50-1.32)	468/3418	0.75(0.58-0.98)
P for trend		<0.001		0.030		0.001

Grain snack after lunch						
Q1	13/1201	1	22/1201	1	86/1201	1
Q2	76/3496	1.46(0.75-2.85)	128/3496	1.16(0.69-1.93)	369/3496	0.98(0.75-1.28)
Q3	103/3704	1.28(0.66-2.49)	200/3704	0.98(0.59-1.63)	593/3704	0.92(0.71-1.20)
Q4	71/2504	1.63(0.85-3.14)	96/2504	0.92(0.55-1.52)	328/2504	0.92(0.71-1.20)
P for trend		0.334		0.525		0.837
Starchy snack after lunch						
Q1	19/1190	1	27/1190	1	85/1190	1
Q2	22/2321	0.89(0.47-1.69)	25/2321	0.65(0.36-1.16)	109/2321	0.95(0.70-1.28)
Q3	79/3627	1.07(0.61-1.87)	104/3627	0.80(0.50-1.28)	353/3627	1.01(0.78-1.31)
Q4	143/3767	1.16(0.66-2.03)	290/3767	1.14(0.72-1.80)	829/3767	1.30(1.00-1.68)
P for trend		0.797		0.031		0.004
Dairy snack after lunch						
Q1	26/1238	1	46/1238	1	146/1238	1
Q2	67/2494	1.11(0.67-1.84)	124/2494	0.95(0.64-1.41)	358/2494	0.94(0.75-1.17)
Q3	95/4163	0.96(0.57-1.61)	181/4163	0.82(0.55-1.23)	518/4163	0.84(0.67-1.05)
Q4	75/3010	0.97(0.59-1.60)	95/3010	0.65(0.43-1.01)	354/3010	0.83(0.66-1.03)
P for trend		0.869		0.053		0.233
Starchy snack after dinner						
Q1	19/964	1	19/964	1	62/964	1
Q2	25/2229	0.67(0.36-1.25)	30/2229	0.98(0.53-1.80)	106/2229	1.00(0.72-1.39)
Q3	73/3731	0.74(0.42-1.30)	112/3731	1.23(0.72-2.11)	362/3731	1.31(0.98-1.77)

Q4	146/3981	0.91(0.51-1.63)	285/3981	1.48(0.85-2.58)	846/3981	1.63(1.20-2.02)
P for trend		0.390		0.225		<0.001
Grain snack after dinner						
Q1	28/1466	1	41/1466	1	149/1466	1
Q2	77/2931	1.33(0.84-2.12)	126/2931	1.20(0.82-1.75)	384/2931	1.14(0.93-1.40)
Q3	95/4067	1.03(0.64-1.68)	187/4067	1.27(0.86-1.87)	516/4067	0.98(0.80-1.22)
Q4	63/2441	1.19(0.73-1.94)	92/2441	1.06(0.70-1.58)	327/2441	1.13(0.92-1.40)
P for trend				0.487		0.134
Dairy snack after dinner						
Q1	22/1062	1	45/1062	1	130/1062	1
Q2	81/3157	1.03(0.62-1.72)	158/3157	0.92(0.63-1.35)	425/3157	0.87(0.70-1.08)
Q3	97/4145	0.90(0.53-1.55)	154/4145	0.68(0.45-1.03)	491/4145	0.84(0.67-1.06)
Q4	63/2541	0.95(0.56-1.61)	89/2541	0.64(0.43-0.98)	330/2541	0.77(0.61-0.98)
P for trend		0.889		0.019		0.158

Adjustments included age, sex, ethnicity, income, education, exercise, smoking, alcohol intake, BMI, diabetes, hypertension, dyslipidemia, nutrient supplement use, total intake of energy, percentage of energy provided by snacks, fat, protein, cholesterol, breakfast skipping, lunch skipping, hours of restricted eating, dietary information collected at working day or week-end and AHEI.

Case/N, number of case subjects/total; Q, quartile

Table S16. Adjusted HRs for snack patterns after breakfast, lunch and dinner and cancer, CVD and all-cause mortality in the context of high dietary quality.

	Cancer mortality		CVD mortality		All-cause mortality	
	Case/N	HR (95%CI)	Case/N	HR (95%CI)	Case/N	HR (95%CI)
Grain snack after breakfast						
Q1	67/4666	1	62/4666	1	243/4666	1
Q2	75/2704	1.22(0.77-1.94)	97/2704	1.22(0.78-1.91)	307/2704	1.01(0.80-1.28)
Q3	22/714	1.50(0.82-2.73)	27/714	1.20(0.66-2.20)	89/714	1.06(0.78-1.45)
Q4	49/2514	1.33(0.88-2.01)	44/2514	1.19(0.77-1.83)	177/2514	1.13(0.91-1.40)
P for trend		0.453		0.808		0.723
Starchy snack after breakfast						
Q1	75/4447	1	50/4447	1	212/4447	1
Q2	64/3515	0.87(0.57-1.33)	74/3515	1.21(0.77-1.89)	260/3515	1.20(0.96-1.50)
Q3	52/1657	1.05(0.62-1.78)	79/1657	1.66(0.98-2.81)	238/1657	1.35(1.01-1.80)
Q4	22/979	0.58(0.34-1.05)	27/979	1.17(0.64-2.15)	106/979	1.53(1.17-2.01)
P for trend		0.105		0.238		0.017
Fruit snack after breakfast						
Q1	72/4057	1	50/4057	1	253/4057	1
Q2	73/2783	1.14(0.76-1.69)	80/2783	1.28(0.83-1.97)	250/2783	1.07(0.86-1.32)
Q3	42/1755	0.70(0.39-1.26)	65/1755	1.26(0.72-2.23)	191/1755	0.98(0.74-1.31)
Q4	26/2003	0.59(0.36-0.96)	35/2003	1.10(0.69-1.76)	122/2003	0.84(0.66-1.06)
P for trend		0.024		0.708		0.231

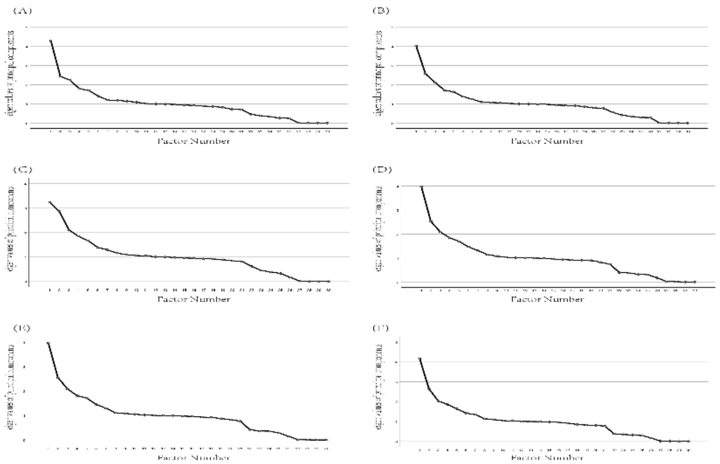
Grain snack after lunch						
Q1	62/4151	1	55/4151	1	232/4151	1
Q2	58/1975	1.31(0.85-2.04)	75/1975	1.21(0.79-1.84)	224/1975	1.10(0.87-1.38)
Q3	35/1610	1.14(0.73-1.79)	37/1610	0.88(0.55-1.41)	141/1610	0.98(0.78-1.24)
Q4	58/2862	1.17(0.79-1.72)	63/2862	1.25(0.84-1.87)	219/2862	1.07(0.87-1.31)
P for trend		0.668		0.330		0.736
Starchy snack after lunch						
Q1	54/4182	1	41/4182	1	165/4182	1
Q2	50/3074	1.13(0.74-1.73)	43/3074	1.27(0.80-2.01)	175/3074	1.18(0.93-1.48)
Q3	61/1821	1.14(0.70-1.84)	88/1821	1.64(1.01-2.64)	282/1821	1.46(1.14-1.87)
Q4	48/1521	1.44(0.91-2.30)	58/1521	1.73(1.06-2.81)	194/1521	1.64(1.28-2.09)
P for trend		0.442		<0.001		0.001
Dairy snack after lunch						
Q1	74/4034	1	53/4034	1	267/4034	1
Q2	70/2938	0.95(0.64-1.41)	82/2938	1.49(0.98-2.25)	267/2938	0.94(0.76-1.15)
Q3	24/1205	0.80(0.46-1.37)	32/1205	1.30(0.77-2.20)	91/1205	0.80(0.60-1.05)
Q4	45/2421	0.94(0.64-1.37)	63/2421	1.84(1.25-2.72)	191/2421	1.10(0.91-1.34)
P for trend		0.871		0.018		0.149
Starchy snack after dinner						
Q1	61/4402	1	43/4402	1	192/4402	1
Q2	48/3150	0.84(0.56-1.26)	40/3150	1.13(0.74-1.75)	172/3150	0.92(0.74-1.14)
Q3	54/1734	0.80(0.50-1.28)	95/1734	1.55(0.97-2.47)	262/1734	1.12(0.88-1.42)

Q4	50/1312	1.23(0.79-1.91)	52/1312	1.77(1.11-2.82)	190/1312	1.44(1.14-1.83)
P for trend		0.199		0.182		0.001
Grain snack after dinner						
Q1	76/4178	1	99/4178	1	304/4178	1
Q2	30/1723	1.09(0.71-1.68)	49/1723	0.75(0.51-1.11)	149/1723	0.85(0.68-1.05)
Q3	38/1845	1.24(0.77-1.97)	34/1845	0.91(0.59-1.42)	146/1845	1.00(0.79-1.26)
Q4	69/2852	1.31(0.92-1.87)	48/2852	0.69(0.48-1.01)	217/2852	0.91(0.76-1.09)
P for trend		0.472		0.182		0.377
Dairy snack after dinner						
Q1	95/4276	1	80/4276	1	315/4276	1
Q2	41/2349	0.73(0.48-1.12)	69/2349	0.80(0.54-1.19)	194/2349	0.90(0.73-1.11)
Q3	19/1111	0.80(0.50-1.28)	25/1111	0.93(0.60-1.45)	82/1111	0.79(0.61-1.01)
Q4	58/2862	0.68(0.48-0.96)	56/2862	0.63(0.44-0.91)	225.2862	0.79(0.66-0.94)
P for trend		0.148		0.035		0.046

Adjustments included age, sex, ethnicity, income, education, exercise, smoking, alcohol intake, BMI, diabetes, hypertension, dyslipidemia, nutrient supplement use, total intake of energy, percentage of energy provided by snacks, fat, protein, cholesterol, breakfast skipping, lunch skipping, hours of restricted eating, dietary information collected at working day or week-end and AHEI.

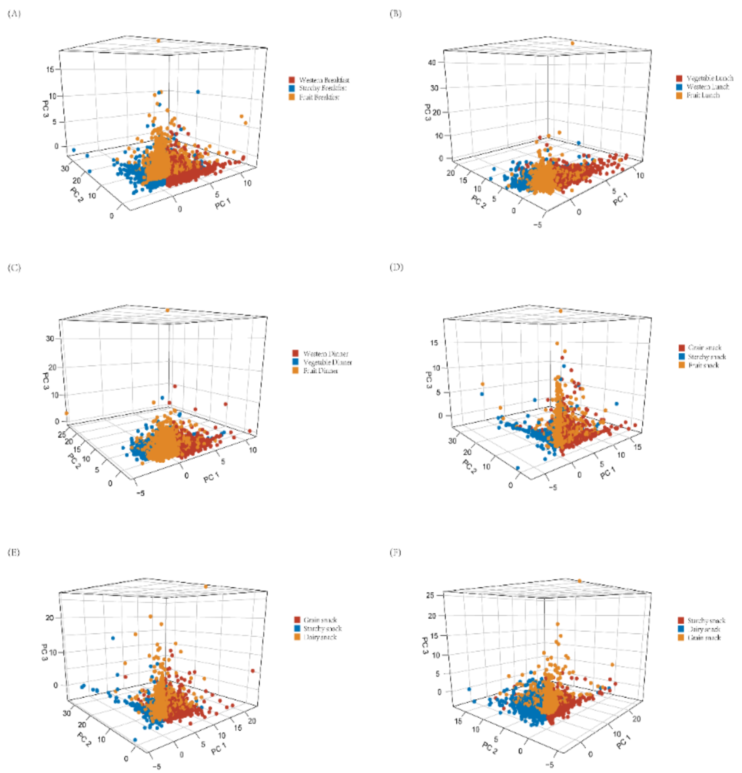
Case/N, number of case subjects/total; Q, quartile

Figure S1. The Scree plot with parallel analysis of meal patterns and snacks patterns.



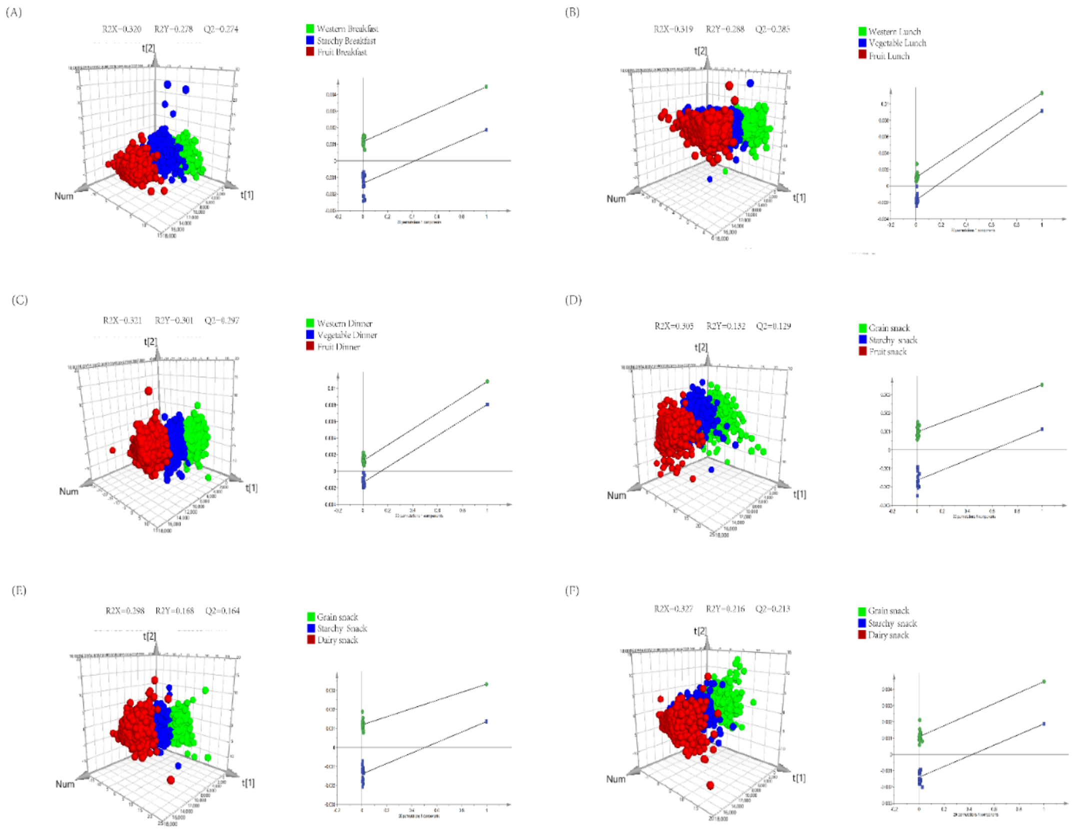
(A) Meal patterns at breakfast. (B) Meal patterns at lunch. (C) Meal patterns at dinner. (D) Snacks patterns after breakfast. (E) Snacks patterns after lunch. (F) Snacks patterns after dinner.

Figure S2. The PCA models of meal patterns and snacks patterns.



(A) Meal patterns at breakfast. (B) Meal patterns at lunch. (C) Meal patterns at dinner. (D) Snacks patterns after breakfast. (E) Snacks patterns after lunch. (F) Snacks patterns after dinner.

Figure S3. The PLS-DA models of meal patterns and snacks patterns with permutation tests.



(A) Meal patterns at breakfast. (B) Meal patterns at lunch. (C) Meal patterns at dinner. (D) Snacks patterns after breakfast. (E) Snacks patterns after lunch. (F) Snacks patterns after dinner.

Figure S4. The coefficient of each food group in the meal patterns at breakfast (A), lunch (B) and dinner (C) after additionally adjustment for the behavior of diet control (N=21503).

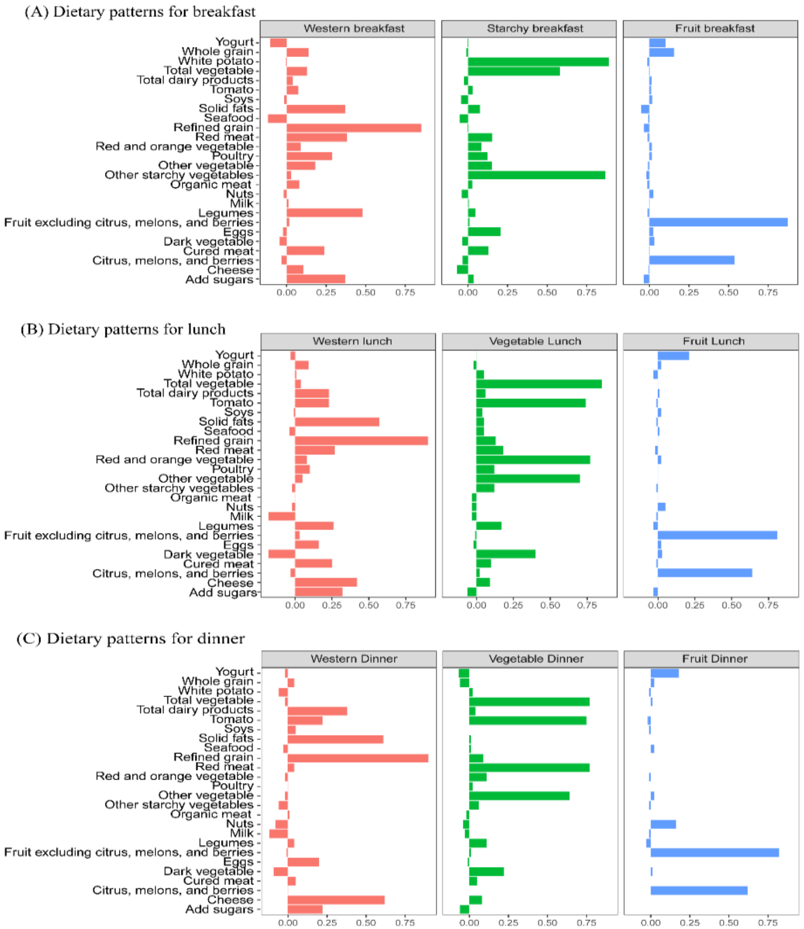


Figure S5. The coefficient of each food group in the snack patterns after breakfast (A), lunch (B) and dinner (C) with additionally adjustment for the behavior of diet control (N=21503).