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Consumption of ultra-processed foods decreases the quality of the overall diet of middle-aged Japanese adults

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Abstract

Objective: To estimate the consumption of ultra-processed foods and determine its association with dietary quality among middle-aged Japanese adults.

Design: Cross-sectional study using data from the Saitama Prefecture Health and Nutrition Survey 2011. Dietary intake was assessed using one- or two-day dietary records. Sociodemographic and lifestyle factors were obtained via self-administered questionnaire. Food items were classified according to the NOVA system into four groups: unprocessed or minimally processed foods; processed culinary ingredients; processed foods; and ultra-processed foods. The dietary share of each NOVA food group and their subgroups was calculated in relation to total energy intake, and the average dietary content of key nutrients was determined across tertiles of the dietary energy share of ultra-processed foods (low, middle and high intake).

Setting: Saitama Prefecture in Japan.

Participants: Community-dwelling adults aged 30–59 years (256 men, 361 women).

Results: Consumption of unprocessed or minimally processed foods, processed culinary ingredients, processed foods and ultra-processed foods contributed 44·9 (SE 0·8) %, 5·5 (SE 0·2) %, 11·3 (SE 0·4) % and 38·2 (SE 0·9) % of total daily energy intake, respectively. A positive and statistically significant linear trend was found between the dietary share of ultra-processed foods (tertiles) and the dietary content of total and saturated fat, while an inverse relationship was observed for protein, vitamin K, vitamin B_6, dietary fibre, magnesium, phosphorus and iron.

Conclusions: Our findings show that higher consumption of ultra-processed foods was associated with decreased dietary quality among Japanese adults.

Keywords
Ultra-processed foods
Dietary quality
Japanese

The consumption of processed foods is increasing globally[1], including in Japan[2], and is a frequent topic of current research and public health concern[3–5]. It is generally agreed that the impact of the degree of food processing on all forms of malnutrition needs to be better understood and explained, raising the need for standardized classifications and definitions. The NOVA system, developed by Monteiro and colleagues[6,7], is based on the nature, extent and purpose of food processing and has been used in recent research and official international reports[8–10]. NOVA classifies food items into four groups: Group 1, unprocessed or minimally processed foods; Group 2, processed culinary ingredients; Group 3, processed foods; and Group 4, ultra-processed foods[11].

Globally, dietary patterns based on unprocessed and minimally processed foods and their culinary preparations have been replaced by the consumption of ultra-processed foods[12]. These are industrial formulations manufactured from cheap ingredients extracted or derived from foods (i.e. sugar, plant oils, modified starches) plus additives (i.e. colorants, flavourings, emulsifiers, artificial sweeteners), using a series of processes (hence 'ultra-processed'), in order to create

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hyper-palatable, convenient, accessible and attractive products able to be consumed anywhere and at any time[11].

Evidence from countries such as the USA, the UK, Canada, Chile, France and Brazil shows that ultra-processed foods, and diets high in these products, tend to be higher in total fat[13–15], saturated fat[13–20], carbohydrate[13,15,17–20], sodium[13–16,19], and added or free sugars[13–19,21–23]. On the other hand, they tend to be lower in protein[14–20], fibre[14–20,22], vitamin C[17,18,20,22], vitamin A[17–20], β-carotene[22], vitamin D[17,18,20], vitamin E[18], thiamin[17,20], riboflavin[17], vitamin B_6[17,20], vitamin B_{12}[17], niacin[17,20], folic acid[22], zinc[17,18], potassium[15,17–20], phosphorus[17,18], magnesium[17,18,20], calcium[17,18,22] and iron[17,19,20], and also fruits and vegetables[13,18,22,24].

Cross-sectional and longitudinal studies conducted in the USA, Brazil, France and Spain have shown that ultra-processed food consumption is associated with higher BMI[22,25–28], overweight or obesity[25–30], waist circumference[27,28], hypertension[31], metabolic syndrome[32], dyslipidaemias[33], asthma and wheezing[34], functional gastrointestinal disorders[35] and cancer, including breast cancer[36]. Moreira *et al.* estimated that halving the intake of ultra-processed foods in the UK could result in approximately 17 060 fewer CVD-related deaths in 2030, representing a 10 % reduction in CVD mortality[37].

In the Asia Pacific region, ultra-processed foods sales have increased rapidly in most middle-income countries, including China, Malaysia and Thailand[38]. Data on annual retail sales of ultra-processed foods in 2013 showed that Japan ranked tenth out of eighty countries evaluated[39].

Japan has the highest average life expectancy at birth in the world[40]. The main contributor to this is thought to be the traditional Japanese dietary patterns[5], which are characterized by eating dishes and meals with fish, soyabean products, rice and other grains, and vegetables cooked using traditional methods[41,42], as well as eating at mealtimes, at home and with other people[43]. Although the traditional Japanese diet may be associated with lower risk of diseases[5], the consumption of ultra-processed foods among the Japanese population, and their effects on diet quality and health, have not been clarified yet.

Therefore, the present study aimed to estimate the consumption of ultra-processed foods and determine its association with dietary quality among middle-aged Japanese adults.

Methods

Data source and sample

The data analysed in the present study were collected from the Saitama Health and Nutrition Survey, which was conducted in Saitama Prefecture from October to November 2011[44]. Saitama is located to the north of Tokyo and has an approximate population of 7 million people (at the time of the 2011 survey)[45]. The total number of cities of Saitama is sixty-three (as of October 2018). The survey was conducted using two-stage stratified random sampling; 1351 individuals aged 30–59 years who lived in four cities of Saitama Prefecture were randomly selected.

A total of 691 respondents (response rate = 51·0 %) who completed a self-administered dietary record and 762 respondents (response rate = 56·4 %) who completed a sociodemographic and health-related lifestyle questionnaire agreed to be interviewed, and trained interviewers visited their homes to confirm their answers and records (Fig. 1).

Dietary assessment

Dietary intake of participants was assessed using dietary records. Participants were instructed to record their diet on a typical day, such as a weekday, except for holidays or when travelling. The dietary record included the name of meals (breakfast, lunch, dinner, between-meal eating); meal time; names of dishes (i.e. sushi); names of foods or ingredients in the dishes (i.e. rice, tuna, soya sauce); approximate amount of foods consumed in household measures (amount measured by measuring spoon or measuring cup, or number of consumed food items); measured weight of each ingredient, food and/or meal; and place where the participant ate the meal. In addition, participants recorded the weight and product name listed when they ate pre-prepared foods purchased at a convenience store. For foods consumed outside of home, they recorded the name of the store or restaurant and menu items. When grams or millilitres were unknown, we asked participants to write the approximate amount (i.e. one serving or one-half serving). In the case of foods consumed outside the home, researchers contacted the convenience store and/or restaurant and confirmed the detailed ingredients and weight as much as possible. Food intake recorded in household measures was converted into grams or millilitres by researchers based on the standard weight table used in the National Health and Nutrition Survey (NHNS)[46] and a popular recipe book[47]. Energy and nutrient intakes were calculated based on the 'shokujishirabe' nutrient analysis program[48], which was designed to estimate usual food and nutrient intakes in the NHNS, of the Ministry of Health, Labour and Welfare in Japan.

Food classification

We classified all recorded food items according to the NOVA system[7,11], a food classification based on the extent and purpose of industrial food processing. Meals purchased and eaten outside the home were excluded, as the recipes could not be analysed according to the respective ingredients used in their preparation[16]. Alcoholic beverages were also excluded following the methodology of previous studies using the NOVA system[16,49]. Food items or underlying ingredients were classified according to the NOVA system into the following four groups (and subgroups within these groups): Group 1, 'unprocessed or minimally processed foods' (e.g. fresh, dry or frozen grains

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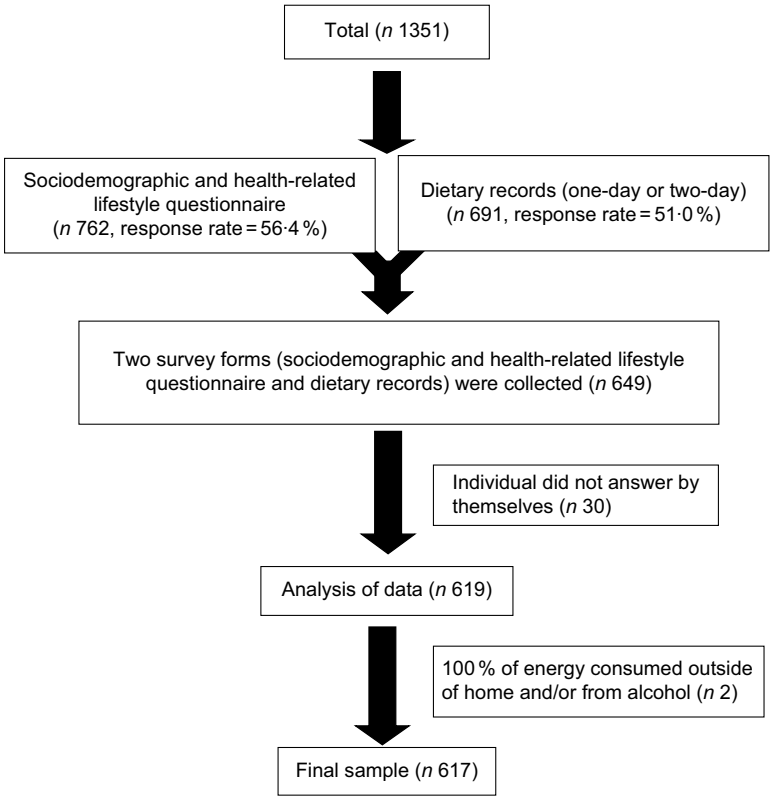

Fig. 1 Flowchart showing participants in the present study

such as rice, meat, fish, fruits and vegetables); Group 2, 'processed culinary ingredients' (e.g. plant oils, *shoyu* (soya sauce)), miso (fermented soyabean paste) or other ingredients extracted from foods or from nature and used in kitchens to make culinary preparations); Group 3, 'processed foods' (foods manufactured with the addition of salt, sugar or other processed culinary ingredients to unprocessed or minimally processed foods, such as steamed *udon* (salted, boiled wheat noodles), *kamaboko* (fish-paste loaf) and *takuan* (pickles)); and Group 4, 'ultra-processed foods' (e.g. soft drinks, salty snacks, confectionery, ready-to-heat frozen meals, *onigiri* (rice ball) or instant miso soup from a store). We judged whether the food was handmade according to the product and/or brand name listed in the dietary record. We identified ultra-processed foods based on the presence of substances only found in these products, such as protein isolates, colours and flavours, in the list of ingredients of the products. Ultra-processed foods included packaged ready-to-eat meals, called *souzai* in Japan, which were consumed at home.

A detailed definition of each NOVA food group[7,11] and examples of Japanese food items classified according to the NOVA system are shown in the online supplementary material (Supplemental Table S1).

Dietary nutrient profile indicators

We considered the following dietary nutrient profile indicators: total energy intake (kcal), percentage of energy from protein, total fat, saturated fat and carbohydrate, and the absolute daily intake of vitamins A, E, D and K, thiamin, riboflavin, niacin, vitamins B_6, B_{12} and C, folic acid, dietary fibre, sodium, potassium, calcium, magnesium, phosphorus and iron.

Self-administered questionnaire

The self-administered questionnaire included questions about sex, age, family structure, work status, income and health-related lifestyle factors, such as smoking and exercise habits.

Data analysis

A total of 619 participants who completed one-day or non-consecutive two-day dietary records and a self-administered questionnaire were included in the analyses. We excluded those who consumed 100 % of their energy intake outside of the home and/or from alcohol (*n* 2). Finally, 617 participants (256 men, 361 women) were analysed (Fig. 1). We utilized all available dietary records for each participant, using means of both recall days when available (60·4 % of participants) and one day otherwise.

We estimated the mean dietary share of each NOVA food group and their subgroups to total energy intake, overall and across each tertile of the dietary energy share of ultra-processed foods (low, middle and high intake).

ANCOVA was used to assess the association between tertiles of the dietary share of ultra-processed foods and the mean percentage of energy from each NOVA group

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and subgroups. Covariates showing statistical differences according to tertile of ultra-processed food consumption were included in the adjusted multivariate model.

The χ^2 test and Fisher's exact test were used to compare the sociodemographic distribution of categorical variables across tertiles of ultra-processed food consumption. One-way ANOVA was used to compare age (continuous) across tertiles. Missing values were excluded for each sociodemographic variable.

ANCOVA was used to compare average total energy intake and intakes of twenty-three nutrients across tertiles of ultra-processed food consumption. Furthermore, multiple comparisons were performed by the Bonferroni method. Covariates included in the adjusted multivariate model were sex (men, women), age (continuous), income (low, middle, high) and family structure (alone, other). The content of micronutrients was also adjusted by total energy intake (kcal, continuous). As sixty-six participants had missing values for family structure (n 8) or income (n 57) or both (n 1), adjusted analyses included 551 individuals.

Linear trends were assessed using the ordinal score of the tertiles of consumption of ultra-processed foods. We analysed log-transformed data when variables did not follow a normal distribution.

All analyses were conducted using the statistical software package IBM SPSS Statistics version 24.0. $P < 0{\cdot}05$ was considered statistically significant.

Results

The average daily energy intake of Japanese adults in the study sample was 6440·0 kJ (1539·2 kcal; excluding energy consumed outside the home and/or from alcohol). Unprocessed or minimally processed foods accounted for 44·9 % of total energy intake, processed culinary ingredients for 5·5 %, processed foods for 11·3 % and ultra-processed foods for 38·2 %. Rice accounted for half of the energy (22·4 %) from unprocessed and minimally processed foods, followed by meat (5·2 %) and vegetables (3·0 %). Most energy from processed culinary ingredients came from plant oils and animal fats (3·3 %). Processed grains (6·3 %), such as noodles and breads, were the highest contributors of energy among processed foods. Grain products (10·8 %), such as rice balls acquired from convenience stores, snacks (7·7 %) and seasonings (7·7 %) provided the highest proportion of energy among ultra-processed foods (Table 1).

The dietary share of ultra-processed foods ranged from <26·6 % of energy in the lower tertile (crude mean intake, 15·0 % of energy) to ≥46·0 % of energy in the upper tertile (crude mean intake, 63·6 % of energy). The minimum and maximum energy ratio values for ultra-processed foods were 0 % (n 4) and 100 % (n 7). The dietary share of unprocessed or minimally processed foods ($P < 0{\cdot}001$), processed culinary ingredients ($P < 0{\cdot}001$) and processed foods ($P < 0{\cdot}001$) decreased significantly across tertiles of the dietary share of ultra-processed foods. The dietary share of most subgroups belonging to the ultra-processed food group was significantly higher in the highest tertile of ultra-processed food consumption. An opposite trend was observed for subgroups from all three remaining groups (Table 1).

Table 2 shows sociodemographic characteristics across tertiles of the dietary share of ultra-processed foods. Age, sex and number of children were not significantly associated with ultra-processed food consumption. More participants in the highest tertile of ultra-processed food consumption were never married ($P = 0{\cdot}023$), lived alone ($P = 0{\cdot}033$), had regular full-time work ($P = 0{\cdot}032$) and lower income (<2 000 000 Japanese yen; $P = 0{\cdot}030$).

Table 3 shows the average energy and nutrient content overall and across tertiles of the dietary share of ultra-processed foods. The dietary content of total fat ($P = 0{\cdot}001$) and saturated fat ($P < 0{\cdot}001$) increased significantly with the increase in consumption of ultra-processed foods, while an inverse relationship was observed for the dietary content of protein ($P < 0{\cdot}001$), vitamin K ($P < 0{\cdot}001$), vitamin B_6 ($P = 0{\cdot}033$), dietary fibre ($P < 0{\cdot}001$), magnesium ($P < 0{\cdot}001$), phosphorus ($P = 0{\cdot}004$) and iron ($P = 0{\cdot}040$).

Discussion

In the present study, ultra-processed food consumption resulted in a general deterioration in the quality of diets of Japanese adults, especially increasing the content of total and saturated fat, and decreasing protein, dietary fibre, vitamins K and B_6, magnesium, phosphorus and iron. To our knowledge, the present study is the first to evaluate the consumption of ultra-processed foods and its association with dietary quality using individual-level data in Japan.

The average contribution of ultra-processed foods to the total energy intake has been reported as 20·4 % among Brazilians aged ≥10 years[50], 29·8 % among Mexicans aged ≥1 year[51], 35·9 % among French aged ≥18 years[22], 47·7 % among Canadians aged ≥2 years[17], 56·8 % among British aged ≥1·5 years[15] and 57·5 % among Americans aged ≥1 year[18]. Although traditional meals still play an important role in the Japanese diet[5], we found that the consumption of ultra-processed foods in our Japanese population was 38·2 % of total energy intake, which is similar to other high-income countries.

The share of ultra-processed foods is considered an excellent predictor of the quality of overall diets in high- and middle-income countries[12]. Consistent with previous studies from the USA, the UK, Canada and Brazil[13–19,22], we found that the consumption of ultra-processed foods was associated with unfavourable nutrient intake among Japanese adults. This low nutritional quality dietary pattern has been associated with obesity and other non-communicable diseases and gastrointestinal disorders in

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Table 1 Mean relative daily energy intake according to NOVA groups and subgroups across tertiles of the dietary share of ultra-processed food. Japanese population aged 30–59 years (*n* 617), Saitama Prefecture Health and Nutrition Survey 2011

	Overall diet (*n* 617*)				Dietary share of ultra-processed foods† (tertile)								
	Absolute intake (kcal/d)		Relative intake (% total energy intake)		①Low (*n* 181)		②Middle (*n* 184)		③High (*n* 186)				
NOVA food group	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	*P* value	Multiple comparison‡	*P* for trend
Unprocessed or minimally processed foods	692·5	14·7	44·9	0·8	61·8	1·0	46·9	1·0	25·8	1·0	<0·001	① > ② ①, ② > ③	<0·001
Rice	351·9	10·6	22·4	0·6	32·5	1·0	23·3	1·0	11·8	1·0	<0·001	① > ② ①, ② > ③	<0·001
Meat (incl. poultry)	81·3	3·8	5·2	0·2	6·9	0·4	5·7	0·4	3·1	0·4	<0·001	①, ② > ③	<0·001
Vegetables (incl. unsalted vegetable juices)§	45·3	1·5	3·0	0·1	3·8	0·2	3·2	0·2	2·1	0·2	<0·001	①, ② > ③	<0·001
Fish and seafood§	44·1	2·9	3·0	0·2	3·9	0·4	3·3	0·3	1·9	0·3	<0·001	①, ② > ③	0·001
Milk and plain yoghurt§	38·8	2·3	2·5	0·2	3·1	0·3	2·7	0·3	1·9	0·3	0·006	① > ③	0·002
Egg	36·0	1·7	2·3	0·1	2·9	0·2	2·6	0·2	1·4	0·2	<0·001	①, ② > ③	<0·001
Other unprocessed or minimally processed foods§,‖	34·4	2·3	2·4	0·2	3·4	0·3	2·1	0·3	1·5	0·3	<0·001	① > ②, ③	<0·001
Fruits (incl. unsweetened fruit juices)§	30·7	1·8	2·1	0·1	2·6	0·2	2·0	0·2	1·6	0·2	0·012	① > ③	0·005
Soyabean (e.g. *nattou* (fermented soybean))§	17·8	1·3	1·2	0·1	1·6	0·2	1·5	0·2	0·7	0·2	<0·001	①, ② > ③	<0·001
Other grain§,¶	12·2	2·1	0·8	0·1	1·6	0·3	0·9	0·3	0·3	0·3	<0·001	①, ② > ③	<0·001
Processed culinary ingredients	85·9	3·0	5·5	0·2	7·5	0·3	6·2	0·3	3·0	0·3	<0·001	① > ② ①, ② > ③	<0·001
Plant oils and animal fats	52·4	2·2	3·3	0·1	4·6	0·2	3·9	0·2	1·6	0·2	<0·001	①, ② > ③	<0·001
Soya sauce and miso (Japanese special seasoning)	16·6	0·6	1·1	0·0	1·4	0·1	1·2	0·1	0·7	0·1	<0·001	①, ② > ③	<0·001
Sugar (including honey, maple syrup)§	11·8	0·7	0·8	0·0	0·9	0·1	0·9	0·1	0·5	0·1	<0·001	①, ② > ③	<0·001
Other processed culinary ingredients§,**	2·4	0·3	0·2	0·0	0·3	0·0	0·2	0·0	0·1	0·0	<0·001	①, ② > ③	<0·001
Processed foods††	171·1	6·3	11·3	0·4	15·9	0·8	10·6	0·8	8·1	0·8	<0·001	① > ②,③	<0·001
Grains§	95·1	5·4	6·3	0·4	9·0	0·7	6·0	0·7	4·3	0·7	0·001	①, ② > ③	<0·001
Cured/salted soyabean§	29·7	1·9	2·0	0·1	2·6	0·2	1·9	0·2	1·6	0·2	0·050		0·026
Cured/salted fish§	20·7	1·8	1·4	0·1	2·2	0·2	1·2	0·2	1·1	0·2	0·003	① > ②, ③	0·002
Cured/salted meat§	12·5	1·1	0·8	0·1	1·2	0·1	0·8	0·1	0·6	0·1	0·022	① > ③	0·006
Cheese§	8·2	0·9	0·5	0·1	0·7	0·1	0·6	0·1	0·4	0·1	0·248		0·370
Preserved vegetables§	2·7	0·3	0·2	0·0	0·3	0·0	0·2	0·0	0·2	0·0	0·437		0·359
Other processed foods§	1·9	0·4	0·1	0·0	0·2	0·1	0·2	0·1	0·1	0·1	0·149		0·052
Preserved fruits§	0·4	0·1	0·0	0·0	0·1	0·0	0·1	0·0	0·1	0·0	0·442		0·317
Ultra-processed foods‡‡	589·7	15·0	38·2	0·9	14·8	0·7	36·3	0·7	63·2	0·7	<0·001	① < ② ①, ② < ③	<0·001
Grain dishes	170·5	10·2	10·8	0·6	1·1	1·0	8·9	1·0	21·4	1·0	<0·001	① < ② ①, ② < ③	<0·001
Sweets, fatty or salty snacks§	116·7	6·9	7·7	0·5	3·2	0·8	7·7	0·8	13·0	0·8	<0·001	① < ② ①, ② < ③	<0·001
Seasoning	116·1	4·5	7·7	0·3	5·6	0·5	9·0	0·5	8·6	0·5	<0·001	① < ②, ③	<0·001
Meat, fish, egg and soyabean dishes§	72·4	4·5	4·6	0·3	2·6	0·5	5·1	0·5	6·1	0·5	<0·001	① < ②, ③	<0·001
Bentou§	53·2	6·7	3·3	0·4	0·1	0·7	1·7	0·7	8·1	0·7	<0·001	①, ② < ③	<0·001
Drink§	27·5	2·3	1·9	0·2	1·0	0·4	2·1	0·4	2·9	0·4	<0·001	① < ②, ③	<0·001
Vegetable dishes§	16·5	1·8	1·2	0·1	0·7	0·2	1·2	0·2	1·6	0·2	0·051		0·021
Dairy products§	11·1	1·1	0·8	0·1	0·8	0·1	0·8	0·1	1·2	0·1	0·034		0·022
Soup§	7·1	0·9	0·5	0·1	0·5	0·1	0·4	0·1	0·9	0·1	0·005	①, ② < ③	0·005
Total	1539·2	19·9	100·0		100·0		100·0		100·0				

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Table 1 *Continued*

NOVA food group	Overall diet (*n* 617*) Absolute intake (kcal/d) Mean	SE	Overall diet (*n* 617*) Relative intake (% total energy intake) Mean	SE	Dietary share of ultra-processed foods† (tertile) ①Low (*n* 181) Mean	SE	②Middle (*n* 184) Mean	SE	③High (*n* 186) Mean	SE	*P* value	Multiple comparison‡	*P* for trend
Alcohol§	43·0	6·5	1·9	0·2	2·5	0·5	1·7	0·5	1·9	0·5	<0·001	① > ②, ③	<0·001
Eating out (e.g. restaurant)	276·0	16·1	14·1	0·8	16·6	1·4	13·4	1·4	13·4	1·4	0·169		0·107

To convert to kJ, multiply kcal value by 4·184.
ANCOVA. Values are adjusted means with their SE. Models adjusted for age, sex, family structure and income.
*Overall diet was calculated including sixty-six participants having missing values on income and/or family structure.
†Percentage of total energy intake from ultra-processed foods. Mean: low = 15·0 %; middle = 36·2 %; high = 63·6 %.
‡Multiple comparison was used with Bonferroni correction. '>' and '<' show intake size.
§These data did not follow a normal distribution, so were log-transformed. The values in the table indicate the values before the log transformation.
‖Potato, mushroom, seeds, tea and coffee.
¶Flour, pasta and macaroni.
**Vinegar, sweet sake (*mirin*) used as seasoning.
††Grains: e.g. salted, boiled wheat noodles (e.g. steamed *udon* wheat noodles), bread (e.g. slice of bread). Cured/salted soyabean: e.g. tofu. Cured/salted fish: e.g. cake of fish paste. Cured/salted meat: e.g. ham, bacon. Preserved vegetables: e.g. pickles. Other processed foods: dried and salted seaweed, salted butter. Preserved fruits: e.g. salted plums.
‡‡Grain dishes: e.g. rice ball, sushi, soba noodles. Sweets, fatty or salty snacks: e.g. sweet red bean ban, rice cracker. Seasoning: margarine, instant basic stock, ready-to-eat-sauces (e.g. mabo-tofu sauce, dried seasoning powder). Meat, fish, egg and soyabean dishes: e.g. grilled chicken skewers, deep-fried horse mackerel, steamed savoury cup custard. *Bentou*: one plate meal. Drink: e.g. salted or sugared vegetable or fruit juice, soft drink. Vegetable dishes: e.g. spinach with sesame dressing. Milk and dairy products: e.g. sugared or sweetened milk drinks, fruit yoghurts. Soup: e.g. instant miso soup.

Table 2 Sociodemographic characteristics according to tertiles of the dietary share of ultra-processed foods. Japanese population aged 30–59 years (*n* 617), Saitama Prefecture Health and Nutrition Survey 2011

Variable	Dietary share of ultra-processed foods* (tertile) All (*n* 617) Mean or *n*	SD or %	①Low (*n* 206) Mean or *n*	SD or %	②Middle (*n* 206) Mean or *n*	SD or %	③High (*n* 205) Mean or *n*	SD or %	*P* value
Age† (years)	45·6	8·4	46·0	8·6	45·5	8·3	45·4	8·4	0·775
Sex‡									
Men	256	41·5	92	44·7	72	35·0	92	44·9	0·066
Women	361	58·5	114	55·3	134	65·0	113	55·1	
Marital status‡									
Never married	87	14·1	23	11·2	23	11·2	41	20·1	0·023
Married (has a spouse)	493	80·2	175	85·0	167	81·5	151	74·0	
Married (divorce/bereavement)	35	5·7	8	3·9	15	7·3	12	5·9	
Has children‡									
Yes	444	72·2	147	71·7	159	77·2	138	67·6	0·096
No	171	27·8	58	28·3	47	22·8	66	32·4	
Family structure§									
Alone	35	5·8	7	3·5	6	3·0	22	10·8	0·033
One generation	117	19·2	42	20·8	35	17·2	40	19·7	
Two generation	396	65·1	134	66·3	140	69·0	122	60·1	
Three generation	50	8·2	14	6·9	19	9·4	17	8·4	
Other	10	1·6	5	2·5	3	1·5	2	1·0	
Work status‡									
Full-time, regular work	350	57·0	122	59·5	99	48·1	129	63·5	0·032
Part-time	128	20·8	36	17·6	56	27·2	36	17·7	
Unemployed	114	18·6	39	19·0	45	21·8	30	14·8	
Other	22	3·6	8	3·9	6	2·9	8	3·9	
Income‡									
<2 000 000 yen	49	8·8	11	5·9	16	8·6	22	11·7	0·030
2 000 000–6 000 000 yen	266	47·6	77	41·6	97	52·2	92	48·9	
≥6 000 000 yen	244	43·6	97	52·4	73	39·2	74	39·4	

Missing values are excluded for each variable.
*Percentage of total energy intake from ultra-processed foods. Mean: low = 15·0 %; middle = 36·2 %; high = 63·6 %.
†One-way ANOVA. Values are mean and SD.
‡χ^2 test. Values are *n* and %.
§Fisher's exact test. Values are *n* and %.

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Table 3 Average nutrient content of the overall diet according to tertiles of the dietary share of ultra-processed foods. Japanese population aged 30–59 years (*n* 617), Saitama Prefecture Health and Nutrition Survey 2011

	Dietary share of ultra-processed foods* (tertile)										
	Overall diet (*n* 617†)		①Low (*n* 181)		②Middle (*n* 184)		③High (*n* 186)				
Energy and nutrient intake	Adjusted average	SE	Adjusted average	SE	Adjusted average	SE	Adjusted average	SE	*P* value	Multiple comparison‡	*P* for trend
Total energy (kcal)	1895·6	17·9	1858·6	31·9	1947·6	31·7	1920·1	31·6	0·131		0·174
Protein (% of energy)	14·0	0·1	14·5	0·2	14·0	0·2	13·5	0·2	0·002	① > ③	<0·001
Fat (% of energy)	27·4	0·2	26·0	0·4	28·5	0·4	28·1	0·4	<0·001	① < ②, ③	0·001
Saturated fat (% of energy)	7·2	0·1	6·7	0·2	7·5	0·2	7·5	0·2	<0·001	① < ②, ③	<0·001
Carbohydrate (% of energy)	58·5	0·3	59·5	0·5	57·6	0·5	58·4	0·5	0·022	① > ②	0·112
Vitamin A (μg RAE)§	488	18	453	34	486	34	538	34	0·352		0·201
Vitamin D (μg)§	6·5	0·3	7·0	0·5	6·6	0·5	5·9	0·5	0·763		0·492
Vitamin E (mg)§	7·6	0·4	7·1	0·6	7·7	0·6	7·5	0·6	0·119		0·164
Vitamin K (μg)	209	5	235	10	232	10	166	9	<0·001	①, ② > ③	<0·001
Thiamin (mg)§	1·22	0·19	0·88	0·36	1·71	0·35	0·98	0·35	0·009	① < ②	0·555
Riboflavin (mg)§	1·29	0·08	1·13	0·15	1·46	0·15	1·24	0·15	0·115		0·440
Niacin (mg NE)	14·7	0·2	15·1	0·4	14·7	0·4	14·6	0·4	0·697		0·428
Vitamin B_6 (mg)§	1·5	0·2	1·3	0·4	2·0	0·4	1·4	0·4	0·015	② > ③	0·033
Vitamin B_{12} (μg)	5·9	0·2	6·2	0·4	5·8	0·4	5·6	0·4	0·526		0·276
Folic acid (μg)	251	4	259	6	252	6	243	6	0·199		0·073
Vitamin C (mg)§	87	4	87	8	88	8	89	8	0·680		0·418
Dietary fibre (g)	12·9	0·2	13·7	0·3	13·2	0·3	12·0	0·3	<0·001	①, ② > ③	<0·001
Na (mg)	3763	50	3781	79	3810	78	3736	78	0·798		0·690
K (mg)	2005	24	825	25	877	25	802	25	0·097		0·511
Ca (mg)	444	8	457	13	443	13	435	13	0·488		0·237
Mg (mg)	224	2	238	4	225	4	215	4	<0·001	① > ②, ③	<0·001
P (mg)	925	10	953	13	934	13	898	13	0·014	① > ③	0·004
Fe (mg)	7·0	0·1	7·1	0·2	7·1	0·2	6·7	0·2	0·058		0·040

RAE, retinal activity equivalents; NE, niacin equivalents.
To convert to kJ, multiply kcal value by 4·184.
ANCOVA. Values are adjusted average and their SE.
Total energy, protein (% of energy), fat (% of energy) and carbohydrate (% of energy) adjusted for age, sex, income and family structure. Other nutrient intakes adjusted for age, sex, income, family structure and total energy.
*Percentage of total energy intake from ultra-processed foods. Mean: low = 15·0 %; middle = 36·2 %; high = 63·6 %.
†Overall diet was calculated including sixty-six participants having missing values on income and/or family structure.
‡Multiple comparison was used with Bonferroni correction. '>' and '<' show intake size.
§These data did not follow a normal distribution, so were log-transformed. The values in the table indicate the values before the log transformation.

national-level cross-sectional and longitudinal studies in the USA, Brazil, Spain and France[22,25–33,35,36]. Although Japan is one of the countries with the lowest proportion of obesity[52], 2013 Euromonitor data showed that the retail sales of ultra-processed foods in Japan was high, with Japan ranked tenth out of eighty countries[39], calling for attention to the potential replacement of traditional meals with ultra-processed foods in the country.

The Ministry of Agriculture, Forestry and Fisheries of Japan revealed that skipping meals, lower intake of rice, higher incidence of eating out, consumption of processed foods at dinner and an inability to cook have reduced the practice of Japanese traditional dietary patterns[5]. All these circumstances are related with the modes of eating ultra-processed foods. Because of their formulation, they negate the necessity of culinary preparation and are omnipresent, which make them convenient and accessible. The aggressive marketing amplifies their 'advantages' over unprocessed or minimally processed foods, contributing to the replacement of traditional meals by ultra-processed foods that are not only associated with health problems, but are also troublesome for social, cultural, economic, political and environmental factors[11]. On the other hand, traditional meals can contribute to better health and a greater sense of well-being by providing a rich source of nutrients and through the sharing of meals[39].

Our study has several strengths. It is the first study carried out in Japan aiming to analyse food consumption according to the NOVA system, which has been recognized as a relevant approach for linking dietary intakes and all forms of malnutrition[11,53]. We analysed dietary records based on individual data which were from a two-stage stratified random sampling survey. Handmade recipes were also disaggregated into underlying ingredients,

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enabling the assessment of the four food groups of the NOVA system and consequent comparisons with similar studies[13–20,22].

Nevertheless, some limitations deserve mention. First, the sample size was small and limited to one study area in Japan. The second limitation of our study is that dietary intake was assessed using two-day dietary records. Longer dietary records more closely reflect habitual food intake[54]. Therefore, a one- or two-day dietary record may not reflect habitual dietary intake, although these have been used in most population-based studies[13,15,17,18,50]. Third, the present study may include systematic errors, such as the misreporting of true intake. A previous study suggested that people may under-report consumption of some foods, such as those rich in fat and/or in carbohydrates (i.e. French fries, confectionery, cakes, pastries, biscuits, etc.), like ultra-processed foods[55], which could have resulted in an underestimation of the true level of total energy, fat and saturated fat intake. Should upper tertiles have a higher chance of under-reporting these kinds of food, this may have attenuated the magnitude of the studied associations. Finally, we did not consider the effects of alcohol or eating out because we excluded these from the analyses. However, alcohol consumption and eating out were minimal by participants in the present study. The median percentage of total energy intake from alcohol was 0·0 %, and 0·1 % for eating out. Furthermore, future studies are needed to investigate the impact of ultra-processed foods on the diet quality and health outcomes in Japan, using a larger sample size and age range.

Conclusion

In summary, we found that the consumption of ultra-processed foods among middle-aged Japanese adults was significantly related to an unhealthy diet. Avoiding ultra-processed food consumption is a potentially effective way to improve the nutritional quality of diets among Japanese adults.

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Supplementary material

To view supplementary material for this article, please visit https://doi.org/10.1017/S1368980019001514

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