RESEARCH
Research Brief

Association between Ultra-processed Food Consumption and Dietary Intake and Diet Quality in Korean Adults

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ABSTRACT

Background Food environments have changed rapidly, and the global interest in ultra-processed foods has increased. Ultra-processed foods are typically energy dense, high in sugars and fat, and low in fiber, protein, minerals, and vitamins.

Objective This study aimed to estimate the energy contribution of ultra-processed foods in the diet of Korean adults and to examine the association between ultra-processed food consumption and dietary intake and diet quality.

Design This study is a secondary analysis of cross-sectional data from the Korea National Health and Nutrition Examination Survey (2016–2018).

Participants/settings A total of 16,657 adults aged ≥19 years who completed a 1-day 24-hour recall.

Main outcome measures Absolute and relative intake of energy and nutrients were measured and dietary quality was assessed using the Korean Healthy Eating Index (KHEI).

Statistical analysis Multiple regression models adjusted for sociodemographic variables were used to examine the association between quintiles of ultra-processed foods dietary energy contribution and dietary intake and quality.

Results Mean reported daily energy intake was 2,031 kcal, with 25.1% of calories coming from ultra-processed foods. Mean energy contribution from ultra-processed foods ranged from 3.6% kcal (Q1) to 52.4% kcal (Q5). Energy contribution of ultra-processed foods was positively associated with reported intake of daily energy, total sugars, and total and saturated fat and inversely associated with reported intake of carbohydrates, fiber, minerals, and vitamins. Both sodium and potassium were negatively associated with percentage of energy from ultra-processed foods. However, the sodium-to-potassium ratio was high regardless of quintile of energy contribution from ultra-processed foods, and the ratio was positively associated with percentage of total energy from ultra-processed foods. Although the KHEI score was inversely associated with percentage of daily energy from ultra-processed foods, all levels of ultra-processed food consumption were associated with poor diet quality.

Conclusions The ultra-processed foods consumption of Korean adults accounted for one fourth of daily energy intake, and a higher dietary energy contribution from ultra-processed foods was associated with poorer dietary intakes and a lower dietary quality. Further studies are needed to understand factors influencing selection and consumption of ultra-processed foods and to identify effective strategies to promote healthy food choices.
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Because of rapid transformations of the food supply system, food environments are changing dramatically.[1-3] In traditional food systems, food is consumed primarily in the form of fresh food or a dish prepared from fresh ingredients through the cooking process.[4] However, modern food environments have been dominated by various types of processed food products, owing to industrialization, urbanization, increased international trade, and socio-structural changes such as increases in working women and single-person households.[2,4]

Food processing includes all sorts of intentional changes made to food from farm to fork. The extent of food processing ranges from relatively simple operations by which raw foodstuffs are made appropriate for consumption, cooking, or storage (such as the removal of inedible parts, crushing, vacuum packing, drying, or freezing) to foodstuffs

manufactured through complex industrial processing.[5,6] Ultra-processed foods are industrial products made using substances extracted from foods (eg, fats, sugars, and oils) or derived from food constituents (eg, hydrogenated fats) or synthesized from other organic sources (eg, flavor enhancers and sweeteners), with little or even no whole foods.[5,7] They are designed for hyper-palatability, high convenience (durable, able to be consumed anywhere and at any time), and high profitability (low-cost ingredients and long shelf-life).[4,5,7] As a result, they have poor nutritional quality (typically energy-dense, high in sugars and fats, and low in fiber, protein, minerals, and vitamins).[5] Moreover, ultra-processed foods tend to be habitually consumed and less satiating, which may lead to overconsumption.[5,8,9] Growing evidence has suggested positive associations between ultra-processed food consumption and the risk of chronic disease and mortality.[10-14]

The energy contribution from ultra-processed products in North American and European countries is considerable.[15-19] Although consumption of ultra-processed food in Latin American countries is relatively low, growing evidence suggests that consumption and sales of these foods are increasing rapidly.[20,21] However, little evidence is available concerning the contribution of ultra-processed foods to dietary intake of Koreans, and whether this contribution is associated with dietary quality.

Therefore, this study aimed to estimate the energy contribution of ultra-processed foods in the Korean diet and to examine the association between the consumption of ultra-processed foods and dietary intakes and quality in Korean adults.

RESEARCH SNAPSHOT

Research Question: Is there an association between ultra-processed foods consumption and dietary intake and quality in Korean adults?

Key Findings: Analysis of data from 16,657 adults in the Korea National Health and Nutrition Examination Survey 2016–2018 showed that 25.1% of daily energy intake came from ultra-processed foods (UPFs). Energy from UPFs was positively associated with intake of energy, total sugars, fat, and sodium-to-potassium ratio, and was negatively associated with intake of carbohydrates, fiber, minerals and vitamins. Moreover, the dietary contribution of UPFs among Korean adults had an inverse relationship with overall dietary quality

METHODS

Data Source and Population

This study was based on data from the Korea National Health and Nutrition Examination Survey (KNHANES) 2016–2018. KNHANES, which is a nationwide cross-sectional survey to assess the health and nutritional status of Koreans, collects information regarding socioeconomic status, quality of life, healthcare utilization, anthropometric measures, biochemical and clinical profiles, health-related behaviors, and dietary intakes through health interview, health examination, and nutrition survey.[22] Approximately 10,000 individuals aged 1 year or older were included as representative samples of the Korean population each year, and all of the surveys were conducted by the Korea Centers for Disease Control and Prevention (KCDC). The survey protocols were approved by the Institutional Review Board of the KCDC, and informed consent was obtained from each participant before data collection.

Among the 31,689 sampled individuals for the KNHANES 2016–2018, 24,269 (76.6%) participated in at least one of three surveys (health interview, health examination, and nutrition survey).[23] Among 16,853 adults who completed a 1-day 24-hour recall, women who were pregnant (n = 90) or breast-feeding (n = 106) were excluded. A final sample of 16,657 adults aged 19 years or older was included in this study.

Dietary Assessment and Dietary Intake

The nutrition survey was conducted approximately 1 week after the health interview and health examination. The nutrition survey comprised a dietary behavior questionnaire, dietary intake assessment, and household food security survey. Trained dietitians visited each participant's home and collected dietary information in a face-to-face interview.

Dietary intake was assessed using a 1-day 24-hour recall. During the interview, all respondents were requested to describe details concerning their dietary intake over the 24 hours of the previous day, such as when, where, what, and how much they consumed. The day the dietitians visited the participant's home was selected at random between Monday and Sunday to avoid bias toward a specific day of the week. The KNHANES dietary assessment has been administered using a computer-assisted interviewing and data entry system since 2014. Similarly to the US Department of Agriculture Automated Multiple-Pass Method designed for complete and accurate collection of dietary data,[24] the KNHANES system also has a multiple-pass approach consisting of five steps for each respondent's food consumption and another three steps for collection of home recipes. For those who had difficulty recalling and reporting their diet (eg, children and cognitively disabled adults), the interviews were completed with the help of the person who prepared their meals or took care of them (eg, their mother). However, there were no set guidelines for such proxy interviews (eg, proxies assist with children aged ≤5 years) specified in the KNHANES.[22,25] To help a respondent estimate the amount of food consumed, various measuring tools (ie, standard measuring cups, spoons, a ruler, and two-dimensional drawings of measuring guides) were used. The respondents were also asked to report whether the food they consumed was homemade, prepared at a restaurant or other place, or a manufactured product. If the food was made at home, the home recipe (individual ingredient food items and amount) was additionally collected from the person who prepared the food. If the recipes could not be obtained or if the foods were prepared outside the home, standard recipes developed by the KCDC were applied and disaggregated into individual ingredient foods.

Before dietary intake calculation, multi-ingredient foods were disaggregated into individual ingredients, using home or standard recipes. The estimated amount of food consumption reported by the respondent was converted into weight (g) on the basis of a database for the volume and weight of foods.[25,26] Dietary intake of energy and nutrients

were calculated using data from the Korean Food Composition Table (version 9.1), which was released by the National Institute of Agricultural Sciences,[27] and a separate database maintained by the KCDC.[26] Raw data were obtained from the KNHANES website.[28] The absolute intake of energy, carbohydrates, protein, total fat, total sugars, dietary fiber, saturated fat, sodium, phosphorus, potassium, calcium, iron, vitamin A, thiamin, riboflavin, vitamin C, and niacin were included in the raw data. The relative intakes of macronutrients (percentage of daily energy intake), minerals, and vitamins (unit/1,000 kcal) and the ratio of sodium to potassium were calculated for this study.

Korean Healthy Eating Index

Overall diet quality was evaluated using the Korean Healthy Eating Index (KHEI), which was developed to assess the diet quality of Korean adults. The KHEI is an indicator of how well an individual's diet complies with the recommended guidelines. The initial version was developed by Yook and colleagues[29] in 2015 based on dietary guidelines for Korean adults, the 2010 Dietary Reference Intakes for Koreans, and the fourth Health Plan 2020.[29] In 2018, the KCDC modified the initial KHEI to reflect updated information such as dietary guidelines for adults and the 2015 Dietary Reference Intakes for Koreans.[30] In this study, the modified KHEI was used for analysis. The modified KHEI has a total of 14 components: eight for adequate intake (breakfast; mixed grains; total fruits; fresh fruits; total vegetables; vegetables excluding kimchi and pickled vegetables; meat, fish, eggs, and beans; milk and milk products), three for moderate intake (saturated fatty acid; sodium; sweets and beverages), and three for balanced diet (carbohydrates; total fat; total energy). Each component is scored from 0 to 5 (or 10) points, and total score ranges from 0 to 100. Higher scores reflect better diet quality. KHEI scores were evaluated based on food and nutrient intake (assessed by a 1-day 24-hour recall) and the frequency of breakfast consumption over the past week (collected in the dietary behavior survey). For each component, a diet that met the recommended standard received the maximum score for that component, whereas the further the intake was from the recommended standard, the lower the score was proportionately. Thus, in the case of adequacy components, higher intakes scored higher points, whereas in moderation components, higher intakes scored lower points.

Among the KHEI components, each food was classified into a specific food group mainly according to the general characteristics of the food, not the degree of processing. Hence, all dairy products such as plain or sweetened milk, yogurts, and cheeses were grouped into the milk and dairy group. The sweets and beverages group included sugars (eg, sugar, honey, molasses, syrup), confectionary (eg, candy, chocolate, jelly, caramel), coffee or tea (with or without sugar), cocoa, alcoholic beverages, soft drinks, fruit and vegetable drinks, and other beverages (eg, energy drinks). More details on the modified KHEI components and scoring standards are found elsewhere.[30]

Food Classification According to the NOVA System

Food items reported in the 24-hour recall were classified into four groups as follows, according to the NOVA system,[5,7] which classifies foods on the basis of the nature, extent, and purpose of industrial processing: unprocessed or minimally processed foods, processed culinary ingredients, processed foods, and ultra-processed foods. Foods obtained directly from nature or minimally altered by processes that do not add any additional ingredients were classified as unprocessed or minimally processed foods. Food products extracted (eg, plant oils, animal fats, sugar, and starch) from foods or purified (eg, salt) directly from nature were classified as processed culinary ingredients. Foods manufactured by adding culinary ingredients to unprocessed or minimally processed foods were classified as processed foods. These foods are generally made by adding processed culinary ingredients such as salt, sugar, or oils to unprocessed or minimally processed foods. In this process, preservation methods such as canning, bottling, and fermentation are used to improve storability. Finally, industrial formulations manufactured using substances derived from foods, other organic sources, preservatives, and additives were classified as ultra-processed foods. These foods typically contain little or no original foods and often imitate the appearance, shape, and taste of foods using processing techniques. The main aim of these processes is to create highly convenient, palatable, and profitable products with a long shelf life. More details on these definitions and explanations are described elsewhere.[5,7]

A total of 3,894 food items were consumed as food itself or ingredients in the 24-hour recall dataset. Food classification was performed independently by three researchers, and items with disagreements were resolved by discussion. Each food was classified into one of four NOVA food groups (unprocessed or minimally processed foods [n = 265], processed culinary ingredients [n = 427], processed foods [n = 1,164], and ultra-processed foods [n = 2,038]) and into one of 34 subgroups. The detailed rationale of classification is described elsewhere.[5,7]

Sociodemographic Characteristics

Information on sex, age, household income, household's size and composition, and residence area was obtained using an interviewer-administered questionnaire. Household income was adjusted according to the number of people within the household. Residence area was classified into urban and rural area based on the administrative units of the South Korea. The quartiles of equivalized household income and urban/rural area were defined by KNHANES.[23]

Statistical Analysis

The energy contribution of NOVA food groups and subgroups was presented as daily dietary energy intake (kcal) from each group and its relative contribution to daily energy intake (%). To present the nutrient content from non–ultra-processed and ultra-processed foods, four NOVA food groups were reclassified into two groups: ultra-processed foods and non–ultra-processed foods, with the latter comprising the three other NOVA food groups (unprocessed or minimally processed foods, processed culinary ingredients, and processed foods). Nutrient intake, including the absolute intake and relative intake (% of daily intake), and nutrient density (% of daily energy intake for macronutrients and unit per 1,000 kcal for micronutrients) of non–ultra-processed and ultra-processed foods were estimated. To compare food groups and nutrient intake by the level of ultra-processed food

consumption, individuals were divided into quintiles according to the energy contribution of ultra-processed foods: Q1 (<7.25%), Q2 (7.26%–14.88%), Q3 (14.89%–24.10%), Q4 (24.11%–37.54%), and Q5 (≥37.55%). Multiple regression models were used to test trends in dietary intake across quintiles of ultra-processed food energy contribution and to examine the association between this energy contribution and diet quality. Multiple regression models were adjusted for sex, age (years), residence area (rural and urban), and household income (in quartiles).

All estimates presented in this study took into account sampling weights provided by the KCDC and survey design. Data analyses were performed using SAS 9.4 software,[31] and results were regarded as significant at $P < 0.05$.

RESULTS

The study sample comprised 16,657 Korean adults aged 19 years or older. Survey-weighted socioeconomic characteristics of the respondents are shown in Table 1. Nearly half of the adults were 40 to 64 years old. Approximately 85% of the Korean adults lived in urban areas.

The mean reported daily energy intake of Korean adults aged 19 year or older was 2,031 kcal, 59.8% of which came from unprocessed or minimally processed foods, 4.0% from processed culinary ingredients, 11.2% from processed foods, and 25.1% from ultra-processed foods (Table 2). Within the unprocessed or minimally processed foods, most calories came from grains (33.7% of daily energy intake), followed by meats (8.1%), fruits (4.6%), vegetables, mushrooms, and seaweeds (3.2%), and eggs (2.3%). The other five subgroups accounted for 7.9% of daily energy intake. Most calories in processed culinary ingredients came from plant oils (2.7%) and sugars (0.9%). Among processed foods, noodles and starchy gelatin (5.8%), salted or pickled vegetables including kimchi (1.8%), and fermented alcoholic beverages (1.7%) were major contributors to daily energy intake. The largest contributors to dietary energy intake in the ultra-processed food group were cereals, bread, cakes, and sandwiches (6.4%), distilled alcoholic beverages (2.8%), sugar-sweetened beverages (2.8%), and fish and meat processed foods (2.3%). The remaining eight subgroup foods accounted for 10.8% of total energy intake.

Table 3 shows mean reported dietary intake per day from non–ultra-processed and ultra-processed foods. Although dietary energy consumption from ultra-processed foods only accounted for one-fourth of daily energy intake, nearly half of daily total sugars (43.2%) and sodium (43.4%) intake came from ultra-processed foods. In contrast, dietary intake of protein, dietary fiber, and micronutrients consumed from ultra-processed foods amounted to less than one fourth of total intake.

Table 4 shows reported consumption of NOVA food groups and subgroups by quintile of ultra-processed food energy contribution. The mean energy contribution of ultra-processed foods ranged from 3.6% (Q1) to 52.4% (Q5). Positive trends in the energy contribution of all subgroups within ultra-processed foods were observed across quintiles of ultra-processed contribution, except for traditional sauce. The energy intake from unprocessed or minimally processed foods and processed foods was half the amount in Q5 vs Q1: 36.6%

Table 1. Distribution of study population aged 19 years or older, KNHANES 2016–2018[a]

Characteristics	Total sample, unweighted n	Quintiles of Energy Contribution of Ultra-processed Foods (Weighted %[b])			
		All	Q1	Q3	Q5
Sex					
Men	7,164	50.3	43.2	49.9	54.3
Women	9,493	49.7	56.8	50.1	45.7
Age, year					
19–39	4,442	34.8	17.2	32.8	40.2
40–64	7,745	48.2	49.8	53.0	49.3
65+	4,470	16.9	32.9	15.2	10.4
Household income					
Low (Q1)	3,366	16.0	26.6	14.4	11.4
Low-middle (Q2)	4,066	23.7	25.8	22.1	22.7
High-middle (Q3)	4,402	28.7	22.5	29.6	32.3
High (Q4)	4,777	31.6	25.0	33.9	33.6
Residence					
Urban	13,436	84.8	80.3	85.2	86.3
Rural	3,221	15.2	19.7	14.8	14.7

[a]This analysis was performed using 1-day 24-hour dietary recall data from Korea National Health and Nutrition Examination Survey (KNHANES).
[b]Weighted numbers and percentages have been adjusted to be nationally representative.

Table 2. Mean energy intake and its mean contribution to total daily energy intake of NOVA food groups and subgroups in Korean adults aged 19 years or older, KNHANES 2016–2018[a]

	Energy intake (kcal/day)		Contribution to total daily energy intake (%)	
Food groups	**Mean**	**(SE)**	**Mean**	**(SE)**
Total	**2,031**	**(11.9)**	—	—
Unprocessed or minimally processed foods	**1,163**	**(7.6)** [b]	**59.8**	**(0.3)**
Grains	626	(5.0)	33.7	(0.3)
Meats	189	(4.1)	8.1	(0.1)
Fruits	86	(1.6)	4.6	(0.1)
Vegetables, mushrooms, and seaweeds	63	(0.6)	3.2	(0)
Eggs	45	(0.8)	2.3	(0)
Fish and sea foods	44	(1.1)	2.1	(0)
Legumes, nuts and seeds	38	(0.8)	2.0	(0)
Milk and plain yogurts	34	(0.8)	1.8	(0)
Potatoes	33	(1.3)	1.7	(0.1)
Coffee and tea without sugar	5	(0.1)	0.3	(0)
Processed culinary ingredients	**86**	**(1.2)**	**4.0**	**(0.1)**
Plant oils	58	(0.9)	2.7	(0)
Sugars (sugar, honey, molasses, etc.)	19	(0.4)	0.9	(0)
Animal fats	5	(0.4)	0.2	(0)
Starch	3	(0.2)	0.1	(0)
Salt, vinegars, and others	0	(0)	0	(0)
Processed foods	**241**	**(3.9)**	**11.2**	**(0.1)**
Noodles, starchy gelatin	126	(3.1)	5.8	(0.1)
Fermented alcoholic beverages	44	(1.6)	1.7	(0.1)
Salted or pickled vegetables, including kimchi	34	(0.4)	1.8	(0)
Soybean curd	19	(0.5)	1.0	(0)
Canned or bottled fish and sea foods	11	(0.4)	0.6	(0)
Fruit jams, canned fruits	5	(0.2)	0.2	(0)
Others (seasoned nuts, seeds, etc.)	2	(0.2)	0.1	(0)
Ultra-processed foods	**541**	**(6.4)**	**25.1**	**(0.2)**
Cereals, breads, cakes, sandwiches, etc.	135	(3.0)	6.4	(0.1)
Distilled alcoholic beverages	84	(3.1)	2.8	(0.1)
Sugar-sweetened beverages[c]	53	(0.9)	2.8	(0.1)
Fish and meat processed foods	50	(1.6)	2.3	(0.1)
Instant noodles and dumplings	36	(1.5)	1.9	(0.1)
Traditional sauce	34	(0.5)	1.7	(0)
Sweetened milk and its products	33	(1.0)	1.7	(0)
Others (instant sauce, condiments, etc.)	32	(0.9)	1.5	(0)
Cookies, chips, and snacks	31	(1.2)	1.5	(0)
Soft drinks, fruit and vegetable drinks	31	(0.9)	1.4	(0)
Instant cooked rice, soup, and other dishes	12	(0.7)	0.6	(0)
Confectionary	10	(0.5)	0.5	(0)

[a]This analysis was performed using 1-day 24-hour dietary recall data from Korea National Health and Nutrition Examination Survey (KNHANES).
[b]Energy intakes (kcal/day and % of total daily energy intake) were presented after rounding, so the value for each NOVA food group may not equal the sum of the food subgroups.
[c]Includes coffee or tea products with added sugar or milk, cocoa, or other sugar-sweetened beverages.

Table 3. Mean dietary intake and nutrient density of non–ultra-processed and ultra-processed foods of Korean adults aged 19 years or older, KNHANES 2016–2018[a]

	Non–ultra-processed Foods[b]			Ultra-processed Foods		
Nutrients intake/day	Absolute intake (% of total daily intake)		Nutrient density [c]	Absolute intake (% of total daily intake)		Nutrient density
Energy (kcal)	1,490	(75.0)		541	(25.1)	
Carbohydrate (g)	229.5	(76.8)	64.5	69.7	(23.4)	63.0
Total sugars (g)	34.5	(57.4)	9.8	27.8	(43.2)	26.1
Protein (g)	60.2	(81.8)	16.5	13.0	(18.3)	12.4
Fat (g)	32.2	(70.8)	18.9	14.1	(29.5)	24.1
Saturated fat (g)	9.6	(64.6)	5.6	5.4	(35.9)	9.6
Dietary fiber (g)	20.8	(82.0)	14.5	4.3	(18.2)	10.4
Sodium (mg)	2,012.0	(56.8)	1391.9	1,472.7	(43.4)	6281.2
Calcium (mg)	404.2	(77.5)	285.5	115.1	(22.6)	261.8
Phosphorous (mg)	873.9	(80.0)	594.5	211.1	(20.1)	503.2
Potassium (mg)	2,417.6	(83.4)	1680.9	434.8	(16.7)	1250.4
Iron (mg)	10.0	(82.7)	6.9	2.2	(17.4)	4.9
Vitamin A (RAE)	314.2	(83.1)	218.8	67.8	(17.7)	161.8
Vitamin B_1 (mg)	1.1	(81.2)	0.7	0.3	(19.0)	0.7
Vitamin B_2 (mg)	1.2	(77.8)	0.8	0.4	(22.4)	1.1
Niacin (mg)	11.2	(80.7)	7.7	2.7	(19.4)	6.3
Vitamin C (mg)	51.0	(87.0)	36.8	11.2	(14.4)	25.8

[a]This analysis was performed using 1-day 24-hour dietary recall data from Korea National Health and Nutrition Examination Survey (KNHANES).
[b]Includes unprocessed or minimally processed foods, processed culinary ingredients, and processed foods.
[c]Nutrient density for each food was expressed as percentage of total energy (ie, carbohydrate, total sugars, protein, total and saturated fat) or as density (unit per 1,000 kcal, ie, dietary fiber, minerals, and vitamins), respectively.

vs 80.0% for unprocessed/minimally processed and 7.4% vs 12.8% for processed foods.

The overall mean daily dietary intake reported by Korean adults and the mean density profiles of selected nutrients across quintiles of ultra-processed food dietary energy contribution are presented in Table 5. In terms of the daily energy intake of Korean adults (2,031 kcal), 64.3% came from carbohydrates, 15.2% from proteins, and 20.5% from fat. The mean intake of total sugars and sodium was 62.3 g (13.1% of daily energy intake) and 3,484.8 mg per day (1,748.2 mg per 1,000 kcal), respectively. Daily energy intake and the energy from total sugars, total fat, and saturated fat showed a significantly positive association with the energy contribution of ultra-processed foods, whereas the energy consumed from carbohydrates and the nutrient density of fiber, minerals, and vitamins showed a negative association with the energy contribution of ultra-processed foods. In the current study, a negative trend in sodium density was observed across quintiles of energy contribution of ultra-processed food consumption (1,719.3 mg/1,000 kcal in Q1–1,648.4 mg/1,000 kcal in Q5). However, the difference in potassium density by quintile of ultra-processed food energy contribution was much greater, and thus a positive trend in the ratio of sodium to potassium was observed across quintiles of energy contribution from ultra-processed foods (1.1 in Q1–1.5 in Q5).

Table 6 presents the association of dietary quality with ultra-processed food energy contribution in Korean adults aged ≥19 years. The total KHEI score had a significantly negative association with quintiles of energy consumption from ultra-processed foods. For most adequacy and moderation components (except meat, fish, eggs, and legumes and milk and dairy), the mean scores were negatively associated with high energy from ultra-processed foods. The score of the meat, fish, eggs, and legumes component did not differ by quintile of ultra-processed food energy contribution ($P = 0.157$). For milk and dairy consumption, the mean score showed positive trends with higher ultra-processed food energy contribution quintile ($P < 0.0001$). For balance components, the mean scores of carbohydrate and fat were positively associated with energy from ultra-processed foods ($P < 0.0001$). The balance component of total energy did not vary by quintiles of total daily energy contribution from ultra-processed foods ($P = 0.740$).

DISCUSSION

This nationwide representative survey found that approximately one fourth of the daily energy consumption of Korean adults aged 19 years or older came from ultra-processed foods. High energy contribution from ultra-processed foods

Table 4. Mean energy contribution according to *NOVA* food groups and subgroups across quintiles of energy contribution of ultra-processed foods in Korean adults aged 19 years or older, KNHANES 2016–2018[a]

Food groups[b]	Quintiles of Energy Contribution of Ultra-processed Foods					*P* for linear trend[c]
	Q1	Q2	Q3	Q4	Q5	
Unprocessed or minimally processed foods	**80.0**	**71.5**	**63.7**	**54.3**	**36.6**	**<0.0001**
Grains	48.4	41.9	35.2	29.5	18.5	<0.0001
Meats	8.0	8.7	9.2	8.8	6.2	<0.0001
Fruits	6.7	5.6	5.0	3.8	2.6	<0.0001
Vegetables, mushrooms, and seaweeds	3.8	3.7	3.5	3.1	2.2	<0.0001
Eggs	2.4	2.5	2.5	2.3	1.8	<0.0001
Fish and sea foods	2.3	2.4	2.3	2.0	1.7	<0.0001
Legumes, nuts and seeds	3.3	2.5	2.0	1.6	1.0	<0.0001
Milk and plain yogurts	2.0	1.8	2.0	1.8	1.6	0.0001
Potatoes	2.9	2.1	1.7	1.1	0.8	<0.0001
Coffee and tea without sugar	0.3	0.2	0.3	0.3	0.3	0.576
Processed culinary ingredients	**3.5**	**4.1**	**4.5**	**4.4**	**3.5**	**<0.0001**
Plant oils	2.4	2.8	3.0	3.0	2.2	<0.0001
Sugars (sugar, honey, molasses, etc.)	0.9	1.0	1.0	1.0	0.8	0.001
Animal fats	0.1	0.1	0.3	0.3	0.3	0.014
Starch	0.1	0.2	0.2	0.2	0.1	<0.0001
Salt, vinegars, and others	0.0	0.0	0.0	0.0	0.0	0.099
Processed foods	**12.8**	**13.3**	**12.5**	**10.8**	**7.4**	**<0.0001**
Noodles, starchy gelatin	6.8	7.2	6.6	5.3	3.5	<0.0001
Fermented alcoholic beverages	1.5	1.7	1.8	2.0	1.5	0.004
Salted or pickled vegetables including kimchi	2.4	2.1	1.9	1.7	1.2	<0.0001
Soybean curd	1.2	1.2	1.1	0.9	0.6	<0.0001
Canned or bottled fish and sea foods	0.6	0.7	0.7	0.6	0.4	<0.0001
Fruit jams, canned fruits	0.3	0.2	0.3	0.2	0.2	0.067
Others (seasoned nuts, seeds, etc.)	0.1	0.1	0.1	0.1	0.0	0.0001
Ultra-processed foods	**3.6**	**11.1**	**19.3**	**30.4**	**52.4**	**<0.0001**
Cereals, breads, cakes, sandwiches, etc.	0.2	1.6	4.2	7.8	15.4	<0.0001
Distilled alcoholic beverages	0.0	0.3	0.9	3.5	8.1	<0.0001
Sugar-sweetened beverages[d]	0.8	2.8	3.3	3.4	3.5	<0.0001
Fish and meat processed foods	0.2	0.9	1.6	2.8	5.2	<0.0001
Instant noodles and dumplings	0.0	0.2	0.7	2.1	5.3	<0.0001
Traditional sauce	1.5	2.0	1.9	1.7	1.3	0.010
Sweetened milk and its products	0.2	0.9	1.7	2.2	2.9	<0.0001
Others (instant sauce, condiments, etc.)	0.3	0.9	1.6	1.9	2.3	<0.0001
Cookies, chips, and snacks	0.1	0.7	1.3	1.8	2.9	<0.0001
Soft drinks, fruit and vegetable drinks	0.1	0.6	1.3	1.9	2.8	<0.0001
Instant cooked rice, soup, and other dishes	0.0	0.1	0.3	0.7	1.8	<0.0001
Confectionary	0.1	0.3	0.4	0.6	0.9	<0.0001

[a]This analysis was performed using 1-day 24-hour dietary recall data from Korea National Health and Nutrition Examination Survey (KNHANES).
[b]Numbers represent % of energy coming from each designated food group.
[c]Linear trends across quintiles of energy contribution of ultra-processed foods were adjusted for sex, age (years), residence area (rural and urban), and household income (in quartiles).
[d]Includes coffee or tea products with added sugar or milk, cocoa, or other sugar-sweetened beverages.

Table 5. Nutrient density profiles of the overall diet across quintiles of energy contribution of ultra-processed foods in Korean adults aged 19 years or older, KNHANES 2016–2018[a]

	All		Quintiles of Energy Contribution of Ultra-processed foods					*P* for linear trend[b]
Nutrients intake/day	Mean	(SE)	Q1	Q2	Q3	Q4	Q5	
Energy (kcal)	2,031	(11.9)	1,722	1,879	2,013	2,165	2,278	<0.0001
Carbohydrate (% of energy)	64.3	(0.1)	69.9	67	64.3	62.2	59.7	<0.0001
Total sugars (% of energy)	13.1	(0.1)	10.7	11.9	13.3	13.6	15.0	<0.0001
Protein (% of energy)	15.2	(0.1)	14.9	15.2	15.3	15.2	15.3	<0.0001
Fat (% of energy)	20.5	(0.1)	15.3	17.8	20.4	22.5	25.1	<0.0001
Saturated fat (% of energy)	6.7	(0)	4.5	5.5	6.6	7.4	8.7	<0.0001
Dietary fiber (g/1,000 kcal)	13	(0.1)	15.8	14.5	13.5	11.9	10.4	<0.0001
Sodium (mg/1,000 kcal)	1,748.2	(8.6)	1,719.3	1,818.2	1,819.9	1,751.1	1,648.4	<0.0001
Potassium (mg/1,000 kcal)	1,464.3	(6.3)	1,685.4	1,629.3	1,537.2	1,393.1	1,168.3	<0.0001
Ratio of Na:K	1.3	(0)	1.1	1.2	1.3	1.3	1.5	<0.0001
Calcium (mg/1,000 kcal)	268	(1.5)	274.6	275.6	278.8	265.4	250.2	<0.0001
Phosphorous (mg/1,000 kcal)	545	(1.6)	575.4	578.9	567.5	537.5	482.1	<0.0001
Iron (mg/1,000 kcal)	6.2	(0)	6.8	6.7	6.4	6.0	5.4	<0.0001
Vitamin A (RAE/1,000 kcal)	191.7	(2.1)	192.4	199	201.3	200.7	168.6	<0.0001
Vitamin B_1 (mg/1,000 kcal)	0.7	(0)	0.7	0.7	0.7	0.7	0.6	<0.0001
Vitamin B_2 (mg/1,000 kcal)	0.8	(0)	0.8	0.8	0.8	0.8	0.8	<0.0001
Niacin (mg/1,000 kcal)	6.9	(0)	7.1	7.2	7.1	6.8	6.5	<0.0001
Vitamin C (mg/1,000 kcal)	32.6	(0.4)	36.3	34.4	35.1	31.5	27.4	<0.0001

[a]This analysis was performed using 1-day 24-hour dietary recall data from Korea National Health and Nutrition Examination Survey (KNHANES).
[b]Linear trends across quintiles of energy contribution of ultraprocessed foods were adjusted for sex, age (year), residence area (rural and urban), and household income (in quartiles).

was positively associated with daily intakes of energy, total sugars, total and saturated fat, and sodium-to-potassium ratio and was negatively associated with carbohydrates, dietary fiber, calcium, sodium, potassium, phosphorus, iron, vitamins A, thiamin, riboflavin, niacin, and vitamin C intakes. Moreover, high energy contribution from ultra-processed foods was negatively associated with overall dietary quality.

Globally, the proportion of traditional homemade meals in the diet has decreased, and the consumption of highly processed foods has been increasing rapidly.[19,20,32] Consumption of ultra-processed foods accounts for 57.9% of total energy intake in the United States,[17] 56.8% in the United Kingdom,[15] 47.7% in Canada,[16] 42.0% in Australia,[33] 61% in Sweden, and 78% to 79% in the Netherlands and Germany.[18] Canadian Household Food Budget Surveys showed that the dietary energy contribution of ready-to-consume or ultra-processed products increased from 28.7% in 1938 to 61.7% in 2001, demonstrating a remarkable change of Canadian household food expenditures and energy availability.[19] Contrary to the findings in high-income countries, ultra-processed food consumption in Brazil,[34] Mexico,[35] and Indonesia[36] are far lower, accounting for 20.4%, 30.0%, and 15.7% of daily energy intake, respectively. Relatively low-income countries seem to still have diets based on unprocessed and minimally processed foods. Notable differences can be seen in ultra-processed food consumption between high-income countries and middle- or low-income countries. These differences are generally influenced by the gaps in the demand for such foods after industrialization, urbanization, and labor market changes as well as the food environment, including the affordability, accessibility, and availability of ultra-processed foods.[1,4,37]

In the current study, the energy contribution of ultra-processed foods among adults in Korea resembled intake levels observed in lower-income countries rather than those of higher-income countries. This may be partly attributable to the unique food culture in Korea. Although Korea also has experienced a rapid transition in diet,[38] the Korean diet still has different features compared with other countries, that is, meals based on rice and freshly prepared side dishes.[38,39] The Korean mean consumption of sugar-sweetened beverages, an ultra-processed food consumed globally, has been found to be low compared with other countries.[40] However, along with rapid social change (ie, increases in the female workforce and single-person households), Koreans' consumption behavior is moving toward convenience, and the market size of highly processed foods (ie, ready-to-eat-foods) is dramatically expanding.[41] Furthermore, Korea also faces the aggressive marketing of transnational corporations targeting Asian countries.[4] Thus, further research and monitoring of ultra-processed food consumption is needed.

Table 6. Korean healthy eating index (KHEI) score across quintiles of energy contribution of ultra-processed foods in Korean adults aged ≥19 years, KNHANES 2016–2018[a]

KHEI	All		Quintiles of Energy Contribution of Ultra-processed foods					*P* for linear trend[b]
	Mean	(SE)	Q1	Q2	Q3	Q4	Q5	
Total KHEI score (0–100)	62.4	(0.17)	65.2	66.0	64.8	62.1	55.4	<0.0001
Component of KHEI score								
Adequacy								
Breakfast (0–10)	7.1	(0.05)	8.3	7.8	7.3	6.7	5.8	<0.0001
Mixed grains (0–5)	1.9	(0.02)	2.5	2.3	2.0	1.8	1.2	<0.0001
Total fruits (0–5)	2.1	(0.03)	2.6	2.5	2.3	1.9	1.5	<0.0001
Fresh fruits (0–5)	2.3	(0.03)	2.7	2.7	2.5	2.1	1.7	<0.0001
Total vegetable (0–5)	3.4	(0.02)	3.7	3.8	3.7	3.5	2.8	<0.0001
Vegetable, excluding kimchi and pickles (0–5)	3.2	(0.02)	3.2	3.4	3.4	3.3	2.5	<0.0001
Meat, fish, eggs, and legumes (0–10)	7.1	(0.04)	6.5	7.1	7.5	7.5	6.9	0.157
Milk and dairy (0–10)	3.3	(0.05)	2.1	2.8	3.6	3.7	3.8	<0.0001
Moderation								
Sodium (0–10)	6.7	(0.04)	7.6	6.9	6.5	6.3	6.5	<0.0001
Saturated fatty acid (0–10)	7.3	(0.04)	8.9	8.5	7.7	6.9	5.2	<0.0001
Sweets and beverages (0–10)	9.1	(0.02)	9.9	9.7	9.1	8.8	8.3	<0.0001
Balance								
Carbohydrate (0–5)	2.5	(0.02)	1.8	2.3	2.6	2.9	2.8	<0.0001
Fat (0–5)	3.3	(0.02)	2.5	3.1	3.5	3.7	3.6	<0.0001
Total energy (0–5)	3.0	(0.02)	2.9	3.2	3.2	3.1	2.9	0.740

[a]Korean Healthy Eating Index score was calculated using several sources of information (dietary intakes assessed by a 1-day 24-hour recall; breakfast frequency per dietary behavior questionnaire) from Korea National Health and Nutrition Examination Survey (KNHANES).
[b]Linear trend across quintiles of energy contribution of ultra-processed foods were adjusted for sex, age (years), residence area (rural and urban), and household income (in quartiles).

In the current study, a higher consumption of ultra-processed foods in Korean adults was associated with poorer dietary intake characterized by higher intake of dietary energy, protein, total fat, sugars, and saturated fat and lower intake of carbohydrate, dietary fiber, minerals, and vitamins. Although a higher energy contribution of ultra-processed foods was strongly associated with lower diet quality, all levels of ultra-processed food consumption were associated with poor diet quality. Although the results of the current study were similar to those of previous studies,[15-17,33,34] there were also some dissimilar findings. In studies conducted in the United Kingdom,[15] Cananda,[16] and Australia,[33] dietary sodium consumption had a positive association or no significant relationship with ultra-processed foods. However, in the current study, sodium density was negatively associated with the dietary energy contribution of ultra-processed foods. These conflicting results may be explained by the differences in the types of ultra-processed foods consumed in each country.[15] In the current study, a negative and significant linear trend was found between quintiles of ultra-processed food energy contribution and sodium density, but the difference in dietary potassium between the quintiles was much greater, resulting in higher sodium–potassium ratios in higher quintiles of ultra-processed food consumption.

Excessive sodium, high carbohydrate, low fat, and low calcium intake have been noted as major nutritional problems in the Korean diet.[26,42] In regard to diet quality as measured by the KHEI, the current study found that a high energy contribution of ultra-processed foods was positively associated with scores of balanced carbohydrate (Q1: 1.8; Q5: 2.8; $P < 0.0001$) and fat intake (Q1: 2.5; Q5: 3.6; $P < 0.0001$). In addition, the score of the milk and dairy component was higher in the highest quintile of ultra-processed food contribution (Q1: 2.1; Q5: 3.8; $P < 0.0001$); hence, there seems to be a beneficial aspect of ultra-processed food consumption on the Korean diet. However, for most adequacy and moderation components, the mean scores were negatively associated with high energy from ultra-processed foods. In successive quintiles of ultra-processed foods energy contribution, milk and plain yogurts were consumed less, from 2.0% of total energy intake to 1.6%, and sweetened milk and its products consumed more, from 0.2% to 2.9%. This indicates that the overall picture of the association of ultra-processed foods

with dietary intake is complex, warranting further investigation.

This is the first study conducted to estimate the energy contribution of ultra-processed foods in Korean adults and to investigate the association of ultra-processed food consumption with dietary quality. This study has several strengths. First, the current study used data from nationally representative surveys and applied the weights assigned to individuals for the analysis to reduce the impact of sampling and non-response errors. Thus, the results are generalizable to the Korean adult population. Second, some previous studies on ultra-processed food consumption have used household-level data under the assumption that all individuals within each household consume the same diet,[1] whereas the current study analyzed individual-level actual food consumption data measured using 24-hour recall interviews. Third, the Food and Agricultural Organization of the United Nations[43] suggests guidelines on how to collect information on processed foods during food consumption surveys. To distinguish highly processed food products from prepared-at-home (or restaurant) foods, various information is essential, including an ingredients list and preparation method (for dishes), and brand and product names (food products). The KNHANES obtained details on individual foods and home recipes from each participant or the person in charge of cooking at their home, and had standard recipes for dietary data processing.[23,26] Given such information, this study could classify foods according to NOVA classification. Finally, although the concepts and guidelines of the NOVA food classification system are well known,[5,7] some foods are still likely to be interpreted and classified differently. For this reason, the present study made a special effort to classify the foods reliably. Three researchers independently categorized foods according to the NOVA classification system and then, items for which there were inconsistencies were resolved by discussion.

Despite these strengths, this study has potential limitations. The first issue is related to the inherent weaknesses of the dietary assessment method. The KNHANES data collected dietary information on only one day and thus, could not reflect individuals' usual intake.[44] However, because this study focused on estimating the mean intake of a large population, not the habitual intake of each individual, 1-day assessment data were acceptable for this study.[44,45] Moreover, dietary assessment data such as 24-hour recall likely involves social desirability bias in self-reporting what each respondent ate.[46] Thus, some foods, especially those known as unhealthy, may be underreported. Second, during the survey, if a new commercial product (ie, ready-to-eat noodle soup) was reported to be consumed but it was not on the list of food composition data, the KNHANES coded it as a similar dish (ie, hand-made noodle soup), not as an ultra-processed product. Possibly some ultra-processed foods were treated as freshly prepared dishes, which may thus underestimate the consumption of ultra-processed food in the Korean adult diet. Fortunately, the food composition data applied in KNHANES was regularly updated to reflect the food market, so this issue would likely have little impact on the results. Third, in Korea, traditional sauces such as soy sauce and soybean paste are widely used when cooking. Some Koreans still use homemade sauces, whereas others use commercial brand products. Although the KNHANES had many data on food, information regarding sauces was, unfortunately, lacking. Thus, based on the general evidence that the proportion of home-prepared sauces has decreased over time,[47] whereas the use of industrial products has concomitantly increased even at home,[48] those Korean traditional sauces were classified as ultra-processed foods in this analysis. Finally, the KHEI is a tool for assessing diet quality, but the modified KHEI used in this study has yet to be evaluated for validity and reliability.

CONCLUSIONS

Ultra-processed food consumption of Korean adults constituted one fourth of the daily energy intake, and a higher energy contribution of ultra-processed foods was associated with poorer dietary intakes and a lower dietary quality. Further studies are needed to understand factors influencing selection and consumption of ultra-processed foods and to identify effective strategies to promote healthy food choices.

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STATEMENT OF POTENTIAL CONFLICT OF INTEREST

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AUTHOR CONTRIBUTIONS

J. S. Shim designed and conducted the research, classified and revised the food groups, analyzed and interpreted data, and wrote the manuscript. S. Y. Shim and H. J. Cha classified and revised the food groups. J. Kim and H. C. Kim contributed to the preparation and the revision of the manuscript. All authors read and approved the final manuscript.