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Trends in intake and sources of dietary protein in Korean adults, 1998–2018

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Abstract

Although a decrease in carbohydrate intake and an increase in fat intake among Koreans have been reported, investigations of changes in protein intake have been limited. Thus, this study aimed to explore trends in the dietary intake of total, plant and animal proteins overall and by socio-demographic subgroups in Korea over the past two decades. A total of 78 716 Korean adults aged ≥ 19 years who participated in the seven survey cycles of the Korea National Health and Nutrition Examination Survey 1998–2018 were included. Dietary protein intake, overall and by source, was calculated using a single 24-h dietary recall data. Changes in dietary protein over 20 years were estimated using multiple linear regression analysis after adjusting for potential covariates. For total protein intake, a significant decrease was reported from 1998 to 2016–2018 (P for trend$_{linearity}$ < 0·001), whereas an increasing trend was observed from 2007–2009 to 2016–2018 (P for trend$_{linearity}$ < 0·001). In terms of protein intake by source, plant protein intake decreased while animal protein intake increased over the past two decades, indicating steeper trends during the recent decade (P for trend$_{linearity}$ < 0·001). These trends were more pronounced among younger adults and those with higher household income and education levels. These findings suggest that continuous monitoring of dietary protein intake overall and by source (plant *v.* animal) across socio-demographic group is needed.

Key words: Dietary protein: Plant protein: Animal protein: Protein source: Korean adults

The Korean government recently announced the updated Dietary Reference Intakes for Koreans. In 1962, the Korean Recommended Dietary Allowance (RDA) were first established by the Korea Food and Agriculture Organization (FAO) Association; since then, six revisions have been made. In 2005, the Korean Nutrition Society changed its paradigm from the Korean RDA to the Dietary Reference Intakes for Koreans, updating them every 5 years. The newly published 2020 Dietary Reference Intakes for Koreans recommend 55–65 % and 15–30 % as the acceptable macronutrient distribution ranges of carbohydrates and fats, respectively, for adults aged ≥ 19 years[1]. The acceptable macronutrient distribution ranges, which indicate the proportion of energy from macronutrients to total energy, for carbohydrate and fat have changed over the past decade. Since 2015, the acceptable macronutrient distribution ranges for carbohydrates have been adjusted from 55–70 % to 55–65 %, while that for fat has changed from 15–25 % to 15–30 %. However, the acceptable macronutrient distribution ranges for protein have remained unchanged at 7–20 % since 2005[1,2].

In addition, many studies have investigated the changes in energy and macronutrient intake in Koreans, mainly focusing on carbohydrates and fats with large intake variations[3–6]. During the period from 1998 to 2013–2015, the percentage of energy from carbohydrates decreased by 3·4 % in men and 3·7 % in women. In contrast, men and women exhibited a 4 % and 4·4 % increase in the percentage of energy from fat during the same period, respectively, more so in younger age groups than in older age groups[3]. Similar to global trends, previous studies reported that changes in protein intake are relatively stable compared with those in carbohydrates and fat in Korean populations. Despite the small changes in protein intake over time, it is well known that proteins play many important roles in the body: functioning as essential structural elements; regulating tissues and organs; functioning as enzymes, hormones and antibodies; and maintaining proper pH and fluid balance. In addition, the effect of dietary protein intake on health outcomes has long been among the main interests in the field of nutrition. The relationships between dietary protein intake and diseases, such as abdominal obesity[7], type 2 diabetes[8], hypertension[9], sarcopenia[10], hand grip strength[11] and even mortality[12,13], have been investigated.

In recent years, several studies have focused on the differential health effects of protein intake by source. In the pooled analysis of the three cohorts, plant protein was negatively associated with type 2 diabetes, while animal protein was positively associated with type 2 diabetes[14]. An inverse association

Abbreviation: CVD, Cardiovascular disease; FAO, Food and Agriculture Organization; KNHANES, Korea National Health and Nutrition Examination Survey; RDA, Recommended Dietary Allowance.

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between plant protein and obesity has also been reported[15] along with a 5-year change in systolic and diastolic blood pressures[16]. Findings from the EPIC-InterAct Case-Cohort Study showed unfavourable effects of animal proteins on type 2 diabetes[17]. A recent meta-analysis of 112 randomised controlled trials highlighted that the substitution of animal protein with plant protein showed serum lipid-lowering effects[18]. A pooled analysis of six prospective cohort studies also reported beneficial effects of the substitution of plant protein for animal protein on incident Cardiovascular disease (CVD) and all-cause mortality[19]. The effects of protein intake by source on health outcomes remain under debate[12–17].

According to nationwide analyses in Korea, the prevalence of metabolic diseases is steadily increasing, decreasing and then increasing, with differing trends across socio-demographic characteristics (obesity: from 29·1 % in 2009 to 32·5 % in 2018[20]; diabetes: from 11·8 % in 2012 to 13·8 % in 2018[21]; hypertension: from 19·7 % in 2007 to 23·5 % in 2018[22]; hypercholesterolaemia: 8·8 % in 2007 to 18·0 % in 2018[23] and the metabolic syndrome: from 21·6 % in 2007 to 22·9 % in 2018[24]). Such changes in the prevalence of metabolic diseases can be explained by the transition to a Western-style diet characterised by a high consumption of animal-based foods and a low consumption of plant-based foods. In addition, as the source of foods shifted from plant to animal based, trends in dietary protein intake may also vary by source despite there being no significant change in total protein intake over time. Nevertheless, limited information is available to document secular trends in dietary protein overall and by source among the general Korean adult population.

Therefore, this study aimed to estimate changes in dietary protein (total, plant and animal) intake overall and by socio-demographic characteristics and describe trends in dietary protein intake by food source (plant *v.* animal based) over the period of 1998–2018 in Korean adults.

Materials and methods

Data source and study population

The Korea National Health and Nutrition Examination Survey (KNHANES) is an ongoing national surveillance conducted by the Korea Centers for Disease Control and Prevention. The KNHANES was initiated in 1998 with the aim of evaluating the health and nutritional status of adults and children and monitoring trends in the prevalence of chronic diseases and health risk factors in Korea. The KNHANES was initially conducted every 3 years. However, since 2007, the survey system has been conducted every year, and data from each 3-year period comprise one survey cycle. The KNHANES has been described in detail elsewhere[25].

For this study, the data collected through seven survey cycles (1998–2018) from the KNHANES were combined: 1998 (KNHANES I), 2001 (KNHANES II), 2005 (KNHANES III), 2007–2009 (KNHANES IV), 2010–2012 (KNHANES V), 2013–2015 (KNHANES VI) and 2016–2018 (KNHANES VII). A total of 78 716 Korean adults aged ≥ 19 years who completed the nutrition survey and reported their plausible energy intake (2092–20 920 kJ/d[13,26]) were included in the analytic samples. The protocols and procedures of the KNHANES were approved by the Korea Centers for Disease Control and Prevention Institutional Review Board (2007-02CON-04-P, 2008-04EXP-01-C, 2009-01CON-03-2C, 2010-02CON-21-C, 2011-02CON-06-C, 2012-01EXP-01-2C, 2013-07CON-03-4C, 2013-12EXP-03-5C, 2018-01-03-P-A), and all participants provided written informed consent.

Socio-demographic characteristics

Data on the following socio-demographic characteristics were included in the current analyses: sex (men or women), age group (19–29, 30–49, 50–64, ≥ 65 years), household income (lowest, lower middle, upper middle and highest), education level (less than elementary school, middle school, high school, and college or higher) and residential area (urban or rural).

Dietary intakes

Dietary intake was assessed based on a 24-h dietary recall. A nutrition survey of the KNHANES including 1-d 24-h dietary recall was conducted 1 week after the health interview and health examination to avoid the impacts of external factors that can affect diet such as fasting. In the nutrition survey, four specialised investigation teams consisting of two trained dieticians each were responsible for one primary sampling unit per week, and the investigation was conducted using the face-to-face computer-assisted personal interview method by a visit to each household[27]. In the 24-h dietary recall survey, information about the types, amount, timing and location of each food and beverage item consumed by individuals during the previous day was recorded. Based on the National Standard Food Composition Table of the Korean Rural Development Administration, the daily intake amount and percentage of energy from macronutrients (carbohydrates, proteins and fat) were estimated. Intakes of total, plant and animal protein were presented as follows: (1) grams of protein per day and (2) percentage of energy from protein per day. The percentage of energy from macronutrients (carbohydrate, protein and fat) was calculated as the proportion of energy from each macronutrient to the total energy intake. To assess the intake of dietary protein from different food sources, we aggregated all food and beverage items into fifteen food groups from the KNHANES coding system[27] and previous studies[28–30]. Of the fifteen food groups, grains and their products, flour and bread, legumes, vegetables, kimchi and pickles, fruits, nuts and other plant foods were classified as plant sources (eight food groups), while unprocessed red meat, seafood, poultry, eggs, dairy products, processed meat and other animal foods were classified as animal sources (seven food groups). Likewise, protein intakes from plant sources were classified as plant proteins, whereas those from animal sources were classified as animal proteins.

Statistical analyses

All statistical analyses were performed using SAS version 9.4 (SAS Institute). The KNHANES used a complex stratified multi-stage probability sampling to achieve representativeness. To obtain nationally representative estimates, we used sample weight, primary sampling unit and stratum variables in all analyses according to the KNHANES analytic guidelines[27]. This adjustment allowed for the extrapolation of data from each survey to the entire civilian non-institutionalised Korean population. The results are presented as frequencies (weighted percentages) for categorical variables and as medians and interquartile ranges for continuous variables with non-symmetrical distributions. The general characteristics of the participants according to survey cycle were compared using the χ^2 test for categorical variables. Trends in dietary protein intake over time were described overall and by socio-demographic subgroups and food sources. To reduce the impact of measurement error in the dietary estimates, the intakes of total, plant and animal protein (g/d) were energy adjusted using the residual method[31,32]. A multiple linear regression analysis was performed to estimate trends in dietary protein intake (total, plant and animal) across survey cycles, treating the midpoint of each survey cycle as a continuous variable. The nonlinearity of trends across survey cycles was determined by adding a quadratic term to the analytic models. The potential covariates included in the models were sex (men or women), age (continuous), household income (lowest, lower middle, upper middle and highest), education level (less than elementary school, middle school, high school, and college or higher) and residential area (urban or rural). Statistical significance was determined at a two-tailed P value < 0·05 in all analyses.

Results

The general characteristics of the study population from the KNHANES by survey cycle are presented in Table 1. A total of 78 716 Korean adults aged ≥ 19 years across all seven survey cycles were included in this study. The unweighted sample size was 7404 in 1998, 6577 in 2001, 6286 in 2005, 14 521 in 2007–2009, 15 439 in 2010–2012, 13 498 in 2013–2015 and 14 991 in 2016–2018, respectively. The distribution of age, household income, education level and residential area differed significantly across the survey cycles (all, P < 0·001), whereas no differences were observed in the distribution of sex among the survey cycles.

The overall trends in total energy intake and the percentage of energy from macronutrients for each survey cycle are presented in Fig. 1. The total mean energy intake (from 8249 kJ in 1998 to 8328 kJ in 2016–2018) and percentage of energy from fat (from 16·9 % in 1998 to 20·5 % in 2016–2018) increased, whereas the percentage of energy from carbohydrates (from 67·8 % in 1998 to 64·4 % in 2016–2018) and protein (from 15·3 % in 1998 to 15·1 % in 2016–2018) decreased (all P for $\text{trend}_{\text{linearity}}$ <0·0001).

The total protein intake for each survey cycle is presented in Table 2. The absolute intake and percentage of energy from total protein among Korean adults significantly decreased over the two decades (β: –0·44 (95 % CI –0·67, –0·21) g/survey cycle, P for $\text{trend}_{\text{linearity}}$ = 0·0002 for absolute total protein intake; β: –0·20 (95 % CI –0·23, –0·16) %/survey cycle, P for $\text{trend}_{\text{linearity}}$ < 0·0001 for percentage of energy from total protein intake). However, from 2007–2009 to 2016–2018, trends in absolute total protein intake demonstrated a significant increase (β: 0·71 (95 % CI 0·35, 1·07) g/survey cycle, P for $\text{trend}_{\text{linearity}}$ = 0·0001). From 1998 to 2016–2018, most of the subgroups by socio-demographic variables showed decreasing trends in absolute intake and percentage of energy from total protein, with the largest decline in adults aged 50–64 years (β: –0·99 (95 % CI –1·37, –0·61) g/survey cycle, P for $\text{trend}_{\text{linearity}}$ < 0·0001 for absolute intake; β: –0·30 (95 % CI –0·35, –0·24) %/survey cycle, P for $\text{trend}_{\text{linearity}}$ < 0·0001 for percentage of energy), and an increasing linear trend was found only in adults aged 19–29 years (β: 0·76 (95 % CI 0·28, 1·24) g/survey cycle, P for $\text{trend}_{\text{linearity}}$ = 0·0021 for absolute total protein intake). However, in terms of changes between 2007–2009 and 2016–2018, increasing trends in absolute total protein intake were observed among the subgroups with the greatest increase in adults aged 19–29 years (β: 1·67 (95 % CI 0·67, 2·68) %/survey cycle, P for $\text{trend}_{\text{linearity}}$ = 0·0011).

The mean plant protein intake for each survey cycle is summarised in Table 3. Absolute intake and percentage of energy from plant protein among Korean adults significantly decreased over the two decades among all subgroups (P for $\text{trend}_{\text{linearity}}$ < 0·001). From 1998 to 2016–2018, the most obvious decreasing trend of absolute plant protein intake was found in adults aged 30–49 years (β: –1·21 (95 % CI –1·35, –1·07) g/survey cycle, P for $\text{trend}_{\text{linearity}}$ < 0·0001), while the greatest decrease in percentage energy of plant protein was found in adults aged 19–29 years (β: –0·29 (95 % CI –0·32, –0·27) %/survey cycle, P for $\text{trend}_{\text{linearity}}$ < 0·0001). From 2007–2009 to 2016–2018, the steepest decreasing trends in plant protein intake were observed in adults aged 30–49 years (β: –1·69 (95 % CI –1·94, –1·44) g/survey cycle, P for $\text{trend}_{\text{linearity}}$ < 0·0001 for absolute intake; β: –0·44 (95 % CI –0·48, –0·41) %/survey cycle, P for $\text{trend}_{\text{linearity}}$ < 0·0001 for percentage of energy). Subgroups with younger age, higher incomes and higher education levels showed the steepest decrease in plant protein intake.

The animal protein intake for each survey cycle is presented in Table 4. Overall, the absolute intake and percentage of energy from animal protein among Korean adults substantially increased over the two decades (β: 0·55 (95 % CI 0·35, 0·74) g/survey cycle, P for $\text{trend}_{\text{linearity}}$ < 0·0001 for absolute intake; β: 0·06 (95 % CI 0·03, 0·10) %/survey cycle, P for $\text{trend}_{\text{linearity}}$ = 0·0004 for percentage of energy). These trends became precipitous in the last decade (β: 2·14 (95 % CI 1·84, 2·43) g/survey cycle, P for $\text{trend}_{\text{linearity}}$ < 0·0001 for absolute intake; β: 0·35 (95 % CI 0·30, 0·40) %/survey cycle, P for $\text{trend}_{\text{linearity}}$ < 0·0001 for percentage of energy). Adults aged 19–29 years showed the greatest increase in both absolute intake and percentage of energy from animal protein (β: 1·84 (95 % CI 1·42, 2·26) g/survey cycle, P for $\text{trend}_{\text{linearity}}$ < 0·0001 for absolute intake; β: 0·28 (95 % CI 0·22, 0·35) %/survey cycle, P for $\text{trend}_{\text{linearity}}$ < 0·0001 for percentage of energy). In addition, steeper increases in absolute animal protein intake were observed in men, younger age groups, individuals with a higher income and education level, and rural residents (all, P for $\text{trend}_{\text{linearity}}$ < 0·0001). In terms of the percentage of energy from animal protein, substantial increases were observed in women, younger age groups and rural residents (P for $\text{trend}_{\text{linearity}}$ < 0·0001).

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Table 1. General characteristics of study population by KNHANES survey cycle, 1998–2018*

	Survey cycle														
	1998		2001		2005		2007–2009		2010–2012		2013–2015		2016–2018		
	(*n* 7404)		(*n* 6577)		(*n* 6286)		(*n* 14 521)		(*n* 15 439)		(*n* 13 498)		(*n* 14 991)		
	n	Wt'd %	*n*	Wt'd %	*n*	Wt'd %	*n*	Wt'd %	*n*	Wt'd %	*n*	Wt'd %	*n*	Wt'd %	*P*
Sex															0·0735
Men	3434	49·2	3019	49·5	2797	49·2	5796	48·4	6156	48·0	5443	47·7	6249	48·7	
Women	3970	50·8	3558	50·5	3489	50·8	8725	51·6	9283	52·0	8055	52·3	8742	51·3	
Age group, years															< 0·0001
19–29	1527	26·6	1286	25·9	998	22·0	1748	19·3	1655	18·7	1553	18·0	1690	17·2	
30–49	3294	45·8	3156	45·8	2923	46·3	5738	44·8	5432	42·2	4561	39·8	5087	38·1	
50–64	1631	18·1	1299	18·2	1399	19·6	3646	22·4	4423	24·8	3818	26·5	4211	27·9	
≥ 65	952	9·5	836	10·1	966	12·0	3389	13·5	3929	14·3	3566	15·8	4003	16·9	
Household income															< 0·0001
Lowest	1661	18·7	1412	21·5	1365	19·2	3171	16·2	3150	16·1	2681	15·2	2955	15·6	
Lower middle	1728	21·9	1624	25·2	1587	25·9	3626	25·2	3970	27·0	3445	25·1	3670	23·6	
Upper middle	2128	30·8	1633	25·8	1693	28·2	3843	28·8	4172	29·4	3644	29·4	4054	29·3	
Highest	1887	28·5	1908	27·5	1641	26·7	3881	29·8	4147	27·5	3728	30·4	4312	31·6	
Education level															< 0·0001
≤ Elementary school	2177	22·0	1434	19·4	1507	19·5	4339	20·3	4165	19·0	3337	17·1	3217	14·9	
Middle school	1007	12·5	789	11·9	683	10·2	1671	10·5	1712	10·1	1464	9·2	1524	8·6	
High school	2581	39·2	2339	37·6	2453	42·2	4948	40·4	5040	38·6	4474	37·4	4704	34·6	
≥ College	1639	26·4	2015	31·2	1643	28·2	3563	28·8	4522	32·3	4223	36·3	5546	41·9	
Region															0·0009
Urban	4572	77·5	5071	79·9	4951	81·5	10 501	80·1	12 108	79·8	10 864	82·8	12 172	85·4	
Rural	2832	22·5	1506	20·1	1335	18·5	4020	19·9	3331	20·2	2634	17·2	2819	14·6	

KNHANES, Korea National Health and Nutrition Examination Survey; Wt'd %, weighted %.
* Data were obtained from the KNHANES. All data except for sample size were weighted to account for the complex study design according to the directions of the KNHANES analytical guidelines.

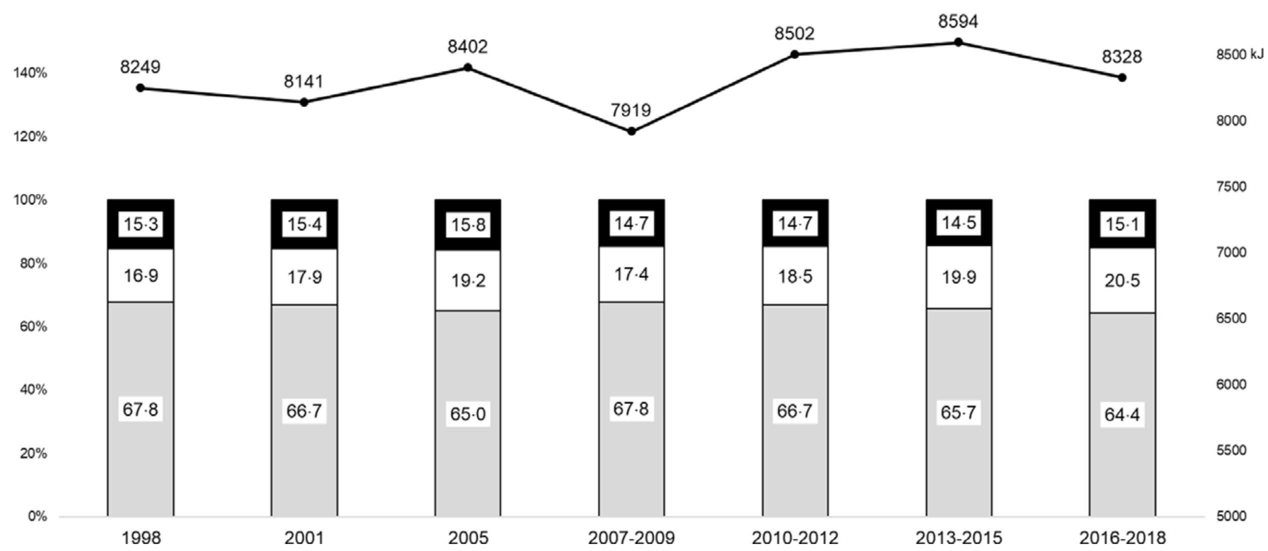

Fig. 1. Percentage of energy from carbohydrate, protein and fat among Korean adults from the KNHANES, 1998–2018*. *Data were obtained from the KNHANES. All data except for sample size were weighted to account for the complex study design according to the directions of the KNHANES analytical guidelines. Proportions were adjusted for sex, age, household income and region. KNHANES, Korea National Health and Nutrition Examination Survey. ▭, carbohydrate (%); ▭, fat (%); ▬, protein (%); –•–, total energy (kJ).

The dietary protein intake from different food sources for each survey cycle is presented in Table 5. The dietary protein intake from plant sources decreased significantly (β: –1·21 (95 % CI –1·32, –1·09) %/survey cycle, P for trend$_{linearity}$ < 0·0001 from 1998 to 2016–2018; β: –2·50 (95 % CI –2·70, –2·31) %/survey cycle, P for trend$_{linearity}$ < 0·0001 from 2007–2009 to 2016–2018), but dietary protein intake from animal sources has increased (β: 1·21 (95 % CI 1·09, 1·32) %/survey cycle, P for

Table 2. Trends in total protein intake among Korean adults in the KNHANES, 1998–2018*

	Survey cycle														1998 to 2016–2018				2007–2009 to 2016–2018			
	1998		2001		2005		2007–2009		2010–2012		2013–2015		2016–2018									
	(*n* 7404)		(*n* 6577)		(*n* 6286)		(*n* 14 521)		(*n* 15 439)		(*n* 13 498)		(*n* 14 991)									
	Median	IQR	Median	IQR	Median	IQR	Median	IQR	Median	IQR	Median	IQR	Median	IQR	β-coefficient†	95 % CI	P-linear trend‡	P-quadratic trend§	β-coefficient	95 % CI	P-linear trend	P-quadratic trend
Total protein (g)																						
Total	63·8	44·4–90·0	64·6	46·6–90·4	67·6	48·6–94·4	57·2	40·9–78·7	61·9	44·3–86·6	60·1	42·5–83·3	61·2	43·3–84·8	−0·44	−0·67, −0·21	0·0002	0·0009	0·71	0·35, 1·07	0·0001	< 0·0001
Sex																						
Men	73·0	52·8–102·2	75·2	54·6–101·9	78·8	56·2–107·5	69·6	51·0–93·1	75·6	53·7–103·0	72·0	52·7–96·7	73·9	53·0–99·9	–		0·8308	0·6812	0·65	0·07, 1·23	0·0280	< 0·0001
Women	56·0	39·6–78·4	56·8	41·0–77·5	60·3	44·0–83·1	50·4	36·4–68·2	54·8	39·5–74·4	53·0	38·4–72·4	53·7	38·7–73·4	−0·95	−1·19, −0·71	< 0·0001	< 0·0001	0·68	0·33, 1·03	0·0002	< 0·0001
Age group, years																						
19–29	66·1	46·7–90·2	64·7	45·4–91·2	70·1	49·3–96·8	62·1	44·9–86·1	68·3	49·4–95·2	67·0	47·1–94·1	68·4	47·1–96·6	0·76	0·28, 1·24	0·0021	0·4604	1·67	0·67, 2·68	0·0011	0·0023
30–49	70·7	51·1–99·1	70·8	51·8–96·9	73·9	54·0–101·5	63·3	46·7–85·7	69·7	51·0–94·8	66·1	47·7–90·2	68·2	49·4–94·1	−1·01	−1·34, −0·68	< 0·0001	< 0·0001	0·64	0·11, 1·17	0·0180	< 0·0001
50–64	59·4	41·1–83·1	62·4	45·0–84·3	65·6	47·8–91·0	57·9	41·5–79·0	63·0	45·4–86·0	61·2	44·3–83·1	61·7	45·0–83·8	−0·99	−1·37, −0·61	< 0·0001	0·3899	–		0·4007	< 0·0001
≥ 65	45·3	33·8–63·8	48·4	34·0–65·0	52·5	38·3–72·3	44·9	32·0–61·1	48·9	35·2–67·5	48·8	34·8–67·9	49·2	35·3–69·4	–		0·1259	0·0210	0·81	0·31, 1·30	0·0014	0·0019
Household income																						
Lowest	51·6	36·6–74·7	55·1	38·2–75·8	56·8	40·6–77·1	46·0	32·3–63·3	48·9	35·1–68·5	47·0	33·4–65·8	47·1	33·0–67·0	−0·48	−0·91, −0·05	0·0286	0·0328	0·87	0·16, 1·58	0·0163	0·0633
Lower middle	62·1	44·0–86·1	63·2	46·0–87·3	67·4	48·1–94·9	55·9	39·6–77·0	60·4	43·8–84·0	58·2	41·4–80·0	58·7	42·7–82·8	–		0·0744	0·2953	–		0·1105	0·0027
Upper middle	67·5	48·3–93·4	66·2	48·7–92·2	72·1	52·5–98·8	61·2	45·3–82·9	66·4	48·2–91·4	64·1	46·4–86·8	65·9	46·8–88·3	–		0·1458	0·1797	–		0·0551	0·0021
Highest	71·3	50·7–101·4	71·7	51·7–98·7	74·3	53·7–102·7	64·3	46·9–87·4	69·2	50·8–93·8	68·2	49·8–92·7	67·9	49·7–92·5	−0·58	−1·01, −0·15	0·0080	0·0050	0·78	0·14, 1·43	0·0177	< 0·0001
Education level																						
≤ Elementary school	49·9	35·6–71·3	51·1	36·4–70·3	54·7	39·9–75·2	45·1	32·2–62·2	47·7	34·4–65·5	46·3	33·1–64·5	45·8	32·5–63·6	−0·61	−0·97, −0·26	0·0007	0·0019	0·85	0·34, 1·37	0·0012	0·0187
Middle school	62·5	45·5–88·4	62·2	46·3–87·8	66·8	48·1–92·6	56·1	41·2–75·4	60·0	44·1–82·3	56·6	41·0–77·6	55·8	41·0–75·4	−0·79	−1·44, −0·15	0·0155	0·3244	–		0·2314	< 0·0001
High school	70·1	51·2–96·1	68·5	49·2–93·7	71·4	51·3–97·8	61·6	45·2–84·5	66·5	48·4–91·8	63·8	46·4–88·0	63·6	45·4–88·2	−0·57	−0·95, −0·19	0·0034	0·0011	0·78	0·15, 1·41	0·0157	0·0002
≥ College	73·1	52·6–101·7	72·5	53·1–99·1	76·9	56·3–104·2	67·7	50·7–90·4	72·5	53·0–97·3	68·5	50·1–92·3	70·2	51·7–95·0	–		0·7544	0·8667	0·74	0·16, 1·32	0·0124	< 0·0001
Region																						
Urban	60·6	43·1–83·7	67·1	47·7–93·8	66·4	47·7–92·9	68·9	49·4–96·3	58·7	42·1–80·2	63·2	45·4–87·9	62·2	43·9–85·8	−0·49	−0·75, −0·22	0·0003	0·0015	0·74	0·33, 1·14	0·0003	< 0·0001
Rural	58·4	40·0–82·6	59·2	42·1–79·9	63·1	45·5–87·5	53·3	38·0–74·8	57·1	40·9–82·0	57·9	40·3–81·7	57·4	40·2–80·0	–		0·2666	0·2412	–		0·1501	0·0221
Total protein (% energy)																						
Total	13·8	11·6–16·6	14·3	12·0–16·9	14·5	12·4–17·3	13·4	11·3–16·0	13·6	114–16·2	13·0	11·1–15·4	13·6	11·4–16·2	−0·20	−0·23, −0·16	< 0·0001	< 0·0001	−0·06	−0·10, −0·01	0·0135	< 0·0001
Sex																						
Men	14·2	11·9–17·1	14·7	12·4–17·4	14·7	12·5–17·3	13·6	11·5–16·2	13·7	11·5–16·2	13·1	11·2–15·4	13·6	11·5–16·3	−0·22	−0·26, −0·18	< 0·0001	< 0·0001	−0·08	−0·15, −0·02	0·0121	< 0·0001
Women	13·5	11·3–16·3	13·9	11·6–16·5	14·4	12·2–17·2	13·3	11·1–15·9	13·5	11·3–16·1	12·9	10·9–15·4	13·6	11·4–16·1	−0·18	−0·22, −0·14	< 0·0001	0·0001	–		0·1940	< 0·0001
Age group, years																						
19–29	13·7	11·6–16·3	14·3	12·2–16·7	14·5	12·3–17·3	14·1	11·8–16·9	14·3	12·0–17·0	13·4	11·4–16·1	14·4	11·9–17·2	–		0·8056	0·2896	–		0·3727	0·0010
30–49	14·4	12·1–17·3	14·7	12·4–17·3	15·0	12·9–17·6	14·0	11·9–16·5	14·3	12·2–16·8	13·5	11·5–15·9	14·2	12·0–16·9	−0·26	−0·31, −0·21	< 0·0001	< 0·0001	−0·09	−0·15, −0·03	0·0028	0·0017
50–64	13·5	11·2–16·5	14·0	11·5–16·9	14·4	12·1–17·1	13·4	11·2–15·9	13·6	11·4–16·1	13·0	11·1–15·4	13·6	11·5–16·0	−0·30	−0·35, −0·24	< 0·0001	< 0·0001	−0·15	−0·22, −0·07	< 0·0001	0·0007
≥ 65	12·6	10·4–15·2	12·8	10·6–15·7	13·5	11·4–16·0	12·2	10·2–14·6	12·2	10·2–14·7	12·2	10·3–14·4	12·6	10·6–14·9	−0·19	−0·24, −0·14	< 0·0001	< 0·0001	–		0·9806	< 0·0001
Household income																						
Lowest	12·7	10·5–15·4	13·3	11·0–15·9	13·5	11·3–16·2	12·2	10·2–14·7	12·2	10·2–14·7	12·0	10·1–14·3	12·4	10·4–14·8	−0·19	−0·29, −0·10	< 0·0001	0·0061	–		0·9324	0·0027
Lower middle	13·7	11·5–16·4	14·0	11·8–16·7	14·5	12·3–17·2	13·2	11·1–15·8	13·5	11·3–16·0	12·9	11·0–15·2	13·4	11·3–16·0	−0·21	−0·30, −0·12	< 0·0001	0·0268	–		0·2021	0·0224
Upper middle	14·2	11·9–16·8	14·3	12·2–16·8	14·9	12·7–17·4	13·8	11·7–16·2	14·0	11·8–16·4	13·2	11·3–15·6	13·9	11·7–16·5	−0·18	−0·23, −0·13	< 0·0001	0·0271	−0·08	−0·16, −0·001	0·0445	< 0·0001
Highest	14·6	12·4–17·6	15·0	12·7–17·7	15·1	12·8–17·9	14·2	12·0–16·8	14·2	12·1–16·9	13·6	11·6–16·1	14·3	12·1–16·9	−0·21	−0·26, −0·16	< 0·0001	0·0001	–		0·0998	0·0033
Education level																						
≤ Elementary school	12·8	10·5–15·6	12·8	10·7–15·5	13·5	11·5–16·2	12·2	10·2–14·6	12·0	10·1–14·4	11·9	10·1–14·2	12·3	10·3–14·6	−0·25	−0·30, −0·19	< 0·0001	< 0·0001	–		0·3380	< 0·0001
Middle school	13·9	11·6–16·6	14·2	12·0–16·9	14·4	12·5–17·2	13·1	11·1–15·5	13·3	11·3–15·7	12·7	10·9–15·1	13·2	11·3–15·4	−0·26	−0·39, −0·13	< 0·0001	0·0555	–		0·6049	0·2977
High school	14·2	12·1–16·9	14·5	12·1–17·3	14·8	12·5–17·4	13·9	11·7–16·5	14·0	11·9–16·6	13·2	11·3–15·7	13·8	11·6–16·4	−0·20	−0·25, −0·14	< 0·0001	0·0028	−0·08	−0·15, −0·003	0·0419	0·0004
≥ College	14·6	12·4–17·5	14·9	12·8–17·3	15·3	13·0–18·0	14·4	12·3–16·9	14·5	12·4–17·1	13·7	11·7–16·1	14·3	12·2–16·9	−0·15	−0·19, −0·11	< 0·0001	0·0027	–		0·1741	< 0·0001
Region																						
Urban	13·1	11·1–15·5	14·2	12·0–17·1	14·5	12·2–17·1	14·7	12·5–17·4	13·6	11·5–16·2	13·8	11·6–16·3	13·7	11·6–16·3	−0·20	−0·23, −0·16	< 0·0001	< 0·0001	−0·06	−0·11, −0·01	0·0192	< 0·0001
Rural	13·2	10·8–16·0	13·4	11·1–16·2	14·0	11·7–16·7	12·8	10·6–15·5	12·8	10·7–15·4	12·6	10·6–15·1	13·0	10·9–15·6	−0·20	−0·31, −0·09	0·0002	0·0311	–		0·4136	0·0045

IQR, interquartile range; KNHANES, Korea National Health and Nutrition Examination Survey.
All values represent mean ± SE. *P* values were obtained from the multiple linear regression analysis after the adjustment for sex, age, household income, education level, region and total energy intake, where applicable.
* Data were obtained from the KNHANES. All data except for sample size were weighted to account for the complex study design according to the directions of the KNHANES analytical guidelines.
† The β-coefficients (g/survey cycle or %/survey cycle) and 95 % CI were estimated only when the linear trend was significant.
‡ Model includes only time as a single continuous term.
§ Model includes time as a continuous and quadratic term. Only the *P* value for the quadratic term is shown.

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Table 3. Trends in plant protein intake among Korean adults in the KNHANES, 1998–2018*

	Survey cycle														1998 to 2016–2018				2007–2009 to 2016–2018			
	1998		2001		2005		2007–2009		2010–2012		2013–2015		2016–2018									
	(*n* 7404)		(*n* 6577)		(*n* 6286)		(*n* 14 521)		(*n* 15 439)		(*n* 13 498)		(*n* 14 991)									
	Median	IQR	Median	IQR	Median	IQR	Median	IQR	Median	IQR	Median	IQR	Median	IQR	β-coefficient†	95 % CI	*P*-linear trend‡	*P*-quadratic trend§	β-coefficient	95 % CI	*P*-linear trend	*P*-quadratic trend
Plant protein (g)																						
Total	37·2	28·4–47·7	36·1	27·3–46·4	38·9	29·4–50·4	34·9	26·2–45·8	36·4	27·2–47·5	33·7	24·9–44·9	31·9	23·2–43·1	−1·00	−1·11, −0·90	< 0·0001	< 0·0001	−1·44	−1·61, −1·26	< 0·0001	< 0·0001
Sex																						
Men	41·0	32·2–52·0	39·4	30·4–50·2	43·1	33·0–54·8	40·6	31·2–51·4	41·9	32·7–54·2	39·2	29·7–51·1	36·9	27·5–48·5	−0·87	−1·02, −0·73	< 0·0001	< 0·0001	−1·60	−1·87, −1·34	< 0·0001	< 0·0001
Women	33·9	25·9–43·6	33·3	25·1–42·9	35·8	26·8–46·2	31·5	23·8–41·3	32·8	24·7–42·8	30·4	22·7–40·2	28·7	21·2–38·7	−1·14	−1·25, −1·03	< 0·0001	< 0·0001	−1·29	−1·48, −1·11	< 0·0001	< 0·0001
Age group, years																						
19–29	36·4	27·8–47·9	33·6	24·8–44·9	36·3	26·1–48·0	31·4	22·8–42·6	33·2	23·9–44·3	30·8	22·0–41·3	28·1	19·7–39·5	−1·10	−1·30, −0·90	< 0·0001	0·0019	−1·31	−1·72, −0·90	< 0·0001	< 0·0001
30–49	39·5	30·0–50·1	37·4	28·8–47·8	39·6	30·3–51·2	35·8	27·1–46·4	37·0	27·7–48·4	33·4	24·6–44·2	31·7	23·1–42·4	−1·21	−1·35, −1·07	< 0·0001	< 0·0001	−1·69	−1·94, −1·44	< 0·0001	< 0·0001
50–64	36·5	28·3–46·5	37·4	28·7–47·2	41·0	31·1–52·8	37·7	28·2–48·8	38·4	29·4–50·4	36·3	26·9–48·1	34·1	25·1–45·7	−0·78	−0·96, −0·60	< 0·0001	< 0·0001	−1·52	−1·84, −1·19	< 0·0001	< 0·0001
≥ 65	32·2	24·4–40·8	32·8	24·3–42·2	35·9	27·9–46·5	32·7	24·7–42·5	34·5	25·9–44·9	32·9	24·4–44·5	31·3	23·3–42·5	−0·29	−0·48, −0·11	0·0021	< 0·0001	−0·51	−0·80, −0·21	0·0008	< 0·0001
Household income																						
Lowest	34·3	26·0–44·4	35·3	26·6–45·5	36·9	28·1–47·8	32·5	24·3–42·6	33·6	25·2–43·9	31·7	23·5–42·8	29·7	22·0–40·6	−0·79	−0·99, −0·58	< 0·0001	0·0028	−0·86	−1·22, −0·50	< 0·0001	0·0056
Lower middle	37·6	28·9–47·6	35·6	26·9–45·9	38·8	29·0–50·5	34·8	26·1–45·5	36·1	27·3–46·9	33·5	24·4–44·6	31·5	23·0–42·8	−1·01	−1·19, −0·82	< 0·0001	< 0·0001	−1·49	−1·81, −1·16	< 0·0001	< 0·0001
Upper middle	38·0	29·3–48·3	36·5	27·7–46·7	39·7	29·7–51·0	35·9	27·2–46·8	37·1	28·0–48·4	34·2	25·3–45·1	33·0	23·8–43·7	−1·07	−1·25, −0·89	< 0·0001	< 0·0001	−1·59	−1·90, −1·27	< 0·0001	< 0·0001
Highest	38·6	29·1–50·1	36·7	27·9–47·3	39·7	30·0–52·1	36·5	27·1–47·5	38·4	28·4–49·7	35·0	25·9–46·8	32·9	24·1–44·1	−1·05	−1·21, −0·88	< 0·0001	< 0·0001	−1·57	−1·88, −1·25	< 0·0001	< 0·0001
Education level																						
≤ Elementary school	33·7	25·8–43·2	33·7	25·9–43·3	37·5	28·3–47·8	32·8	24·8–43·3	33·8	25·5–43·7	31·8	23·4–43·1	30·0	22·5–40·8	−0·33	−0·51, −0·15	0·0004	< 0·0001	−0·67	−0·99, −0·35	< 0·0001	0·0033
Middle school	37·8	29·0–47·6	36·6	27·0–46·4	40·4	30·4–51·9	36·5	27·7–46·9	38·3	28·7–49·3	34·5	25·6–45·7	32·4	24·3–43·2	−0·90	−1·15, −0·65	< 0·0001	< 0·0001	−1·61	−2·03, −1·19	< 0·0001	< 0·0001
High school	39·4	30·3–50·0	36·9	28·1–47·0	38·6	29·1–50·7	35·1	26·1–46·0	36·8	27·2–48·6	34·1	25·2–44·6	31·8	22·7–43·3	−1·22	−1·37, −1·06	< 0·0001	< 0·0001	−1·49	−1·77, −1·20	< 0·0001	< 0·0001
≥ College	38·5	29·1–49·5	36·8	27·9–48·4	39·8	29·9–51·9	37·0	27·7–47·8	37·8	28·5–49·1	34·3	25·5–46·4	33·1	24·0–44·1	−1·08	−1·24, −0·91	< 0·0001	< 0·0001	−1·62	−1·90, −1·34	< 0·0001	< 0·0001
Region																						
Urban	33·6	24·9–44·7	37·7	28·7–48·0	35·9	27·1–46·4	38·6	29·1–50·4	34·6	26·0–45·4	36·3	27·0–47·4	31·7	23·1–42·9	−1·04	−1·16, −0·92	< 0·0001	< 0·0001	−1·40	−1·59, −1·20	< 0·0001	< 0·0001
Rural	36·5	27·7–47·1	36·8	27·9–46·2	39·7	30·3–50·4	35·8	26·9–47·0	36·6	27·9–47·9	34·2	24·9–45·9	32·8	23·8–43·9	−0·84	−1·08, −0·59	< 0·0001	< 0·0001	−1·60	−2·02, −1·19	< 0·0001	0·0139
Plant protein (% energy)																						
Total	8·2	7·1–9·5	8·0	6·7–9·4	8·5	7·0–9·9	8·3	6·9–9·8	8·0	6·7–9·5	7·5	6·2–8·9	7·4	6·0–8·8	−0·26	−0·28, −0·25	< 0·0001	< 0·0001	−0·41	−0·43, −0·39	< 0·0001	0·0104
Sex																						
Men	8·2	7·0–9·5	7·8	6·6–9·2	8·2	6·9–9·7	8·1	6·7–9·6	7·9	6·5–9·3	7·4	6·0–8·7	7·2	5·8–8·7	−0·27	−0·29, −0·26	< 0·0001	< 0·0001	−0·40	−0·43, −0·37	< 0·0001	0·2217
Women	8·3	7·2–9·6	8·1	6·9–9·5	8·6	7·2–10·1	8·4	7·1–9·9	8·1	6·9–9·6	7·6	6·3–9·0	7·5	6·1–9·0	−0·25	−0·27, −0·24	< 0·0001	< 0·0001	−0·42	−0·45, −0·39	< 0·0001	0·0071
Age group, years																						
19–29	7·8	6·6–9·0	7·5	6·3–8·8	7·6	6·3–8·9	7·1	5·9–8·6	6·9	5·6–8·3	6·3	5·1–7·5	6·1	4·8–7·5	−0·29	−0·32, −0·27	< 0·0001	< 0·0001	−0·40	−0·45, −0·34	< 0·0001	0·9592
30–49	8·2	7·0–9·4	7·9	6·7–9·2	8·2	6·9–9·6	8·0	6·7–9·3	7·7	6·4–9·0	6·9	5·7–8·2	6·8	5·5–8·2	−0·27	−0·29, −0·25	< 0·0001	< 0·0001	−0·44	−0·48, −0·41	< 0·0001	0·1176
50–64	8·6	7·4–9·9	8·4	7·1–9·9	9·0	7·6–10·5	8·7	7·4–10·2	8·4	7·1–9·9	7·9	6·6–9·2	7·7	6·4–9·1	−0·23	−0·25, −0·20	< 0·0001	< 0·0001	−0·39	−0·43, −0·34	< 0·0001	0·0725
≥ 65	8·7	7·5–10·1	8·6	7·4–10·1	9·3	7·9–10·9	8·9	7·6–10·4	8·6	7·4–10·0	8·3	7·2–9·7	8·2	7·0–9·6	−0·18	−0·21, −0·15	< 0·0001	< 0·0001	−0·29	−0·33, −0·24	< 0·0001	0·0271
Household income																						
Lowest	8·5	7·3–9·8	8·5	7·2–9·9	8·8	7·5–10·4	8·7	7·3–10·3	8·4	7·2–9·8	8·2	7·0–9·5	8·1	6·7–9·5	−0·21	−0·24, −0·18	< 0·0001	< 0·0001	−0·32	−0·37, −0·26	< 0·0001	0·0291
Lower middle	8·4	7·3–9·6	8·0	6·7–9·4	8·4	7·0–9·8	8·3	7·0–9·9	8·0	6·8–9·5	7·6	6·3–9·0	7·4	6·0–8·8	−0·28	−0·30, −0·26	< 0·0001	< 0·0001	−0·42	−0·46, −0·37	< 0·0001	0·9058
Upper middle	8·1	6·9–9·4	8·0	6·7–9·2	8·3	6·9–9·8	8·1	6·8–9·6	7·8	6·5–9·3	7·3	6·0–8·6	7·2	5·8–8·6	−0·28	−0·31, −0·26	< 0·0001	< 0·0001	−0·43	−0·48, −0·38	< 0·0001	0·0462
Highest	8·0	6·8–9·3	7·8	6·5–9·1	8·3	6·9–9·7	8·1	6·7–9·5	7·9	6·6–9·4	7·1	5·9–8·5	7·0	5·7–8·5	−0·27	−0·29, −0·25	< 0·0001	< 0·0001	−0·43	−0·47, −0·39	< 0·0001	0·1646
Education level																						
≤ Elementary school	8·7	7·5–9·9	8·6	7·4–10·1	9·2	7·8–10·7	8·9	7·6–10·5	8·5	7·4–10·0	8·3	7·2–9·6	8·2	7·1–9·6	−0·17	−0·20, −0·15	< 0·0001	< 0·0001	−0·35	−0·39, −0·30	< 0·0001	0·0007
Middle school	8·2	7·2–9·7	8·2	7·0–9·7	8·8	7·5–10·3	8·5	7·2–10·0	8·4	7·1–9·9	8·0	6·7–9·4	7·9	6·6–9·4	−0·23	−0·26, −0·20	< 0·0001	< 0·0001	−0·41	−0·48, −0·35	< 0·0001	0·8123
High school	8·1	7·0–9·3	7·8	6·6–9·3	8·2	6·8–9·5	7·9	6·6–9·4	7·8	6·5–9·3	7·2	5·9–8·6	7·1	5·7–8·5	−0·29	−0·31, −0·27	< 0·0001	< 0·0001	−0·43	−0·47, −0·39	< 0·0001	0·4930
≥ College	7·8	6·6–9·1	7·7	6·4–8·9	7·9	6·7–9·4	7·8	6·6–9·2	7·6	6·3–9·0	7·0	5·8–8·3	6·9	5·6–8·4	−0·29	−0·31, −0·27	< 0·0001	< 0·0001	−0·41	−0·45, −0·37	< 0·0001	0·0534
Region																						
Urban	7·5	6·1–8·9	8·2	7·0–9·5	7·9	6·6–9·3	8·4	7·0–9·9	8·2	6·8–9·7	8·0	6·7–9·5	7·3	5·9–8·8	−0·27	−0·28, −0·25	< 0·0001	< 0·0001	−0·40	−0·43, −0·38	< 0·0001	0·1001
Rural	8·4	7·3–9·7	8·3	7·1–9·8	8·8	7·4–10·1	8·6	7·2–10·2	8·3	7·0–9·7	7·7	6·4–9·0	7·7	6·4–9·1	−0·25	−0·28, −0·23	< 0·0001	< 0·0001	−0·44	−0·50, −0·38	< 0·0001	0·0176

IQR, interquartile range; KNHANES, Korea National Health and Nutrition Examination Survey.

All values represent mean ± SE. *P* values were obtained from the multiple linear regression analysis after the adjustment for sex, age, household income, education level, region and total energy intake, where applicable.

* Data were obtained from the KNHANES. All data except for sample size were weighted to account for the complex study design according to the directions of the KNHANES analytical guidelines.

† The β-coefficients (g/survey cycle or %/survey cycle) and 95 % CI were estimated only when the linear trend was significant.

‡ Model includes only time as a single continuous term.

§ Model includes time as a continuous and quadratic term. Only the *P* value for the quadratic term is shown.

Table 4. Trends in animal protein intake among Korean adults in the KNHANES, 1998–2018*

	Survey cycle														1998 to 2016–2018				2007–2009 to 2016–2018			
	1998		2001		2005		2007–2009		2010–2012		2013–2015		2016–2018									
	(*n* 7404)		(*n* 6577)		(*n* 6286)		(*n* 14 521)		(*n* 15 439)		(*n* 13 498)		(*n* 14 991)									
	Median	IQR	Median	IQR	Median	IQR	Median	IQR	Median	IQR	Median	IQR	Median	IQR	β-coefficient†	95 % CI	*P*-linear trend‡	*P*-quadratic trend§	β-coefficient	95 % CI	*P*-linear trend	*P*-quadratic trend
Animal protein (g)																						
Total	23·1	10·5–43·3	25·9	12·6–46·1	26·4	12·5–47·1	19·5	8·1–36·2	22·8	10·0–41·2	22·9	10·9–40·9	26·1	13·2–44·5	0·55	0·35, 0·74	< 0·0001	< 0·0001	2·14	1·84, 2·43	< 0·0001	0·0084
Sex																						
Men	28·7	14·3–51·5	32·6	17·5–55·2	32·0	15·8–56·2	26·1	12·0–45·8	29·7	14·0–52·4	28·7	14·3–49·9	32·8	16·9–55·3	0·89	0·62, 1·17	< 0·0001	< 0·0001	2·23	1·75, 2·72	< 0·0001	0·2349
Women	19·5	8·2–36·2	21·4	10·1–37·9	22·0	10·5–40·2	15·9	6·6–29·9	19·2	8·3–34·7	19·6	9·1–35·1	22·2	11·1–37·3	–		0·0895	< 0·0001	1·97	1·68, 2·25	< 0·0001	0·0005
Age group, years																						
19–29	25·8	13·6–45·6	28·2	15·7–48·4	31·3	16·6–52·1	28·4	15·6–47·6	32·3	18·5–54·0	33·5	18·6–55·6	36·5	21·0–60·4	1·84	1·42, 2·26	< 0·0001	0·0178	2·96	2·08, 3·83	< 0·0001	0·3507
30–49	28·3	14·7–50·3	30·1	16·7–51·0	31·5	16·9–52·5	25·1	13·4–42·0	30·0	16·6–49·9	30·2	17·1–48·9	33·8	19·6–53·8	–		0·1995	< 0·0001	2·32	1·86, 2·78	< 0·0001	0·0318
50–64	18·9	7·1–37·9	21·4	8·9–40·4	21·2	9·7–42·4	17·2	7·0–33·0	21·4	9·8–38·7	21·7	10·7–37·0	25·0	13·2–40·6	–		0·1743	< 0·0001	1·25	0·79, 1·71	< 0·0001	0·1106
≥ 65	12·0	2·8–24·6	12·3	3·0–28·0	13·3	3·9–28·3	8·6	2·1–20·8	10·7	3·4–24·8	12·5	4·6–25·1	15·3	6·2–28·2	–		0·8364	< 0·0001	1·32	0·96, 1·67	< 0·0001	0·7062
Household income																						
Lowest	14·8	4·4–30·9	16·8	5·9–34·8	16·1	5·7–33·6	9·7	2·4–23·5	11·8	3·4–26·5	11·8	3·9–25·3	14·2	5·2–28·0	–		0·1282	< 0·0001	1·72	1·11, 2·32	< 0·0001	0·6958
Lower middle	21·3	9·9–39·6	24·6	12·5–44·1	26·5	12·1–47·8	18·2	7·5–34·7	21·9	9·8–39·5	20·9	9·9–38·3	24·8	12·5–41·9	0·57	0·15, 1·00	0·0082	0·0003	2·03	1·44, 2·62	< 0·0001	0·4609
Upper middle	26·2	13·3–45·9	27·4	14·4–47·0	29·1	14·9–50·5	22·5	11·9–39·6	26·6	13·4–45·4	26·6	14·3–44·3	29·4	17·0–48·3	0·76	0·42, 1·11	< 0·0001	< 0·0001	2·22	1·65, 2·79	< 0·0001	0·2073
Highest	29·7	15·4–54·5	32·2	17·9–54·3	31·2	17·0–53·1	25·5	13·1–43·5	28·1	15·0–47·6	29·5	16·6–48·5	32·5	18·5–51·9	0·45	0·09, 0·81	0·0146	< 0·0001	2·34	1·82, 2·86	< 0·0001	0·0081
Education level																						
≤ Elementary school	13·4	3·9–29·7	13·5	4·0–28·4	14·7	4·8–31·3	8·7	2·1–20·8	10·4	3·1–23·6	11·4	4·0–23·1	13·0	4·9–25·5	−0·29	−0·57, −0·001	0·0497	< 0·0001	1·52	1·13, 1·90	< 0·0001	0·4900
Middle school	22·1	10·9–40·8	24·1	11·6–42·9	22·9	10·3–42·6	16·3	7·5–31·8	20·0	8·5–35·9	18·9	8·4–33·8	20·6	10·0–34·0	–		0·7499	0·0001	2·19	1·37, 3·02	< 0·0001	0·1441
High school	27·0	14·3–48·0	28·4	14·5–50·1	29·8	15·0–50·5	24·2	12·4–40·9	26·9	14·2–45·9	26·7	14·5–44·9	28·5	15·9–47·8	0·64	0·31, 0·96	0·0001	< 0·0001	2·25	1·73, 2·77	< 0·0001	0·1659
≥ College	31·6	17·5–54·3	32·9	19·0–54·0	34·6	19·0–56·0	28·2	16·2–46·2	31·3	18·1–51·9	30·8	17·7–49·5	34·0	20·2–53·6	1·12	0·81, 1·44	< 0·0001	< 0·0001	2·35	1·85, 2·84	< 0·0001	0·0243
Region																						
Urban	23·5	11·5–41·6	26·0	13·5–46·6	28·1	14·1–48·8	27·7	13·6–48·7	21·3	10·0–38·2	24·1	11·3–42·6	27·3	14·0–45·7	0·54	0·32, 0·76	< 0·0001	< 0·0001	2·12	1·79, 2·45	< 0·0001	0·0206
Rural	18·0	6·7–37·4	19·3	7·4–38·2	21·1	8·2–41·0	14·2	4·5–30·4	17·5	6·4–35·0	19·8	8·2–37·6	21·1	9·2–39·1	0·55	0·11, 0·99	0·0147	< 0·0001	2·20	1·56, 2·83	< 0·0001	0·1971
Animal protein (% energy)																						
Total	5·2	2·6–8·6	5·9	3·2–9·1	5·8	3·1–9·1	4·7	2·2–7·7	5·1	2·5–8·2	5·1	2·7–8·1	5·9	3·4–9·0	0·06	0·03, 0·10	0·0004	< 0·0001	0·35	0·30, 0·40	< 0·0001	< 0·0001
Sex																						
Men	5·6	3·2–9·1	6·6	3·8–9·6	6·1	3·5–9·5	5·2	2·7–8·2	5·5	2·9–8·5	5·3	3·0–8·3	6·2	3·6–9·3	0·05	0·01, 0·09	0·0158	< 0·0001	0·31	0·24, 0·38	< 0·0001	< 0·0001
Women	4·8	2·3–8·1	5·2	2·7–8·6	5·5	2·9–8·7	4·3	2·0–7·4	4·8	2·3–7·9	5·0	2·5–7·9	5·7	3·2–8·9	0·08	0·03, 0·12	0·0007	< 0·0001	0·38	0·33, 0·43	< 0·0001	0·0060
Age group, years																						
19–29	5·6	3·3–8·7	6·5	3·9–9·5	6·6	4·1–9·7	6·5	4·0–9·7	7·0	4·4–10·2	7·0	4·3–9·9	8·0	5·1–11·4	0·28	0·22, 0·35	< 0·0001	0·0024	0·45	0·31, 0·59	< 0·0001	0·0022
30–49	5·8	3·4–9·3	6·5	3·9–9·5	6·5	4·0–9·6	5·7	3·3–8·6	6·3	3·8–9·3	6·3	4·0–9·1	7·1	4·7–10·3	–		0·8160	< 0·0001	0·35	0·28, 0·42	< 0·0001	0·0266
50–64	4·4	1·8–7·9	4·9	2·3–8·4	4·8	2·4–8·2	4·0	1·8–7·0	4·7	2·4–7·6	4·7	2·6–7·3	5·6	3·2–8·3	−0·07	−0·12, −0·01	0·0145	< 0·0001	0·24	0·16, 0·31	< 0·0001	0·0185
≥ 65	3·3	0·8–6·2	3·4	1·0–6·8	3·5	1·1–6·7	2·5	0·6–5·3	2·9	0·9–5·6	3·2	1·3–5·8	3·9	1·8–6·6	–		0·6885	< 0·0001	0·29	0·21, 0·36	< 0·0001	0·0085
Household income																						
Lowest	3·8	1·2–6·9	4·1	1·6–7·6	4·1	1·5–7·5	2·7	0·7–5·7	3·1	1·0–6·1	3·1	1·1–6·0	3·9	1·6–6·8	–		0·7639	< 0·0001	0·32	0·21, 0·43	< 0·0001	0·0737
Lower middle	4·8	2·4–8·0	5·6	3·1–8·9	5·7	3·1–9·2	4·4	2·0–7·4	4·9	2·5–8·0	4·9	2·5–7·7	5·7	3·2–8·8	–		0·1816	< 0·0001	0·36	0·26, 0·45	< 0·0001	0·0259
Upper middle	5·7	3·1–8·8	6·1	3·6–9·1	6·3	3·6–9·4	5·2	2·8–8·2	5·6	3·3–8·6	5·7	3·3–8·4	6·5	4·0–9·5	0·10	0·05, 0·15	0·0001	< 0·0001	0·35	0·26, 0·43	< 0·0001	0·0030
Highest	6·2	3·6–9·9	7·0	4·2–10·2	6·4	4·1–9·9	5·7	3·3–8·7	5·9	3·4–9·1	6·1	3·8–9·1	6·9	4·4–10·1	0·06	0·003, 0·11	0·0393	< 0·0001	0·36	0·28, 0·44	< 0·0001	0·0230
Education level																						
≤ Elementary school	3·6	1·1–6·8	3·6	1·2–6·6	3·8	1·3–6·9	2·5	0·7–5·3	2·8	0·9–5·5	3·0	1·1–5·6	3·5	1·4–6·4	−0·08	−0·13, −0·02	0·0070	< 0·0001	0·31	0·24, 0·39	< 0·0001	0·0664
Middle school	5·0	2·6–8·2	5·5	3·0–8·8	5·2	2·6–8·4	3·9	2·0–6·9	4·4	2·2–7·3	4·4	2·2–7·1	4·9	2·7–7·8	–		0·6861	0·0001	0·38	0·25, 0·51	< 0·0001	0·2385
High school	5·6	3·3–9·0	6·2	3·6–9·4	6·2	3·6–9·3	5·6	3·2–8·5	5·8	3·3–8·9	5·7	3·3–8·6	6·5	3·9–9·4	0·09	0·04, 0·15	0·0012	< 0·0001	0·35	0·27, 0·43	< 0·0001	0·0015
≥ College	6·4	3·9–9·8	7·0	4·5–10·0	6·8	4·5–10·1	6·1	3·8–9·1	6·5	4·1–9·5	6·3	4·0–9·1	7·1	4·6–10·2	0·14	0·09, 0·19	< 0·0001	< 0·0001	0·36	0·28, 0·44	< 0·0001	0·0030
Region																						
Urban	5·3	2·9–8·2	5·7	3·3–9·1	6·2	3·5–9·4	6·0	3·4–9·3	5·1	2·6–8·1	5·4	2·8–8·4	6·1	3·6–9·2	0·07	0·03, 0·10	0·0005	< 0·0001	0·34	0·29, 0·39	< 0·0001	< 0·0001
Rural	4·3	1·7–7·6	4·5	1·9–7·9	4·8	2·0–8·0	3·5	1·2–6·7	4·0	1·7–7·2	4·6	2·1–7·6	4·9	2·4–8·2	–		0·3552	< 0·0001	0·39	0·28, 0·50	< 0·0001	0·1458

IQR, interquartile range; KNHANES, Korea National Health and Nutrition Examination Survey.
All values represent mean ± SE. *P* values were obtained from the multiple linear regression analysis after the adjustment for sex, age, household income, education level, region and total energy intake, where applicable.
* Data were obtained from the KNHANES. All data except for sample size were weighted to account for the complex study design according to the directions of the KNHANES analytical guidelines.
† The β-coefficients (g/survey cycle or %/survey cycle) and 95 % CI were estimated only when the linear trend was significant.
‡ Model includes only time as a single continuous term.
§ Model includes time as a continuous and quadratic term. Only the *P* value for the quadratic term is shown.

Table 5. Trends in dietary protein intake from different food sources among Korean adults in the KNHANES, 1998–2018*

	Survey cycle																				
	1998 (*n* 7404)			2001 (*n* 6577)			2005 (*n* 6286)			2007–2009 (*n* 14 521)			2010–2012 (*n* 15 439)			2013–2015 (*n* 13 498)			2016–2018 (*n* 14 991)		
	%	Median	IQR	%	Median	IQR	%	Median	IQR	%	Median	IQR	%	Median	IQR	%	Median	IQR	%	Median	IQR
Plant sources																					
Grains	30·49	16·6	11·7–22·0	26·90	14·1	10·0–19·1	27·33	15·6	10·9–20·9	28·07	14·2	9·8–19·3	27·54	14·4	9·7–19·8	26·06	12·8	8·2–18·3	23·93	11·7	7·4–16·8
Flour/bread	6·78	0·5	0·0–9·6	6·76	0·2	0·0–9·3	6·66	0·3	0·0–8·4	6·86	0·7	0·0–7·2	7·80	2·0	0·0–8·8	8·73	2·5	0·0–9·1	9·47	2·7	0·0–9·7
Legumes	5·77	1·6	0·0–4·9	5·98	1·6	0·0–5·3	6·75	2·4	0·0–6·3	7·34	2·2	0·0–6·2	6·25	1·8	0·0–5·5	5·78	1·4	0·0–4·7	5·63	1·3	0·0–4·8
Vegetables	5·26	2·5	1·3–4·7	5·69	2·8	1·3–5·1	6·94	3·8	1·9–6·6	5·14	2·4	1·1–4·6	5·25	2·6	1·3–4·8	5·40	2·7	1·3–4·8	4·70	2·4	1·2–4·3
Kimchi and pickles	4·70	2·3	1·2–3·7	5·18	2·5	1·4–4·1	4·45	2·2	1·3–3·7	4·70	2·2	1·0–3·7	4·11	1·8	0·7–3·4	3·05	1·2	0·4–2·3	2·92	1·2	0·4–2·3
Fruits	1·87	0·4	0·0–1·7	1·97	0·5	0·0–1·7	0·95	0·0	0·0–0·7	2·02	0·2	0·0–1·5	1·99	0·4	0·0–1·7	1·99	0·5	0·0–1·6	1·61	0·4	0·0–1·4
Nuts	0·47	0·0	0·0–0·1	0·50	0·0	0·0–0·1	0·81	0·2	0·0–0·6	0·60	0·1	0·0–0·3	0·72	0·1	0·0–0·3	1·06	0·1	0·0–0·4	1·14	0·2	0·0–0·5
Other	7·73	3·9	2·1–6·8	8·96	4·7	2·6–7·6	8·37	4·7	2·6–7·6	8·88	4·4	2·4–7·5	8·67	4·5	2·4–7·7	8·41	4·2	2·3–7·1	7·32	3·9	2·2–6·2
All	63·07	37·4	28·4–48·1	61·63	36·0	27·1–46·6	62·27	38·7	29·3–50·6	63·63	35·7	26·5–46·6	62·35	36·7	27·3–48·3	60·48	34·2	25·1–45·4	56·73	32·2	23·2–43·3
Animal sources																					
Unprocessed red meat	9·34	4·2	0·0–13·2	10·32	3·9	0·0–14·9	8·89	3·1	0·0–13·8	8·25	2·6	0·0–11·3	8·35	3·0	0·0–12·5	8·22	3·5	0·0–13·3	10·46	4·6	0·0–15·9
Seafood	18·35	7·4	1·7–20·2	14·75	8·0	1·6–19·8	14·83	8·2	1·8–20·7	10·75	5·3	1·0–14·5	10·18	4·9	0·9–14·9	8·78	4·0	0·5–12·5	8·28	3·8	0·3–12·2
Poultry	1·22	0·0	0·0–0·0	2·62	0·0	0·0–0·0	2·94	0·0	0·0–0·0	3·80	0·0	0·0–0·0	5·11	0·0	0·0–0·0	5·73	0·0	0·0–0·0	6·19	0·0	0·0–0·0
Eggs	2·14	0·0	0·0–3·5	2·11	0·0	0·0–3·6	2·53	0·0	0·0–4·5	2·35	0·0	0·0–3·6	2·47	0·4	0·0–4·2	2·75	0·8	0·0–4·9	3·36	1·0	0·0–6·5
Dairy products	1·49	0·0	0·0–0·6	1·33	0·2	0·0–0·7	1·61	0·0	0·0–1·5	2·02	0·0	0·0–2·1	2·39	0·0	0·0–4·1	2·25	0·1	0·0–4·4	2·59	0·0	0·0–5·0
Processed meat	0·78	0·0	0·0–0·0	0·96	0·0	0·0–0·0	0·79	0·0	0·0–0·0	1·41	0·0	0·0–0·0	1·40	0·0	0·0–0·0	1·77	0·0	0·0–0·5	2·47	0·0	0·0–1·4
Other	0·01	0·0	0·0–0·0	0·00	0·0	0·0–0·0	0·00	0·0	0·0–0·0	0·00	0·0	0·0–0·0	0·01	0·0	0·0–0·0	0·01	0·0	0·0–0·0	0·04	0·0	0·0–0·0
All	36·93	25·3	12·2–46·1	38·37	26·5	13·2–47·2	37·73	27·8	13·7–48·5	36·37	23·0	10·8–41·2	37·65	25·9	12·5–45·9	39·52	26·1	13·1–45·8	43·27	29·2	15·4–49·3

	1998 to 2016–2018				2007–2009 to 2016–2018			
	β-coefficient†	95 % CI	*P*-linear trend‡	*P*-quadratic trend§	*β*-coefficient	95 % CI	*P*-linear trend	*P*-quadratic trend
Plant sources								
Grains	–0·97	–1·05, –0·89	< 0·0001	< 0·0001	–1·57	–1·72, –1·43	< 0·0001	0·0049
Flour/bread	0·63	0·56, 0·70	< 0·0001	< 0·0001	0·97	0·84, 1·10	< 0·0001	0·2298
Legumes	–0·18	–0·23, –0·14	< 0·0001	< 0·0001	–0·57	–0·66, –0·49	< 0·0001	< 0·0001
Vegetables	–0·19	–0·22, –0·16	< 0·0001	< 0·0001	–0·17	–0·21, –0·12	< 0·0001	< 0·0001
Kimchi and pickles	–0·44	–0·47, –0·42	< 0·0001	< 0·0001	–0·69	–0·73, –0·65	< 0·0001	< 0·0001
Fruits	–		0·5316	< 0·0001	–0·13	–0·18, –0·09	< 0·0001	0·0003
Nuts	0·13	0·11, 0·14	< 0·0001	< 0·0001	0·19	0·17, 0·22	< 0·0001	0·2893
Other	–0·19	–0·23, –0·15	< 0·0001	< 0·0001	–0·53	–0·60, –0·47	< 0·0001	< 0·0001
All	–1·21	–1·32, –1·09	< 0·0001	< 0·0001	–2·50	–2·70, –2·31	< 0·0001	0·0003
Animal sources								
Unprocessed red meat	0·41	0·31, 0·51	< 0·0001	< 0·0001	1·12	0·95, 1·29	< 0·0001	0·0002
Seafood	–1·29	–1·39, –1·18	< 0·0001	0·0087	–0·94	–1·10, –0·78	< 0·0001	0·9573
Poultry	0·92	0·84, 1·00	< 0·0001	0·4079	0·93	0·77, 1·09	< 0·0001	0·0052
Eggs	0·37	0·33, 0·41	< 0·0001	< 0·0001	0·55	0·48, 0·63	< 0·0001	0·0011
Dairy products	0·37	0·33, 0·41	< 0·0001	0·2943	0·31	0·24, 0·39	< 0·0001	0·1902
Processed meat	0·42	0·37, 0·46	< 0·0001	< 0·0001	0·51	0·43, 0·59	< 0·0001	< 0·0001
Other	0·01	0·001, 0·01	0·0114	0·0144	0·01	0·003, 0·02	0·0122	0·2792
All	1·21	1·09, 1·32	< 0·0001	< 0·0001	2·50	2·31, 2·70	< 0·0001	0·0003

IQR, interquartile range; KNHANES, Korea National Health and Nutrition Examination Survey.

All values represent mean ± SE. *P* values were obtained from the multiple linear regression analysis after the adjustment for sex, age, household income, education level, region and total energy intake, where applicable.

* Data were obtained from the KNHANES. All data except for sample size were weighted to account for the complex study design according to the directions of the KNHANES analytical guidelines.

† The *β*-coefficients (%/survey cycle) and 95 % CI were estimated only when the linear trend was significant.

‡ Model includes only time as a single continuous term.

§ Model includes time as a continuous and quadratic term. Only the *P* value for the quadratic term is shown.

trend$_{linearity}$ < 0·0001 for 1998 to 2016–2018; β: 2·50 (95 % CI 2·32, 2·70) %/survey cycle, P for trend$_{linearity}$ < 0·0001 from 2007–2009 to 2016–2018) over two decades. Among the plant-based sources, protein intake from grains and their products decreased the most between 1998 and 2016–2018, showing a steeper decreasing trend in the most recent period (β: –0·97 (95 % CI –1·05, –0·89) %/survey cycle, P for trend$_{linearity}$ < 0·0001 for 1998 to 2016–2018; β: –1·57 (95 % CI –1·72, –1·43) %/survey cycle, P for trend$_{linearity}$ < 0·0001 for 2007–2009 to 2016–2018). For 20 years, for animal-based sources, the greatest change in the contribution to protein intake was found in seafood. Contrary to other animal-based foods showing an increasing trend in contribution to protein intake, a decreasing trend was observed only in seafood (β: –1·29 (95 % CI –1·39, –1·18) %/survey cycle, P for trend$_{linearity}$ < 0·0001 from 1998 to 2016–2018). On the other hand, protein intake from unprocessed meat showed a sharp increase in the last decade (β: 1·12 (95 % CI 0·95, 1·29) %/survey cycle, P for trend$_{linearity}$ < 0·0001 for 2007–2009 to 2016–2018). Based on the most recent survey cycle (2016–2018), total dietary protein consisted of 56·7 % plant food sources and 43·3 % animal food sources. The plant food source that contributed most to the protein intake was grains and its products (23·9 %), followed by flour and bread (9·5 %), legumes (5·6 %), vegetables (4·7 %) and kimchi and pickled vegetables (2·9 %); in terms of animal food sources, unprocessed red meat accounted for the greatest protein intake (10·5 %), followed by seafood (8·3 %), poultry (6·2 %), eggs (3·4 %) and dairy products (2·6 %).

Discussion

Based on dietary data from nationally representative samples, this study described protein intake trends in the Korean adult population in 1998–2018. As indicated in previous reports, significant changes in carbohydrate and fat intake were found in the present study, with a declining trend of carbohydrates and an increasing trend of fats. The mean protein intake changed significantly during the same period, but this change was not as pronounced as that of carbohydrates or fat. This finding was in line with previous studies reporting that protein intake showed less variability and was more tightly regulated than other macronutrients[33,34].

Total protein intake, both absolute intake and percentage of energy contribution, showed a significant declining trend over the 20-year period. A previous analysis of Japanese population reported similar decreasing trends in total protein intake[35]. Contrary to the 20-year trend, Koreans' total protein intake has been slightly increasing during the last decade. The key shift in total protein intake over two decades might be attributed to the steeper increase in animal protein intake compared with that of plant protein. Moreover, the difference in dietary protein intake by source is widening. In particular, the decline in plant protein intake can be largely attributed to a decrease in the consumption of grain and its products. Rice is a staple food for Koreans that contributes the most to their protein intake[36]. However, the per capita consumption of rice in Korea decreased significantly from 116·3 kg in 1991 to 61·0 kg in 2018[37]. This resulted in a decrease in plant protein intake and a further decrease in total protein intake. Vegetarianism has been attracting increasing attention in Korea for practical reasons, such as being healthy and dieting, and for ethical reasons such as animal rights and animal welfare[38,39]. Although no significant increase in plant protein intake due to a vegan craze was observed in this nationwide analysis, the monitoring of changes in the contributions of plant and animal sources to total protein intake remains necessary.

As expected, animal protein intake has increased over time, but the increasing pattern differs depending on subgroups stratified by sex, age, income, education level and region. It is noteworthy that animal protein intake increased noticeably in adults aged 19–29 years. Recent reports in 2018 also reported higher mean consumptions of animal foods in young adults than in other age groups: 405 g in those 19–29 years, 389 g in those 30–49 years, 322 g in those 50–64 years and 229 g in those ≥ 65 years[40]. Although plant protein intake decreased in adults aged 19–29 years, the increase in animal protein intake was greater than that of plant protein; thus, an increasing trend in total protein was also observed over time. Some studies also reported the adverse effects of excessive protein intake on bone and Ca homoeostasis, renal function and progression of coronary artery disease[41–43]; thus, efforts should be made to optimise the protein intake of younger adults.

In contrast, in adults aged ≥ 65 years, the trend in animal protein intake differed from that in young adults. In this study, both absolute intake and energy contribution from animal protein among adults aged ≥ 65 years did not show a linear increasing trend over the two decades; rather, it showed an overall linear tendency to increase over the last 10 years. Animal proteins are beneficial for muscle synthesis and the preservation of fat-free mass because they generally have higher bioavailability and an excellent composition of essential amino acids compared with plant proteins[44,45]. Previous studies conducted in various elderly populations demonstrated that animal proteins are linked to bone health, functional decline and muscle-related parameters. In a population-based cohort of 1526 elderly Caucasians, animal protein had a favourable effect on bone mineral density, particularly in women with a low Ca intake[46]. In a 7-year follow-up cohort study of Japanese men aged ≥ 60 years, animal protein intake was associated with a lower incidence of functional decline[47]. Another study of representative samples of an Italian population with an average age of 50·3 years also showed that animal protein was associated with muscle mass and strength[48]. However, the positive role of plant proteins in bone health and muscle mass was not reported in these studies. In addition, the 2020 Dietary Reference Intakes for Koreans do not provide protein recommendations by source[1] because the differential health effects of protein sources remain under debate. Given the increasing number of elderly individuals who experience problems such as frailty, sarcopenia and osteoporosis in Korea[49,50], further investigations of the relationships between protein intake and health parameters by source are needed.

We found differential trends in protein intake by different sources across socio-demographic groups. Subgroups with higher incomes and education levels showed steeper decreases in plant protein intake and a more precipitous increase in animal

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protein intake than those with lower incomes and education levels. Similarly, a recent cross-sectional analysis of 1404 Korean adults indicated that household income was positively associated with animal protein intake both in men and women and negatively associated with plant protein intake in men only[51]. Contrary to our findings, several studies reported that higher education and income levels are drivers of plant and animal protein intakes, respectively[52–55]. A higher education level is associated with acquiring and utilising knowledge related to nutrition and health to make healthy food choices[56], and people with high income levels reportedly have high accessibility to more nutrient-dense food choices without price restrictions[57]. Thus, it has been documented that a higher education level is associated with an increased intake of plant protein, while a higher income is associated with increased intake of animal protein. However, in our study, as both education and household income levels increased, animal protein intake increased, and plant protein intake decreased. This can be explained by the similar distributions of population according to education level and household income in Korea[58].

This study presented the changes in dietary protein intake by food sources over the past two decades. All foods and beverages consumed by the participants were aggregated into fifteen food groups, which were further categorised into plant and animal based. In terms of two sources (plant *v.* animal), in 1998, 63 % of the total protein intake was from plant sources, whereas 37 % was from animal sources, showing that protein from plant sources was twice as plentiful as that from animal sources. However, the gap has recently narrowed to 57 % from plants and 43 % from animal sources. The food sources that contribute to protein intake have also changed. In plant-based sources, 20 years ago, about half of plant-derived proteins consisted of grains and their products; since then, the contribution of this food group to protein intake has been decreasing and that from flour and bread has been substantially increasing. This might be related to changes in dietary patterns, such as a decrease in rice-oriented meals and an increase in the consumption of bread and snacks due to the Westernisation of the Korean diet[59,60]. In the case of protein intake from animal sources, seafood accounted for half of all animal-based protein intake in 1998, whereas in recent years unprocessed meat has made the largest contribution to animal-based protein intake. Moreover, sources of animal proteins have become more diverse in recent years and now include poultry, eggs, dairy products and processed meat. The changes in food sources of protein observed in this study are supported by official reports based on the KNHANES documenting that the consumption of grains, fruits and vegetables, potatoes and starchy vegetables has decreased, whereas the consumption of meat and milk has increased in the last 20 years[4].

This study has several limitations. First, the dietary intake data used in this study consisted of self-reported 24-h dietary recall. Self-reported dietary information is among the main causes of measurement errors in epidemiological studies and may not account for an individual's usual intake due to day-to-day variations in diet. Compared with the methods by which participants record their diet themselves, the 24-h dietary recall method has a weaker tendency towards under-reporting of energy intake[61]. However, they show a wide range of under-reporting of energy intake (10–60 %) depending on the characteristics of the study population. A previous study using KNHANES data found 14·4 and 23·0 % rates of under-reporting of 24-h dietary recalls in men and women, respectively. The ratio of under-reporting was higher among individuals of older age, with lower incomes, with obesity and who rated their own health as poor[62]. Although the 24-h dietary recall method has limitations as discussed above, the KNHANES aims to minimise the errors and risks of under-reporting that may occur when nutrition surveys are conducted through quality management, such as developing an annual investigation guidebook, training investigators, assessing the survey results and developing a tool for improving the accuracy of food portion estimates in 24-h dietary recalls. The 24-h dietary recall method is reportedly the least biased method for best capturing dietary intake in a population[63]. Furthermore, since this study aimed to examine changes in protein intake at the overall and subpopulation levels rather than at the individual level, it was possible to overcome some of the limitations, such as not being able to capture individuals' usual intakes. Second, we estimated the dietary protein intakes using only food and beverage consumption. Although protein intake from protein bars and dietary supplements such as protein or amino acid supplements is increasing in Korea, it was not considered in the estimations because of data unavailability. Third, the cross-sectional nature of the study design did not reflect a shift in socio-demographic characteristics over time.

Despite these limitations, the strengths of this study include its use of nationally representative samples of Korean adults from the KNHANES, which provided an overview of protein intake trends overall and by source at the population level. Moreover, contrary to carbohydrates and fats, few investigations on changes in protein intake have been conducted to date. To fill the gaps in the literature, this study identified changes in dietary protein intake overall and by socio-demographic subgroups of Korean adults over a period of more than 20 years. We both explored dietary protein intake according to source (plant or animal based) and described how dietary protein intake has changed in terms of specific food groups. Furthermore, potential covariates might be related to dietary protein intake, which was added to the analytical models.

Conclusions

Over the period of 1998–2018, Korean adults demonstrated drastic changes in carbohydrate and fat intake, while their protein intake remained relatively stable. Our findings showed decreasing trends in total and plant protein intake and an increasing trend in animal protein intake over these two decades. Differential trends in protein intake by source among the socio-demographic groups were noted, and the trends were steeper in adults of younger age and with a higher household income and education level. In terms of energy contribution, an increased protein intake may cause changes in carbohydrate and fat intake. Therefore, continuous monitoring of dietary protein intake, both overall and by source, is needed. Furthermore, future investigations of trends in dietary protein intake across socio-demographic characteristics are necessary to update the dietary guidelines for protein intake and establish target-specific nutritional policies.

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