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RESEARCH PAPER

Association between dietary protein intake and skeletal muscle mass in older Korean adults

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Key summary points

Aim We assessed the relationship of low and high daily protein intake with skeletal muscle mass in older adults.

Findings There was no association between the amount of protein consumed daily and low skeletal muscle mass in older adults after adjusting for covariates.

Message Further studies are needed to evaluate the impact of protein intake status on muscle health in older Koreans.

Abstract

Purpose We investigated the association of low and high daily protein intakes on skeletal muscle mass status in Korean adults aged 60 years and older.

Methods This cross-sectional study used data from the Korean National Health and Nutrition Examination Survey conducted between 2008 and 2011. The participants' dietary protein intake was assessed using the 24-h dietary recall method and was classified as low (< 0.8 g/kg body weight/day), moderate (0.8–1.2 g/kg/day), and high (> 1.2 g/kg/day). Amount of skeletal muscle mass was measured using whole-body dual-energy X-ray absorptiometry. Low skeletal muscle mass was defined as appendicular skeletal muscle mass index < 7.0 kg/m^2 in men and < 5.4 kg/m^2 in women.

Results The study included data from 4585 participants (2022 men and 2563 women). All skeletal muscle parameters in women and total lean mass in men decreased as the amount of protein consumed daily increased. However, there was no association between high or low protein intake and low skeletal muscle mass in men or women.

Conclusions No association was found between the amount of daily protein intake and skeletal muscle mass status in older Korean adults. Gender-specific further studies focussing on the interactions of dietary protein intake under specific conditions including physical activity status and the daily distribution of protein intake and the quality and source of the protein are needed to evaluate the impact of protein intake status on muscle health in older Koreans.

Keywords Appendicular skeletal muscle mass · Dietary proteins · Elderly · Lean mass · Total skeletal muscle mass

Abbreviations

ASMI	Appendicular skeletal muscle mass index
BMI	Body mass index
CI	Confidence interval
DXA	Dual-energy X-ray absorptiometry
KNHANES	The Korean National Health and Nutrition Examination Survey
LSMM	Low skeletal muscle mass; MPS: Muscle protein synthesis
OR	Odds ratio
SMI	Total skeletal muscle mass index

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Introduction

The gradual loss of skeletal muscle mass that occurs with ageing is associated with an increased risk of adverse health outcomes [1–4], places a considerable socioeconomic burden on older adults [5], and constitutes a significant medical issue.

The age-related decline in skeletal muscle mass may be attributed to a disparity between muscle protein synthesis (MPS) and breakdown [6] and to a blunted postprandial MPS response to protein ingestion, especially in older adults [7, 8]. Several approaches have been proposed to attenuate the blunting of the MPS response, including increasing dietary protein intake [9–12]. In previous studies, the amount of protein required to maximise the postprandial MPS response in older adults was higher than the current recommended dietary allowance [13, 14] and closer to > 1.2 g/kg/day [15, 16]. However, the association between the amount of daily protein intake compared with the dietary reference for protein intake and skeletal muscle mass has not been investigated in older Korean adults.

Therefore, we assessed the relationship of low and high daily protein intake with skeletal muscle mass in Koreans aged 60 years and older using data from the Korean National Health and Nutrition Examination Survey (KNHANES).

Materials and methods

Study population

We used data acquired from KNHANES collected between 2008 and 2011. The KNHANES is performed by the Korean Center for Disease Control and Prevention at 3-year intervals to assess public health status and to provide baseline data for the development, establishment, and evaluation of Korean public health policies. The KNHANES consists of non-institutionalized individuals one-year-old and older selected using a stratified, multistage, cluster probability sampling design to ensure independent, homogeneous, and nationally representative samples. Data are collected using household interviews and through anthropometric and biochemical measurements, and nutritional assessments. All protocols were approved by the Institutional Review Board of the Korean Center for Disease Control and Prevention, and all participants provided written informed consent at baseline.

In this cross-sectional study, we initially assessed the data of 19,527 adults ≥ 60 years of age selected from 37,753 KNHANES participants. We excluded participants with missing body composition data ($n = 2375$) and those whose intake on the day of the 24-h dietary recall survey was not representative of their usual intake ($n = 12{,}567$). Thus, the final analysis included data from 4585 participants (Fig. 1). The study was approved by the Institutional Review Board of the Catholic University of Korea (IRB approval number: VC19ZESI0188).

Dietary protein assessment

The participants' dietary protein intake was assessed by trained dietitians using the 24-h dietary recall method, which included all foods and beverages consumed in the previous 24 h. The nutrition survey was conducted at the participants' homes, and additional tools, such as food models, two-dimensional food volumes, and containers were used to help participants recall their nutrient intake accurately. Dietary intake was estimated from food composition tables published by the Rural Development Administration in combination with the nutrient database of the Korea Health and Industry of Development Institute [14, 17]. Dietary protein intake status, defined as the amount of protein consumed daily per body weight (in kilograms), was classified as low (< 0.8 g/kg body weight/day), moderate (0.8–1.2 g/kg/day), and high (> 1.2 g/kg/day) protein intake [15, 18, 19].

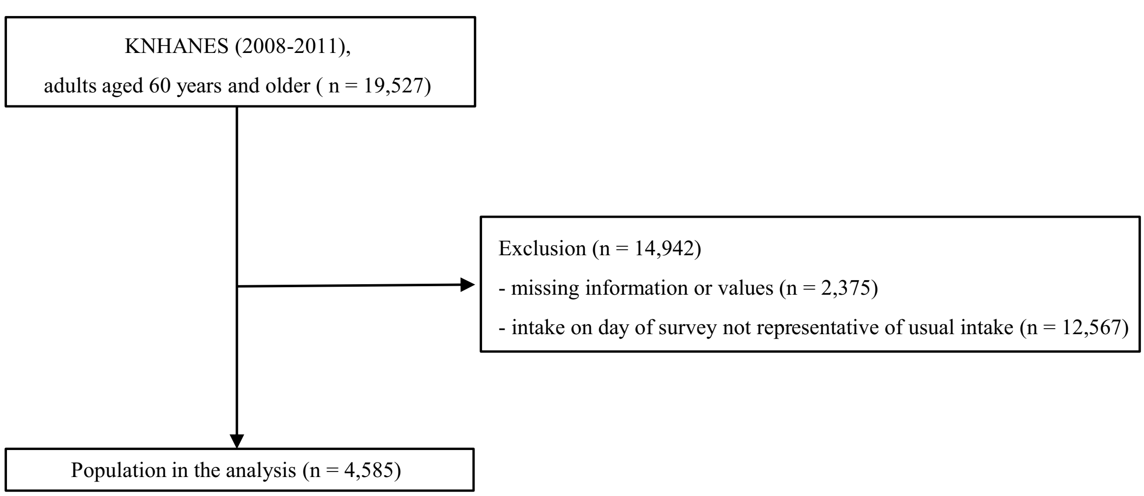

Fig. 1 Study population: data from the 2008 and 2011 Korean National Health and Nutrition Examination Survey (KNHANES)

Skeletal muscle mass measurement

Skeletal muscle mass was measured using a whole-body dual-energy X-ray absorptiometry (DXA) scanner (DISCOVERY-W fan-beam densitometer; Hologic Inc., Waltham, MA, USA). Participants wore a lightweight gown and were free from metal objects during the measurements. The skeletal muscle mass was divided and measured into six regions: head, trunk, and the upper/lower limbs on both sides. The trunk region was bordered by a horizontal line below the chin, vertical borders lateral to the ribs, and oblique lines passing through the femoral neck, and the leg region included all tissue below the oblique lines. Total lean mass, total limbs lean mass, total skeletal muscle mass index (SMI), and appendicular skeletal muscle mass index (ASMI) were included as skeletal muscle parameters. SMI and ASMI were calculated using the following equation: (total lean mass/[height]^2, kg/m^2) and (total limb lean mass/[height]^2, kg/m^2). Low skeletal muscle mass (LSMM) was defined as ASMI < 7.0 kg/m^2 in men and < 5.4 kg/m^2 in women [20].

Other variables

Self-reported data including age, sex, smoking status, alcohol consumption, extent of physical activity, household income data, and history of diabetes, hypertension, dyslipidaemia, cardio- and cerebrovascular diseases, and any cancer were obtained. Cigarette smoking was divided into three categories based on current use: non-smoker, ex-smoker, and current smoker. Information on alcohol consumption included the frequency of drinking days and the number of drinks consumed per day during the 1 year that preceded the KNHANES household interview. We used the Korean version of a "standard drink" (any drink that contains 10 g pure alcohol) based on alcohol content (by volume) of 4.5% for beer, 12% for wine, 6% for Korean traditional makgeolli, 21% for Korean soju, and 40% for whisky. Alcohol consumption was classified as abstinence (no alcoholic drinks consumed within the last year), moderate drinking (≤ 14 standard drinks consumed by men and ≤ 7 by women per week) and heavy drinking (> 14 standard drinks consumed by men and > 7 by women per week) [21]. The self-reported physical activity undertaken during the week before the interview was assessed and the physical activity variable included aerobic- and resistance exercise. The aerobic- and resistance exercise were classified as "low" or "moderate or high activity", and as "no" or "yes", respectively. Low aerobic exercise was defined as ≤ 150 min of moderate-intensity or ≤ 75 min of vigorous exercise per week [22], and the participants not undertaken resistance exercise was included in no resistance exercise. Household income was classified using monthly equivalized household income (quartiles), which was estimated as the total monthly household income divided by the square root of the total number of household members, and was dichotomized at the lower 25% border (≤ 25% vs. > 25%). Bodyweight, height, and waist circumference were measured after an overnight fast with the participants wearing light indoor clothing without shoes. Waist circumference was measured using a tape in the horizontal plane around the umbilical region after exhalation. Body mass index (BMI) was calculated as weight (kilograms) divided by height squared (square meters).

Statistical analysis

Because our study used a complex sampling design, data analyses were performed using the SAS PROC SURVEY module, which considers strata, clusters, and weights. All analyses were performed using the KNHANES sample weights. Sex-specific features were assessed using independent *t* tests for continuous variables and the chi-square test for dichotomous variables. Data are expressed as means ± standard errors or as percentages. Differences in skeletal muscle parameters according to dietary protein intake were assessed using analysis of variance, in which age, smoking status, alcohol consumption, physical activity/exercise level, household income, BMI, daily total energy intake, and histories of comorbidities (diabetes, hypertension, dyslipidemia, cardio- and cerebrovascular diseases, and any cancer) served as covariates. Multiple logistic regression analysis was used to assess the associations between dietary protein intake and LSMM after adjusting for the covariates. Model 1 was adjusted for age, model 2 was adjusted for age, BMI, and total energy intake, model 3 was adjusted for age, BMI, total energy intake, and physical activity, and model 4 was adjusted for age, BMI, total energy intake, physical activity, smoking, alcohol consumption, household income, and history of comorbidities. All statistical analyses were performed using SAS software (ver. 9.2; SAS Institute, Cary, NC, USA). P values < 0.05 were considered to indicate statistical significance.

Results

The study included data from 4585 participants (2022 men and 2563 women) with a mean age of 69.5 ± 0.1 years (68.8 ± 0.2 years in men and 70.1 ± 0.2 years in women). Significant differences in age, smoking status, alcohol consumption, physical activity/exercise level, household income, histories of hypertension and dyslipidemia, BMI, and daily total energy intake were observed according to gender (Table 1).

Table 2 shows the mean skeletal muscle mass parameters according to daily protein intake, adjusted for the covariates. In men, total lean mass decreased with the

Table 1 Characteristics of the study participants

	Total	Men	Women	*p* value
N	4585	2022	2563	–
Age, years	69.5 ± 0.1	68.8 ± 0.2	70.1 ± 0.2	< 0.001
Current smoking, %	15.3	28.7	4.8	< 0.001
Heavy drinking, %	20.1	31.5	10.9	< 0.001
Physical activity, %				
Aerobic exercise, low	80.3	77.1	82.1	0.001
Resistance exercise, no	85.2	75.6	92.7	< 0.001
Low income, %	44.4	39.4	50.4	< 0.001
Comorbidity, %				
Diabetes	16.6	15.9	17.2	0.340
Hypertension	47.7	42.6	51.7	< 0.001
Dyslipidemia	13.7	10.6	16.2	< 0.001
Stroke	4.5	5.1	4.0	0.080
Coronary artery disease	5.6	6.4	5.0	0.114
Cancer	4.1	3.7	4.5	0.243
Waist circumference, cm	84.1 ± 0.2	85.1 ± 0.3	83.4 ± 0.3	< 0.001
Body mass index, kg/m^2	23.8 ± 0.1	23.3 ± 0.1	24.2 ± 0.1	< 0.001
Energy intake, kcal/day	1674.0 ± 14.8	1956.2 ± 21.7	1452.4 ± 13.4	< 0.001
Energy from				
Carbohydrate, %	74.6 ± 0.2	71.3 ± 0.4	77.2 ± 0.2	< 0.001
Fat, %	11.7 ± 0.2	12.7 ± 0.2	10.9 ± 0.2	< 0.001
Protein, %	12.9 ± 0.1	13.3 ± 0.1	12.6 ± 0.1	< 0.001
Dietary protein intake, g/kg/day	0.9 ± 0.01	1.0 ± 0.01	0.8 ± 0.01	< 0.001
Total lean mass, kg	39.6 ± 0.2	46.4 ± 0.2	34.2 ± 0.1	< 0.001
Total limbs lean mass, kg	16.3 ± 0.1	19.9 ± 0.1	13.6 ± 0.1	< 0.001
SMI[a], kg/m^2	15.8 ± 0.04	16.9 ± 0.1	14.9 ± 0.04	< 0.001
ASMI[b], kg/m^2	6.5 ± 0.02	7.2 ± 0.02	5.9 ± 0.01	< 0.001
LSMM[c], %	38.9	39.6	38.3	0.468

Values are expressed as means ± standard errors, or percentages

SMI total skeletal muscle mass index, *ASMI* appendicular skeletal muscle mass index, *LSMM* low skeletal muscle mass

[a]SMI was calculated using the equation: total lean mass/(height)^2

[b]ASMI was calculated using the equation: total limb lean mass/(height)^2

[c]LSMM was defined as ASMI < 7.0 kg/m^2 in men and < 5.4 kg/m^2 in women

amount of protein consumed daily ($p = 0.009$ and p for trend = 0.006). In women, the values of all skeletal muscle mass parameters decreased as the amount of daily protein intake increased.

Table 3 shows the unadjusted, age-adjusted, and multivariate-adjusted odds ratios (ORs) of LSMM according to the amount of dietary protein consumed. The amount of daily protein intake was not associated with LSMM in men or women, and the results remained the same after adjusting for all covariates [multivariate-adjusted OR of LSMM in low- and high protein intake in men 1.12 and 1.21, 95% confidence interval (CI) 0.72–1.74 and 0.77–1.89, p for trend = 0.872; multivariate-adjusted OR of LSMM in low- and high protein intake in women 0.96 and 1.43, 95% CI 0.67–1.38 and 0.91–2.24, p for trend = 0.207].

Discussion

We investigated the association between the amount of dietary protein intake and skeletal muscle mass in community-dwelling Korean adults aged ≥ 60 years. In women, the amount of dietary protein consumed daily was negatively associated with the SMI and ASMI values. However, in terms of the cutoff point of the ASMI value for the diagnosis of sarcopenia (as ASMI < 7.0 kg/m^2 in men and < 5.4 kg/m^2 in women) [20], low appendicular skeletal muscle mass status was not associated with the daily low or high amount of dietary protein consumed in both men and women. Thus, LSMM status was not related to the amount of dietary protein consumed in older Korean adults.

Table 2 Mean values of skeletal muscle parameter according to daily protein intake

	Skeletal muscle parameters	Daily protein Intake[a]			*p* value[b]	*P* for trend[b]
		Low	Moderate	High		
Men	*N*	724	740	558	–	–
	Total lean mass, kg	46.9 ± 0.3	46.3 ± 0.3	45.9 ± 0.3	0.009	0.006
	Total limbs lean mass, kg	19.9 ± 0.2	19.8 ± 0.1	19.8 ± 0.1	0.065	0.063
	SMI, kg/m^2	17.1 ± 0.1	16.9 ± 0.1	16.8 ± 0.1	0.185	0.073
	ASMI, kg/m^2	7.3 ± 0.04	7.2 ± 0.04	7.2 ± 0.04	0.552	0.335
Women	*N*	1364	777	422	–	–
	Total lean mass, kg	34.5 ± 0.2	34.1 ± 0.2	33.2 ± 0.3	0.001	< 0.001
	Total limbs lean mass, kg	13.6 ± 0.1	13.6 ± 0.1	13.2 ± 0.1	0.017	0.005
	SMI, kg/m^2	15.0 ± 0.1	14.8 ± 0.1	14.5 ± 0.1	0.002	0.004
	ASMI, kg/m^2	5.9 ± 0.02	5.9 ± 0.03	5.8 ± 0.04	0.019	0.038

Values are expressed as means ± standard errors

SMI total skeletal muscle mass index, *ASMI* appendicular skeletal muscle mass index

[a]Dietary protein intake status was classified into three categories: low (< 0.8 g/kg body weight/day), moderate (0.8–1.2 g/kg/day), and high (> 1.2 g/kg/day) protein intake

[b]Adjustment for age, body mass index, daily total energy intake, physical activity level, smoking status, alcohol consumption, household income, and histories of comorbidities

Table 3 Association between low skeletal muscle mass and the protein intake status

	Protein intake[a]	LSMM[b]				
		Unadjusted	Model 1	Model 2	Model 3	Model 4
Men	Low	0.99 (0.75–1.31)	0.90 (0.67–1.20)	1.05 (0.71–1.54)	1.07 (0.72–1.56)	1.12 (0.72–1.74)
	Moderate	1	1	1	1	1
	High	0.99 (0.76–1.29)	1.12 (0.85–1.48)	1.21 (0.83–1.77)	1.19 (0.81–1.75)	1.21 (0.77–1.89)
	p for trend	0.979	0.156	0.641	0.740	0.872
Women	Low	0.98 (0.77–1.25)	0.93 (0.73–1.18)	0.87 (0.63–1.20)	0.88 (0.64–1.22)	0.96 (0.67–1.38)
	Moderate	1	1	1	1	1
	High	1.18 (0.87–1.60)	1.21 (0.88–1.66)	1.15 (0.78–1.71)	1.15 (0.78–1.70)	1.43 (0.91–2.24)
	p for trend	0.290	0.099	0.233	0.268	0.207

Values are expressed as odds ratios (with 95% confidence intervals)

Model 1: adjusted for age; Model 2: adjusted for age, body mass index, and total energy intake; Model 3: adjusted for all items in model 2 plus physical activity; Model 4: adjusted for all items in model 3 plus smoking status, alcohol consumption, household income, and history of comorbidities

LSMM low skeletal muscle mass

[a]Dietary protein intake status was classified as low (< 0.8 g/kg body weight/day), moderate (0.8–1.2 g/kg/day), and high (> 1.2 g/kg/day) protein intake

[b]LSMM was defined as appendicular skeletal muscle mass index < 7.0 kg/m^2 in men and < 5.4 kg/m^2 in women

Adequate protein intake could exert an impact on health outcomes and quality of life in relation to muscle health [23], and older adults require higher protein intake to maximize MPS because the response to protein ingestion is blunted in this population [15, 24]. Therefore, we hypothesized that high dietary protein intake would be positively associated with total or appendicular skeletal muscle mass and negatively associated with the prevalence of LSMM in older Koreans. However, our findings revealed no association between LSMM prevalence and total daily protein intake in older adults. There are several previous studies on the relationship of daily protein intake with skeletal muscle mass and the results have been inconsistent. In an observational study, the proportion of energy intake from protein was negatively associated with age-related loss of lean mass in older adults [25] and a longitudinal study found that a higher protein intake was associated with less mid-arm muscle loss in adults aged 50–69 years [26]. A cross-sectional study of older adults aged 65 years and over reported a positive association between protein intake of > 0.8 g/kg/

day and total lean mass measured using DXA scanner [27]. However, in a prospective study of older Chinese, total protein intake was not associated with longitudinal change in total limbs lean mass by DXA scan [28]. Another observational study of well-functioning adults aged 70–79 years also reported no association between daily protein intake and thigh muscle mass, and in the sub-analysis which was classified a higher protein intake as ≥ 0.8, or ≥ 1.2 g/kg/day compared with < 0.8, or < 1.2 g/kg/day, they found no differences between the protein intakes categories regarding thigh muscle mass [29], which were similar to our results. This study was conducted using cross-sectional design, which cannot determine causal relationships, therefore, these findings in the current study could not confirm the effect of dietary protein intake on skeletal muscle mass in older Koreans. However, in a randomized controlled trial of 116 older adults with a low protein intake (< 1.0 g/kg/day) over a 12-week period, the additional milk protein supplementation increased the trunk lean body mass, not limbs lean mass, compared with the placebo [30], and a meta-analysis revealed that protein supplementation only, without concomitant nutritional or exercise interventions, did not increase lean body mass [31].

We also found a negative association between total daily protein intake and height-adjusted total and appendicular skeletal muscle mass in older women, but not in older men. There could be differences in MPS rate and response between men and women [32, 33], and the actual requirement of protein for MPS response may be different by gender [34, 35], suggesting that further study using gender-specific classification for dietary protein intake status is needed to evaluate the association between daily protein intake and skeletal muscle mass in older adults.

Several factors may explain the null findings from the current study. First, we investigated whether high protein intake (> 1.2 g/kg/day) was negatively associated with LSMM. However, growing evidence suggests that protein intake exceeding the current recommended dietary allowance for protein (0.8–1.2 g/kg/day) may benefit older adults by maintaining or improving skeletal muscle mass [24, 36, 37]. Therefore, the adequate amount of daily protein intake for older Koreans may be much higher than the 0.8–1.2 g/kg/day reference used in this study; thus, the null results may reflect a relatively low reference point as opposed to the actual amount of protein required to maintain muscle health. Further study is needed to determine and verify the daily protein intake necessary to maintain muscle health in older Korean adults. Second, other factors that have been shown to affect skeletal muscle mass, including evenly distributed protein intake across meals [38], dietary protein quality (e.g., high-quality protein containing essential amino acids) [39] and the source of dietary protein [40] were not included in our study. Therefore, further studies of the effect of protein intake on muscle mass should consider the distribution, quality, and source of dietary protein in addition to total daily protein intake in older Korean adults. Finally, we assessed the relationship between protein intake and muscle mass by adjusting for the physical activity variable [41], but there was no association between the dietary protein intake and LSMM before – and after adjusting for physical activity. In other studies, the findings regarding associations between protein intake and muscle mass are conflicting [29, 31, 42, 43], although several studies have shown a significant impact of exercise/physical activity on muscle mass [44, 45], and reported strong interactions among physical activity, the amount of dietary protein consumed and muscle mass [43, 46]. Future studies are needed to assess the effects of protein intake on muscle mass in more specific groups, such as functionally limited or hospitalized adults.

A strength of our study is that the data were collected from a representative nationwide survey of the South Korean population. Furthermore, our study is the first to investigate the relationship between the amount of dietary protein intake (high vs. low) and various skeletal muscle parameters in Korean adults aged 60 years and older. Nevertheless, this study has some limitations. First, we used a cross-sectional design. Second, dietary intake was estimated using the 24-h dietary recall method, which may fluctuate on a day-to-day basis. Thus, to reduce error, we excluded participants whose intake on the day of the 24-h dietary recall survey was not representative of their usual intake. Third, data on the mealtime distribution of protein intake and the quality and source of dietary protein were not included in the study because the information was not captured by the KNHANES. Finally, we did not assess muscle strength and function, which are key diagnostic criteria of sarcopenia, because they were not available in the KNHANES.

Conclusion

We found no association between low appendicular skeletal muscle mass status and the amount of daily protein intake (high, > 1.2 g/kg/day; low, < 0.8 g/kg/day) as compared with the reference value (0.8–1.2 g/kg/day). Further studies focussing on the interactions among variables, including physical activity status and mobility limitations, as well as the timing of daily protein intake and protein quality and source, are warranted to clarify the relationship between adequate protein intake status and muscle health in older Korean adults.

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Author contributions HN Kim and SW Song conceived the study; HN Kim and SW Song analysed and interpreted the data; HN Kim wrote the manuscript; SW Song supervised writing of the paper and provided critical revisions; HN Kim and SW Song read and approved the final manuscript.

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Availability of data and material The data is available at https://knhanes.cdc.go.kr/knhanes/eng/index.do.

Code availability All statistical analyses were performed using SAS software (ver. 9.2; SAS Institute, Cary, NC, USA).

Declarations

Conflict of interest All authors declare no conflict of interest.

Ethics approval All protocols of the KNHANES were approved by the Institutional Review Board of the Korean Centers for Disease Control and Prevention, and all participants provided written informed consent at baseline. This study was approved by the Institutional Review Board of the Catholic University of Korea (IRB approval number: VC19ZESI0188).

Informed consent Informed consent was obtained from all individual participants included in the study.

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