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Original Article

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Association Between Nut Consumption and Metabolic Syndrome in Korean Adults

Sunhye Shin

Department of Food and Nutrition, Seoul Women's University, Seoul, Korea

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Correspondence to
Sunhye Shin
Department of Food and Nutrition, Seoul Women's University, 621 Hwarang-ro, Nowon-gu, Seoul 01797, Korea.
Email: sshin@swu.ac.kr

ORCID iDs
Sunhye Shin
https://orcid.org/0000-0002-5916-5390

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Conflict of Interest
The author has no conflicts of interest to declare.

Data Availability Statement
The data (KNHANES VII) presented in this study are available at https://knhanes.kdca.go.kr/knhanes/main.do (accessed on 6 May 2025).

ABSTRACT

Objective: Although nuts have been reported to lower the risk of multiple diseases, evidence regarding their effect on metabolic syndrome (MetS) in Asian populations is limited. Therefore, this study aimed to clarify the association between nut consumption and the risk of MetS.
Methods: A cross-sectional analysis was conducted using data from the seventh Korea National Health and Nutrition Examination Survey (2016–2018). MetS was defined according to the guidelines of the National Cholesterol Education Program Adult Treatment Panel III. Responses to a single 24-hour dietary recall from 4,365 younger adults (19–39 years), 7,498 middle-aged adults (40–64 years), and 4,378 older adults (≥65 years) were analyzed using multivariable logistic regression models.
Results: In this study, based on the culinary definition, nuts included tree nuts and peanuts. Approximately 25% of Korean adults were found to consume nuts. After adjusting for confounding variables, including age, body mass index, total energy intake, household income, alcohol consumption, smoking, aerobic exercise, and energy from carbohydrates, nut consumption was associated with a lower risk of MetS among middle-aged men (40–64 years; odds ratio [OR], 0.68; 95% confidence interval [CI], 0.53–0.88), older men (≥65 years; OR, 0.72; 95% CI, 0.53–0.98), and older women (≥65 years; OR, 0.69; 95% CI, 0.53–0.89).
Conclusion: These results suggest that consuming nuts may exert protective effects against MetS in middle-aged Korean men and older Korean adults.

Keywords: Nuts; Metabolic syndrome; Nutrition surveys

INTRODUCTION

Metabolic syndrome (MetS) has recently become a major public health issue because it increases the risk of cardiovascular disease (CVD), type 2 diabetes (T2D), and all-cause mortality, and its prevalence has risen considerably over the last 2 decades.[1-4] In Korea, recent statistics indicate that the age-adjusted prevalence of MetS increased significantly over a 20-year period, with about 40% of men and 26% of women diagnosed with the syndrome in 2020.[5,6] The definition of MetS varies slightly among expert groups, such as the World Health Organization, the International Diabetes Federation, the American Heart Association, and the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III); however,

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the key components of MetS include abdominal obesity, hypertriglyceridemia, hypo-high-density lipoprotein (HDL) cholesterolemia, hypertension, and insulin resistance.[4,7,8]

To manage or prevent MetS and related chronic diseases, various strategies utilizing physical activity or dietary factors are recommended.[9-11] Both moderate-continuous and high-intensity interval exercise training have been shown to improve insulin sensitivity and reduce the severity of MetS in individuals with prediabetes.[10] Although dietary interventions focusing on a single nutrient have limitations, multiple dietary patterns—such as the Mediterranean, Dietary Approaches to Stop Hypertension (DASH), and Nordic diets—have been reported to facilitate MetS prevention and treatment.[11] A common feature of these dietary patterns is the inclusion of plant-source foods, such as nuts and legumes.[11]

Under the culinary definition, nuts include tree nuts and peanuts. Although peanuts are legumes, their nutrient profiles resemble those of tree nuts, such as almonds, cashews, macadamia nuts, pecans, and walnuts.[12-15] Nuts are rich in monounsaturated fatty acids (MUFAs), dietary fiber, and phytosterols and low in carbohydrates and saturated fatty acids.[16] This composition of nutrients is associated with metabolic health; in fact, recent meta-analyses indicate inverse associations between nut intake and CVD mortality (relative risk [RR], 0.75; 95% confidence interval [CI], 0.71–0.79), diabetes mortality (RR, 0.61; 95% CI, 0.43–0.87), cancer mortality (RR, 0.97; 95% CI, 0.96–0.99), and all-cause mortality (RR, 0.81; 95% CI, 0.77–0.85).[17]

Recently, nut intake was also shown to be inversely associated with the prevalence of MetS.[18] However, that study analyzed the relationship among adults aged 40–79 years without stratification, and the association in different age groups has not yet been demonstrated. Thus, the present study aimed to determine whether nut intake is associated with MetS risk among young, middle-aged, and older adults in Korea by analyzing a nationally representative sample of the population.

MATERIALS AND METHODS

1. Data source and participants

Data from the seventh Korea National Health and Nutrition Examination Survey (KNHANES VII) were analyzed in this study. The KNHANES is a cross-sectional survey designed to obtain nationally representative estimates of the Korean population and encompasses health examinations, health interviews, and nutrition surveys.[19] The data collection procedure for the KNHANES VII was approved by the Institutional Review Board (IRB) of the Korea Centers for Disease Control and Prevention (IRB No. 2018-01-03-P-A). All participants provided informed consent. The requirements for ethical review and approval were waived by the IRB of Seoul Women's University for this study (IRB No. SWU IRB-2023A-02).

Of the 24,269 participants in the KNHANES VII, exclusions were made for children ≤18 years (n=4,880), individuals missing dietary intake data (n=2,535), and those with extreme energy intake (<500 kcal/day or >4,000 kcal/day; n=613). Consequently, data from 16,241 participants were analyzed and categorized by sex and age to account for potential biological differences. The categories were as follows: men 19–39 years (n=1,799), women 19–39 years (n=2,566), men 40–64 years (n=3,054), women 40–64 years (n=4,444), men ≥65 years (n=1,891), and women ≥65 years (n=2,487).

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2. General characteristics

Through health interviews, data on demographic details, socioeconomic status, personal behaviors, and medical conditions were collected. Household income was classified into quartiles: low (Q1), middle-low (Q2), middle-high (Q3), and high (Q4). Individuals who had consumed alcohol at least once a month in the preceding year were categorized as current alcohol consumers. Those who had smoked over 100 cigarettes in their lifetime and continued to smoke were labeled as current smokers. Regular aerobic exercise was defined as engaging in more than 150 minutes of moderate-intensity physical activity, 75 minutes of vigorous-intensity physical activity, or an equivalent mixture of both (with 1 minute of vigorous activity considered equal to 2 minutes of moderate activity) per week. During health examinations, measurements of body weight, height, and blood profiles were taken. Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters.

3. Assessment of nut consumption

Trained dietitians collected a single 24-hour dietary recall from participants. The daily intake of total energy, individual foods, and nutrients was calculated using the KNHANES recipe and food composition database published by the Korean Rural Development Administration. Based on the culinary definition, nuts were considered to include hazelnuts, acorns, macadamia nuts, chestnuts, Brazil nuts, almonds, gingko nuts, pine nuts, cashew nuts, pecans, walnuts, pistachio nuts, and peanuts. Nut intake was calculated in grams per day, and participants were categorized as either non-consumers or consumers of nuts. However, this classification of participants as nut consumers or non-consumers may not reflect their usual dietary habits, as a single 24-hour dietary recall only captures foods and beverages consumed in the past 24 hours.

4. Assessment of MetS

In accordance with the NCEP ATP III guidelines, participants who met at least 3 of the following criteria were defined as having MetS: 1) waist circumference (WC) ≥90 cm in men or ≥80 cm in women, based on Asian cutoffs; 2) triglycerides (TG) ≥150 mg/dL; 3) HDL cholesterol (HDL-C) <40 mg/dL in men or <50 mg/dL in women; 4) blood pressure ≥130/85 mmHg or use of blood pressure medication; and 5) fasting glucose ≥100 mg/dL, use of glucose-lowering medication, or insulin treatment.

5. Statistical analysis

General characteristics by nut consumption were described using mean ± standard error for continuous variables and as numbers with percentages for categorical variables. Differences in overall characteristics between the groups were evaluated using the Student's *t*-test for continuous variables and the Rao-Scott χ^2 test for categorical variables.

The risk of MetS according to nut consumption was assessed using multivariate logistic regression models with the non-consumer group as the reference. Four models were employed. The unadjusted model was used to estimate crude odds ratios (ORs) and 95% CIs; model 1 was adjusted for age, BMI, and total energy intake; model 2 was additionally adjusted for household income, alcohol consumption, smoking, and regular aerobic exercise; and model 3 was further adjusted for energy from carbohydrates, as this variable has been shown to be associated with MetS risk among Korean adults.[20]

All statistical analyses were performed using SPSS (version 26; IBM Corp.) based on the survey procedure.[19] A 2-sided *p*-value of less than 0.05 was considered to indicate statistical significance.

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RESULTS

Approximately 29.2% of Korean adults exhibited MetS. Older women (≥65 years) displayed the highest prevalence (55.6%), followed by older men (≥65 years) at 37.2%, middle-aged men (40–64 years) at 34.6%, middle-aged women (40–64 years) at 25.4%, younger men (19–39 years) at 16.0%, and younger women (19–39 years) at 7.6%.

About one-quarter of Korean adults (24.6%) were found to consume nuts, with rates of 17.1% among younger men, 20.4% in younger women, 26.2% in middle-aged men, 30.8% in middle-aged women, 24.2% in older men, and 21.2% in older women. Chestnuts were the most frequently consumed nut type, followed by peanuts, almonds, and walnuts (**Fig. 1**).

Table 1 presents the distribution of the general characteristics of younger adults (19–39 years) according to nut consumption. Among this demographic, nut consumers tended to be older and to have higher household incomes. Younger men who consumed nuts were less likely to smoke and had lower BMI and WC, while younger women who consumed nuts were less likely to be current alcohol consumers and had lower systolic and diastolic blood pressure. The average nut intake among consumers was 9.4 g for younger men and 9.3 g for younger women.

Table 2 presents the distribution of the general characteristics of middle-aged adults (40–64 years) according to nut consumption. Among this demographic, nut consumers were more likely to have a higher household income and to engage in regular aerobic exercise; they also had a lower prevalence of MetS and a higher energy intake. Middle-aged men who consumed nuts were less likely to smoke and had lower TG levels, higher HDL-C levels, and lower systolic blood pressure, along with higher carbohydrate intake. Middle-aged women who consumed nuts were less likely to be current alcohol consumers and had lower BMI, fasting glucose levels, and diastolic blood pressure. The average nut intake among consumers was 14.4 g for middle-aged men and 14.5 g for middle-aged women.

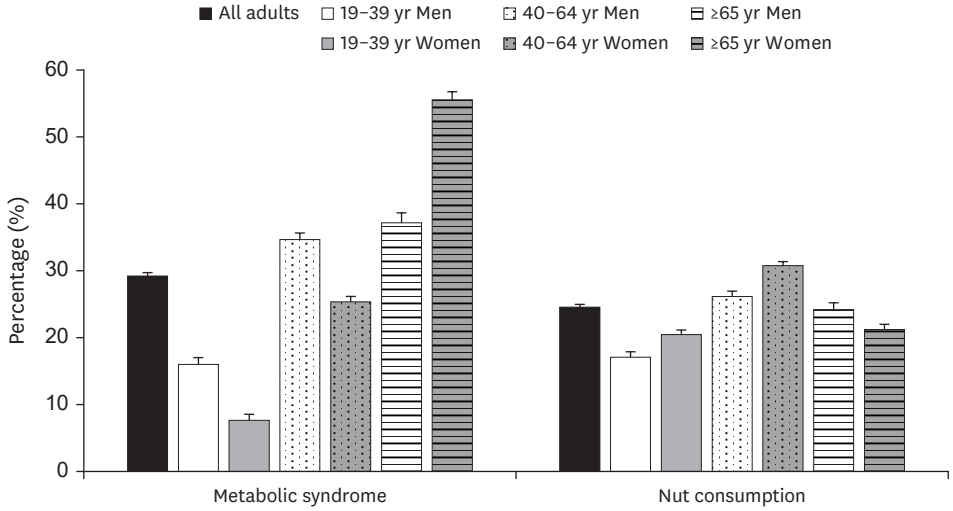

Fig. 1. Proportion of participants with metabolic syndrome and nut consumption by age and sex. Participants who met at least 3 of the following criteria were defined as having metabolic syndrome: 1) waist circumference ≥90 cm in men or ≥80 cm in women, based on Asian cutoffs; 2) triglycerides ≥150 mg/dL; 3) high-density lipoprotein cholesterol <40 mg/dL in men or <50 mg/dL in women; 4) blood pressure ≥130/85 mmHg or use of blood pressure medication; and 5) fasting glucose ≥100 mg/dL, use of glucose-lowering medication, or insulin treatment. Nuts included tree nuts (acorns, almonds, Brazil nuts, cashew nuts, chestnuts, gingko nuts, hazelnuts, macadamia nuts, pecans, pine nuts, pistachio nuts, and walnuts) and peanuts.

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Table 1. General characteristics of nut consumers and non-consumers aged 19–39 years

Characteristics	Men			Women		
	Non-consumers (n=1,485)	Consumers (n=314)	*p*-value*	Non-consumers (n=2,049)	Consumers (n=517)	*p*-value*
Age (yr)	29.2±0.2	30.4±0.4	0.009	29.3±0.2	30.8±0.3	<0.001
Household income†			0.008			0.042
Low	134 (10.7)	15 (5.4)		137 (8.0)	23 (5.1)	
Middle–low	339 (24.7)	55 (20.3)		524 (27.4)	118 (22.4)	
Middle–high	440 (31.9)	119 (40.5)		640 (32.2)	180 (36.4)	
High	458 (32.8)	94 (33.9)		613 (32.4)	172 (36.1)	
Current alcohol consumer	1,013 (73.7)	208 (74.7)	0.762	1,161 (62.6)	262 (54.6)	0.004
Current smoker	549 (39.1)	75 (27.1)	<0.001	148 (8.5)	25 (5.8)	0.118
Regular aerobic exercise	780 (61.4)	174 (66.5)	0.132	924 (52.7)	223 (49.3)	0.222
Metabolic syndrome	223 (15.7)	36 (12.2)	0.156	145 (7.0)	32 (6.0)	0.492
Body mass index (kg/m^2)	24.9±0.1	24.2±0.3	0.018	22.2±0.1	22.2±0.2	0.988
Waist circumference (cm)	85.5±0.3	83.9±0.7	0.031	74.0±0.3	74.1±0.5	0.774
Triglyceride (mg/dL)	174.5±3.7	138.1±6.5	0.215	92.7±0.3	89.6±2.9	0.372
HDL cholesterol (mg/dL)	48.4±0.3	48.7±0.7	0.763	57.8±0.3	58.4±0.6	0.364
Fasting glucose (mg/dL)	94.2±0.5	93.6±0.8	0.504	90.5±0.4	88.8±0.4	0.002
Systolic blood pressure (mmHg)	116.4±0.4	115.0±0.8	0.097	105.9±0.3	104.7±0.5	0.034
Diastolic blood pressure (mmHg)	77.8±0.3	76.6±0.7	0.109	70.6±0.2	70.4±0.4	0.746
Total energy intake (kcal/d)	2,271.4±22.0	2,357.7±50.2	0.112	1,760.4±18.1	1,816.3±29.0	0.107
Energy from carbohydrates (%)	56.60±0.37	55.47±0.78	0.186	58.72±0.33	56.01±0.62	<0.001
Nut intake (g/d)	N/A	9.4±1.6		N/A	9.3±1.0	

Data are expressed as mean ± standard error for continuous variables or as number (%) for categorical variables.
HDL, high-density lipoprotein; N/A, not applicable; KNHANES, Korea National Health and Nutrition Examination Survey.
*Differences between consumers and non-consumers were determined by *t*-test for continuous variables and Rao-Scott χ^2 test for categorical variables.
†For the KNHANES VII-1 (2016), the cutoff values were 750.0, 1,500.0, and 2,463.1 thousand Korean won. For the KNHANES VII-2 (2017), the cutoff values were 894.4, 1,905.7, and 3,104.2 thousand Korean won. For the KNHANES VII-3 (2018), the cutoff values were 1,060.7, 2,020.7, and 3,179.6 thousand Korean won.

Table 2. General characteristics of nut consumers and non-consumers aged 40–64 years

Characteristics	Men			Women		
	Non-consumers (n=2,259)	Consumers (n=795)	*p*-value*	Non-consumers (n=3,080)	Consumers (n=1,364)	*p*-value*
Age (yr)	50.9±0.2	51.6±0.3	0.053	51.2±0.0	52.2±0.2	<0.001
Household income†			<0.001			<0.001
Low	251 (10.4)	43 (5.5)		360 (11.3)	119 (8.5)	
Middle–low	493 (22.0)	122 (14.6)		741 (24.0)	278 (20.4)	
Middle–high	614 (29.5)	237 (32.8)		888 (30.6)	390 (30.1)	
High	748 (38.1)	244 (47.1)		981 (34.0)	531 (41.0)	
Current alcohol consumer	1,530 (73.8)	540 (72.3)	0.465	1,290 (45.8)	524 (40.9)	0.010
Current smoker	865 (42.2)	231 (30.9)	<0.001	156 (5.7)	45 (3.9)	0.056
Regular aerobic exercise	832 (42.9)	335 (50.6)	0.002	1,143 (42.2)	630 (51.2)	<0.001
Metabolic syndrome	745 (36.0)	221 (27.7)	0.001	769 (25.8)	285 (21.6)	0.008
Body mass index (kg/m^2)	24.6±0.1	24.6±0.1	0.856	23.9±0.1	23.1±0.1	<0.001
Waist circumference (cm)	86.8±0.2	86.3±0.3	0.293	79.5±0.2	77.8±0.3	<0.001
Triglyceride (mg/dL)	190.2±4.1	163.5±6.1	<0.001	121.7±2.0	114.8±2.8	0.050
HDL cholesterol (mg/dL)	46.3±0.3	47.6±0.5	0.018	54.7±0.3	55.6±0.5	0.078
Fasting glucose (mg/dL)	105.9±0.6	105.0±1.0	0.425	99.6±0.5	96.8±0.5	<0.001
Systolic blood pressure (mmHg)	121.5±0.4	118.9±0.6	<0.001	116.3±0.4	115.5±0.5	0.150
Diastolic blood pressure (mmHg)	81.2±0.3	80.3±0.4	0.058	76.1±0.2	75.3±0.3	0.032
Total energy intake (kcal/d)	2,238.6±18.6	2,361.0±30.4	0.001	1,651.1±13.1	1,743.5±17.9	<0.001
Energy from carbohydrates (%)	60.48±0.37	58.51±0.56	0.004	65.58±0.26	63.23±0.36	<0.001
Nut intake (g/d)	N/A	14.4±1.1		N/A	14.5±0.8	

Data are expressed as mean ± standard error for continuous variables or as number (%) for categorical variables.
HDL, high-density lipoprotein; N/A, not applicable; KNHANES, Korea National Health and Nutrition Examination Survey.
*Differences between consumers and non-consumers were determined by *t*-test for continuous variables and Rao-Scott χ^2 test for categorical variables.
†For the KNHANES VII-1 (2016), the cutoff values were 750.0, 1,500.0, and 2,463.1 thousand Korean won. For the KNHANES VII-2 (2017), the cutoff values were 894.4, 1,905.7, and 3,104.2 thousand Korean won. For the KNHANES VII-3 (2018), the cutoff values were 1,060.7, 2,020.7, and 3,179.6 thousand Korean won.

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Table 3. General characteristics of nut consumers and non-consumers aged ≥65 years

Characteristics	Men			Women		
	Non-consumers (n=1,442)	Consumers (n=449)	*p*-value*	Non-consumers (n=1,961)	Consumers (n=526)	*p*-value*
Age (yr)	73.1±0.2	72.0±0.3	<0.001	73.4±0.1	71.5±0.3	<0.001
Household income†			<0.001			<0.001
Low	632 (43.6)	130 (29.4)		1,091 (54.7)	192 (37.3)	
Middle–low	404 (28.5)	133 (30.3)		436 (23.0)	158 (29.6)	
Middle–high	199 (16.1)	106 (22.7)		211 (13.2)	89 (17.7)	
High	142 (11.9)	71 (17.6)		143 (9.1)	66 (15.3)	
Current alcohol consumer	755 (56.9)	255 (58.0)	0.732	321 (17.7)	102 (20.9)	0.174
Current smoker	257 (19.4)	55 (11.7)	0.002	42 (2.6)	7 (1.3)	0.100
Regular aerobic exercise	426 (34.1)	176 (45.7)	<0.001	436 (25.5)	171 (33.6)	0.002
Metabolic syndrome	500 (38.2)	139 (32.3)	0.073	1,019 (57.6)	217 (43.3)	<0.001
Body mass index (kg/m^2)	23.6±0.1	23.9±0.2	0.056	24.5±0.1	24.3±0.2	0.264
Waist circumference (cm)	86.6±0.3	86.8±0.5	0.651	84.4±0.3	83.5±0.5	0.091
Triglyceride (mg/dL)	132.9±2.4	125.7±3.8	0.110	138.7±2.8	126.7±5.2	0.037
HDL cholesterol (mg/dL)	45.9±0.4	46.8±0.6	0.204	49.0±0.3	51.1±0.7	0.005
Fasting glucose (mg/dL)	110.1±1.0	108.5±1.5	0.373	108.1±0.8	107.1±1.2	0.003
Systolic blood pressure (mmHg)	126.8±0.5	126.0±0.9	0.395	130.4±0.5	129.2±1.1	0.299
Diastolic blood pressure (mmHg)	71.6±0.4	73.3±0.5	0.003	72.2±0.3	72.9±0.5	0.214
Total energy intake (kcal/d)	1,814.4±19.9	2,099.5±35.9	<0.001	1,409.6±14.5	1,633.7±32.5	<0.001
Energy from carbohydrates (%)	69.16±0.37	65.47±0.56	<0.001	73.84±0.26	68.16±0.53	<0.001
Nut intake (g/d)	N/A	16.8±1.4		N/A	19.4±2.5	

Data are expressed as mean ± standard error for continuous variables or as number (%) for categorical variables.
HDL, high-density lipoprotein; N/A, not applicable; KNHANES, Korea National Health and Nutrition Examination Survey.
*Differences between consumers and non-consumers were determined by *t*-test for continuous variables and Rao-Scott χ^2 test for categorical variables.
†For the KNHANES VII-1 (2016), the cutoff values were 750.0, 1,500.0, and 2463.1 thousand Korean won. For the KNHANES VII-2 (2017), the cutoff values were 894.4, 1,905.7, and 3,104.2 thousand Korean won. For the KNHANES VII-3 (2018), the cutoff values were 1,060.7, 2,020.7, and 3,179.6 thousand Korean won.

Table 3 presents the distribution of the general characteristics of older adults (≥65 years) according to nut consumption. Among this demographic, nut consumers were older, were more likely to have a higher household income and to engage in regular aerobic exercise, and had higher energy and carbohydrate intakes. Older men who consumed nuts were less likely to smoke and had higher diastolic blood pressure, while older women who consumed nuts had a lower prevalence of MetS and lower TG, higher HDL-C, and lower fasting glucose levels. The average nut intake among consumers was 16.8 g for older men and 19.4 g for older women.

Associations between nut consumption and MetS varied by age and sex. Middle-aged men (40–64 years) who consumed nuts had a 32% lower risk of MetS (OR, 0.68; 95% CI, 0.53–0.88), older men (≥65 years) who did so had a 28% lower risk (OR, 0.72; 95% CI, 0.53–0.98), and older women (≥65 years) categorized as nut consumers had a 31% lower risk (OR, 0.69; 95% CI, 0.53–0.89) compared to non-consumers after adjusting for confounding variables. No significant associations were observed among younger adults (19–39 years) or middle-aged women (40–64 years) (**Table 4**).

Nut consumption was also associated with each component of MetS. Among middle-aged men (40–64 years), those who consumed nuts had a 25% lower risk of hypertriglyceridemia (OR, 0.75; 95% CI, 0.59–0.94) after adjustment for all confounding variables. In older women (≥65 years), nut consumption was associated with a 26% lower risk of hypertriglyceridemia (OR, 0.74; 95% CI, 0.55–0.99) when energy from carbohydrates was not included in the final adjustment. After adjusting for confounding variables, nut-consuming younger women (19–39 years) and older women (≥65 years) had a 47% (OR, 0.53; 95% CI, 0.35–0.79) and a 30% lower risk of hyperglycemia (OR, 0.70; 95% CI, 0.54–0.89), respectively. When adjusting only for age, BMI, and total energy intake, nut-consuming middle-aged men (40–64 years) and older women (≥65 years) had a 21% (OR, 0.79; 95% CI, 0.63–0.98) and a 24% lower risk of hypo-HDL cholesterolemia (OR, 0.76; 95% CI, 0.58–0.99), respectively (**Supplementary Tables 1-5**).

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Table 4. Association between nut consumption and metabolic syndrome by age and sex

Nut consumption	Unadjusted	Model 1*	Model 2†	Model 3‡
19–39 yr				
Men				
Non-consumers	1 (ref)	1 (ref)	1 (ref)	1 (ref)
Consumers	0.74 (0.49–1.12)	0.75 (0.47–1.19)	0.84 (0.52–1.36)	0.84 (0.53–1.36)
Women				
Non-consumers	1 (ref)	1 (ref)	1 (ref)	1 (ref)
Consumers	0.85 (0.54–1.35)	0.63 (0.35–1.12)	0.57 (0.31–1.04)	0.57 (0.31–1.07)
40–64 yr				
Men				
Non-consumers	1 (ref)	1 (ref)	1 (ref)	1 (ref)
Consumers	0.68 (0.55–0.85)	0.62 (0.48–0.78)	0.69 (0.54–0.89)	0.67 (0.52–0.86)
Women				
Non-consumers	1 (ref)	1 (ref)	1 (ref)	1 (ref)
Consumers	0.79 (0.67–0.94)	0.96 0.79–1.17)	0.99 (0.81–1.21)	1.02 (0.83–1.25)
≥65 yr				
Men				
Non-consumers	1 (ref)	1 (ref)	1 (ref)	1 (ref)
Consumers	0.77 (0.58–1.03)	0.69 (0.51–0.93)	0.72 (0.53–0.99)	0.71 (0.52–0.97)
Women				
Non-consumers	1 (ref)	1 (ref)	1 (ref)	1 (ref)
Consumers	0.59 (0.47–0.73)	0.65 (0.50–0.84)	0.68 (0.53–0.87)	0.67 (0.52–0.87)

Values are presented as odds ratio (95% confidence interval).
*Model 1: adjusted for age, body mass index, and total energy intake.
†Model 2: adjusted for all covariates included in model 1 plus household income, alcohol consumption, smoking, and aerobic exercise.
‡Model 3: adjusted for all covariates included in model 2 plus energy from carbohydrates.

DISCUSSION

This analysis of data from the KNHANES VII (2016–2018) revealed that approximately 30% of Korean adults had MetS, and less than one-quarter consumed nuts. Among nut consumers, the average intake ranged from 9 to 19 g/day, which is below the recommended 30 g/day outlined in major dietary guidelines such as the Mediterranean and DASH diets.[21,22] Nonetheless, after adjusting for confounding factors, middle-aged men (40–64 years) and older adults (≥65 years) who consumed nuts had significantly lower risks of MetS compared to those who did not. Notably, these groups had a higher prevalence of MetS than younger adults (19–39 years) and middle-aged women (40–64 years), among whom no significant association between nut consumption and MetS was observed.

Previous studies have also reported the beneficial effects of nut consumption on MetS risk. Older Spanish adults (65–79 years) who consumed nuts (including almonds, Brazil nuts, cashews, hazelnuts, pine nuts, pistachios, and walnuts) with at least 3 servings per week (90 g/week) had 38% and 16% lower risks of MetS and abdominal obesity, respectively, compared to those who consumed less than 3 servings of nuts per week.[23] Among Finnish adults (≥18 years) with type 1 diabetes, consuming at least 56.8 g/week of nuts (including peanuts, cashew nuts, almonds, walnuts, hazelnuts, pecans, macadamia nuts, pistachio nuts, Brazil nuts, and pine nuts) reduced the risks of MetS, abdominal obesity, hypertension, hypertriglyceridemia, hypo-HDL cholesterolemia, and impaired fasting glucose levels.[24] Italian adults (≥18 years) with a higher intake of nuts (more than 11.6 g/day), including chestnuts, hazelnuts, almonds, walnuts, and peanuts, had 39% and 56% lower risks of hypertension and T2D, respectively, than those with lower nut intake.[25] Korean adults (40–79 years) who consumed at least 30 g of nuts (including peanuts, almonds, and pine nuts) per week displayed a 15% lower prevalence of MetS compared to non-consumers, and

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nut consumption was inversely correlated with the risks of abdominal obesity, hypo-HDL cholesterolemia, and hypertriglyceridemia.[18]

Nuts are rich in dietary fiber, MUFA, and phytosterols, all of which are beneficial in reducing the risk of MetS. Dietary fiber helps lower the risk of CVD and T2D by improving blood lipid profiles and glycemic control.[26,27] Short-chain fatty acids produced from fiber fermentation suppress the production of pro-inflammatory cytokines and chemokines that contribute to MetS risk.[28,29] MUFA provides metabolic benefits by increasing fatty acid oxidation and energy expenditure, which helps decrease inflammation and lower both blood pressure and TG levels.[30-33] Phytosterols, including campesterol and β-sitosterol, have been reported to reduce intestinal cholesterol absorption and exert anti-obesity, anti-diabetic, and anti-inflammatory effects.[34] Since oxidative stress triggers and exacerbates metabolic dysregulation, and oxidative damage accumulates with age,[35] nuts rich in antioxidative and anti-inflammatory nutrients may offer greater benefits to older adults than to younger adults.

Notably, carbohydrate restriction has been reported to help ameliorate MetS symptoms because carbohydrates increase blood levels of glucose, insulin, and TG while decreasing HDL levels.[36] Among Korean adults, multiple studies have shown carbohydrate intake to be negatively correlated with the risk of MetS.[20,37,38] Therefore, to exclude the possibility that carbohydrate intake influences the association between nut consumption and MetS, the variable "energy from carbohydrates" was included in multivariate logistic regression model 3. Adjusting for this variable substantially strengthened the association in middle-aged men, older men, and older women. These results imply that consuming nuts may help counteract the elevated MetS risk associated with high carbohydrate consumption.

Although the inverse association between nut intake and MetS risk among Korean adults has been recently reported,[18] the strength of the present study lies in demonstrating divergent associations between nut intake and MetS risk among young, middle-aged, and older adults using nationally representative data collected through validated methods from a large number of participants. However, the study also has certain limitations. The KNHANES has a cross-sectional design, making it difficult to establish cause-and-effect relationships, and a single 24-hour dietary recall may not fully represent usual dietary intake. Thus, the nut consumption measured in this study may not reflect a habitual pattern of regular nut consumption.

In summary, this study indicates that nut intake is inversely associated with the risk of MetS among Korean adults. This suggests that consuming nuts may help prevent the development or exacerbation of MetS and its complications, especially in middle-aged men and older adults. To confirm the true effect of nuts on MetS risk in Asian populations, longitudinal and intervention studies are warranted.

SUPPLEMENTARY MATERIALS

Supplementary Table 1

Association between nut consumption and abdominal obesity* by age and sex

Supplementary Table 2

Association between nut consumption and hypertriglyceridemia* by age and sex

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Supplementary Table 3

Association between nut consumption and hypo-high-density lipoprotein cholesterolemia* by age and sex

Supplementary Table 4

Association between nut consumption and hypertension* by age and sex

Supplementary Table 5

Association between nut consumption and hyperglycemia* by age and sex

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