Original Article

The association between noodle consumption and metabolic syndrome in Korean adults

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Background and Objectives: The proportion of noodles in the Korean diet is increasing, but the effect of noodle intake on metabolic syndrome has not been sufficiently investigated. Therefore, we investigated noodle consumption and its relation to metabolic syndrome in Korean adults. **Methods and Study Design:** This study was conducted on 10,505 adults using the combined data of the 2012–2016 Korea National Health and Nutrition Examination Survey (KNHANES). Noodle intake was evaluated with a food frequency questionnaire (FFQ) based on 112 food items. To compute odds ratios (ORs) and their 95% confidence intervals (CIs) controlled for confounders, multivariable logistic regression models were used. **Results:** Compared to people in the lowest levels of noodle intake, the OR of the metabolic syndrome of those in the highest levels was 1.48 (95% CI, 1.16-1.90; p-trend = 0.002). This positive association was also found for hypertriglyceridemia and abdominal obesity, which were metabolic syndrome components. Specifically, the odds of having hypertriglyceridemia were 38% (OR, 1.38; 95% CI, 1.14-1.66; p-trend < 0.001) higher for people with high noodle consumption compared to those with low noodle consumption in the overall population. The tendency for people who consume a lot of noodles to have raised odds of metabolic syndrome was observed when analyzed by the type of noodles. **Conclusions:** This study suggested noodle intake was positively related to metabolic syndrome and its components in Korean adults. Further clinical trials and prospective cohort studies are required to identify a causal relationship between noodle intake and metabolic syndrome in Koreans.

Key Words: noodle consumption, metabolic syndrome, Korean, carbohydrates, diet

INTRODUCTION

In 2009, internationally unified diagnostic guidelines were proposed for metabolic syndrome, in which insulin resistance was considered the primary risk factor.[1, 2] According to this harmonizing criteria, if three or more of the five factors of increased waist circumference, decreased high density lipoprotein (HDL)-cholesterol, elevated triglycerides, increased fasting glucose, and elevated blood pressure are met, it is classified as metabolic syndrome.[1] The prevalence rate of metabolic syndrome varied from 10% to 84% globally.[3] And the morbidity of metabolic syndrome has continued to increase.[4] In Korea, the prevalence of metabolic syndrome has risen from 23.3% to 28.6% over the past 10 years.[5] Prior studies have shown that metabolic syndrome was positively connected with cancer, cerebrovascular disease, cardiovascular disease, and diabetes, which could raise the risk of premature death.[6-9] Considering its high prevalence and association with other chronic diseases, exploring strategies to prevent metabolic syndrome is essential for improving public health.

Various factors such as age, race, obesity, physical activity, and psychological health have been reported as risk factors for metabolic syndrome.[10-13] Dietary factors, including dietary patterns and nutrient intake, were also known to affect metabolic syndrome risk.[14] It is known that carbohydrates occupy a relatively high proportion of calorie intake in Korean adults.[15] A previous study suggested that high carbohydrate intake reduces HDL cholesterol and increases triglycerides, thereby increasing the risk of metabolic syndrome.[15] Noodles are generally known to have a high proportion of carbohydrates.[16] The proportion of Koreans who consume instant ramen more than once a week was 33.6%, and the proportion of noodles other than instant ramen consumed more than once a week was also high at 59%.[17, 18] Most of the studies on noodle consumption in Korea have focused on instant ramen to date, and research on the consumption of noodles other than instant ramen and the effect of noodles themselves on metabolic syndrome was still insufficient. Therefore, the current study investigated the association

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between the consumption of noodles, including instant ramen, gugsu/ kalgugsu (chopped noodles)/ udong (thick white noodles), and jjajangmyeon (black-bean-sauce noodles)/ jjamppong (Chinese-style noodles with vegetables and seafood) and metabolic syndrome and metabolic syndrome components in Koreans utilizing data of the Korea National Health and Nutrition Examination Survey (KNHANES).

METHODS

Study population

The current research used data of the KNHANES published by the Korea Centers for Disease Control and Prevention. The KNHANES is a cross-sectional study that represents the national Korean population, and information on Koreans' health-related behavior, health status, nutritional status, etc., is collected annually through three types of surveys: nutritional survey, health interview survey, and health examination survey.[19] Further detailed information on the health check-up methods and data collection of the KNHANES can be found in a related previous study.[19]

The current study included 32,966 people who finished the nutritional survey, health examination survey, and health interview among 39,156 people who participated in the 3rd year of 5th KNHANES (2012), the 6th KNHANES (2013-2015), and the 1st year of 7th KNHANES (2016). Among them, participants inappropriate for the current study were sequentially excepted according to the following criteria: participants over 65 years old or under 19 years old who were not surveyed by the food frequency questionnaire (FFQ); participants who were diagnosed with hypertension, stroke, dyslipidemia, diabetes, myocardial infarction, cancer, or dosing medication to treat hypertension, diabetes, or dyslipidemia; participants who were pregnant; participants with omitting information on HDL-cholesterol, triglycerides, fasting blood sugar, and diastolic and systolic blood pressure; participants who fasted for less than 8 hours at the time of blood test; participants with extreme calorie intake (more than 6,000 kcal or less than 500 kcal per day); participants with omitting information on alcohol drinking and vigorous or moderate physical activity. Finally, 10,505 people who met the including criteria were selected as final research subjects (Figure 1).

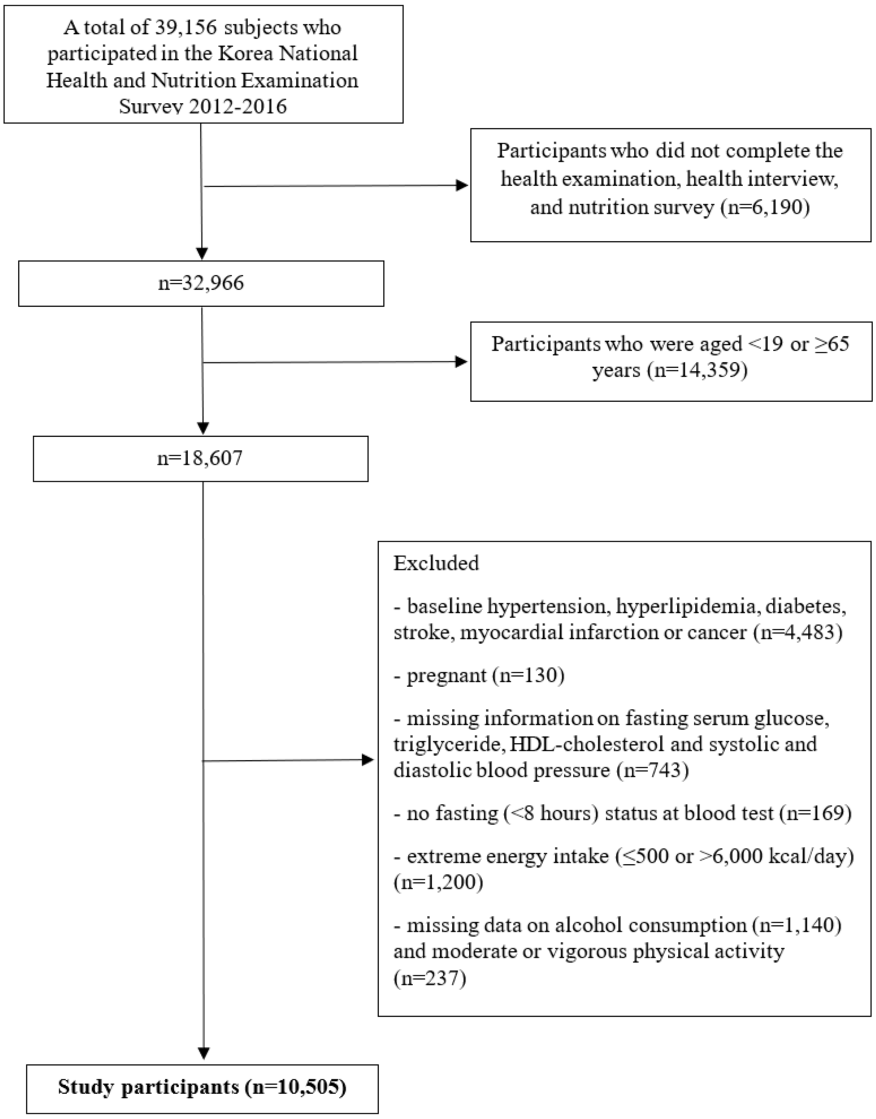

Figure 1. Flow chart of the study population

Ethics approval statement

The KNHANES was performed with the approval from the Institutional Review Board of Korea Centers for Disease Control and Prevention (2013-07CON-03-4C, 2013-12EXP-03-5C, 2012-01EXP-01-2C). From 2015, the KNHANES has been conducted without the review of the institutional review board as it is a study performed by the government for public welfare according to the Bioethics Act.

Noodle consumption and dietary assessment

The information on noodle consumption was collected through the FFQ based on 112 food items of KNHANES. The validity and reproducibility of the FFQ developed for the KNHANES have been verified through a previous study.[20] In this study, the noodles included instant ramen, gugsu/ kalgugsu (chopped noodles)/ udong, and jjajangmyeon (black bean sauce noodles)/ jjamppong (spicy noodles). The average noodle intake was estimated by multiplying the times of consumption per week by portion size. Frequency of noodle consumption over the past year was divided into nine levels, ranging from “hardly” to “3 times per day”, and the serving size comprised three classes (1/2 serving, one serving, and 1.5 servings of the standard serving size).

Other covariates

Demographic factors such as sex, age, and family income and lifestyle information including physical activity, alcohol consumption, and smoking were obtained through a self-administered questionnaire. The education level was categorized as “college or higher”, “middle or high school”, and “less than elementary school”, and family income was classified as “high”, “upper middle”, “lower middle”, and “low”. Regarding alcohol consumption, the weekly drinking amount was evaluated by multiplying the annual drinking times by the amount of alcoholic drinks, and the drinking amount was categorized as 3 or more servings per day, 1 to 2 servings, and less than 1 serving. Physical activity was evaluated through aerobic activity. People were defined as physically active as those who have ≥ 150 min per week of moderate activity, ≥ 75 min per week of vigorous activity, or ≥ 150 min per week of a mixture of vigorous and moderate activity (one minute of vigorous activity was estimated as two minutes of moderate activity). Tobacco use status was classified into current smokers, former smokers, and non-smokers.

Evaluation of metabolic syndrome

Three times blood pressure was measured after the subject rested in a sedentary position for 5 min, and the average of the last two measurements of diastolic blood pressure and systolic blood pressure was selected. A Baumanometer Wall Unit 33 (0850, Baum/ USA) was used for sphygmomanometer. Waist circumference was measured by a trained researcher using a tape measure Seca 200 (Seca/Germany) at the midpoint between the top of the iliac crest and the bottom of the ribs to the nearest 0.1 cm, with the subject’s weight distributed equally on both feet at the end of a normal exhalation. The blood levels of glucose, cholesterol, and triglycerides were analyzed at the Neodin Medical Research Institute in Korea using the enzymatic method with a Hitachi Automatic Analyzer 7600 (Hitachi/Japan). The diagnosis of metabolic syndrome was decided by the harmonizing criteria of Alberti et al.[1] Subjects were recognized to have metabolic syndrome if they met 3 or more of the following criteria: 1) abdominal obesity (waist circumference ≥80 cm for women and ≥90 cm for men); 2) hyperglycemia (fasting serum glucose ≥100 mg/dL); 3) hypertriglyceridemia (triglycerides ≥150 mg/dL); 4) low HDL cholesterol (HDL cholesterol <50 mg/dL for women and <40 mg/dL for men); and 5) elevated blood pressure (diastolic blood pressure/ systolic blood pressure ≥85/130 mmHg).

Statistical analysis

Noodle intake was sorted into four quartiles. The age-standardized mean of demographic factors and prevalence, intakes of food and nutrients were estimated in each quartile of noodle consumption utilizing the PROC SURVEYLOGISTIC and PROC SURVEYREG (SAS Institute) procedures. To examine the association between noodle intake and outcomes (metabolic syndrome and its components), the PROC SURVEYLOGISTIC procedure was utilized. We implemented two distinct models that controlled for diverse confounders. Model 1 was controlled for age (continuous) and sex. Model 2 was controlled for age, sex, total energy intake (kcal, continuous), physical activity (inactive; active), body mass index (BMI, kg/m^2, continuous), family income (highest; upper middle; lower middle; lowest), education (less than elementary school; middle or high school; college or higher), smoking (current smoker; ex-smoker; non-smoker), alcohol drinking (≥3 servings/day; 1-2 servings/day; <1 serving/day), and survey year (2016; 2015; 2014; 2013; 2012). To estimate a linear trend across the noodle consumption quartile, the PROC SURVEYLOGISTIC procedure was utilized by selecting the median value in each quartile. A two-tailed p value < 0.05 was judged to be statistically significant. All statistical analyses were conducted utilizing SAS software (version 9.4; SAS Institute, Cary, NC).

RESULTS

Baseline characteristics

The general characteristics of the study subjects by noodle intake are presented in Table 1. People who consumed more noodles were younger, more likely to be present smokers, and had higher consumption of energy, alcohol, protein, fat, carbohydrates, and sodium. People with the highest quartile of noodle consumption tended to have higher BMI and lower physical activity, household income, and education level than those with the lowest quartile.

Noodle intake and metabolic syndrome

The results from multivariable logistic regression analysis for the relation between noodle intake and metabolic syndrome are shown in Table 2. In model 2 with the multivariable adjustment, participants with the highest noodle consumption had 48% higher odds of having metabolic syndrome in the overall population compared to those with the lowest noodle consumption (odds ratio [OR] for quartile [Q] 4 vs Q1, 1.48; 95% confidence interval [CI],

Table 1. General characteristics, nutrient profiles according to noodle intake in overall population

	Noodle consumption				*p*-value*
	Quartile 1	Quartile 2	Quartile 3	Quartile 4	
No. of subjects	2569	2640	2707	2589	
Age† (y)	43.4±0.3	39.0±0.3	37.2±0.3	33.9±0.3	< 0.001
Energy intake‡ (kcal/d)	1686±16.7	1940±15.4	2230±16.3	2713±20.5	< 0.001
BMI‡ (kg/m²)	23.0±0.1	23.3±0.1	23.6±0.1	23.7±0.1	< 0.001
High physical activity§,†† (%)	50.9	48.8	50.2	50.6	0.567
Alcohol, ≥1 drink/d†† (%)	13.8	21.0	29.3	38.5	< 0.001
High education,¶,††%	41.9	49.1	52.8	41.8	< 0.001
Currently smoking†† (%)	12.8	21.3	27.9	36.8	< 0.001
Highest income quartile†† (%)	36.8	35.2	38.2	33.3	0.011
Protein‡ (g/d)	55.9±0.6	64.3±0.6	75.0±0.6	90.3±0.9	< 0.001
Fat‡ (g/d)	34.0±0.5	39.4±0.5	47.6±0.5	61.7±0.6	< 0.001
Carbohydrates‡ (g/d)	271±2.5	305±2.4	340±2.4	398±2.8	< 0.001
Sodium‡ (mg/day)	2548±32.6	3018±30.3	3691±33.5	4709±46.8	< 0.001

BMI, body mass index
†Values are means ± SEMs.
‡Values are age-standardized means ± SEMs.
§High physical activity was defined as 150 min/week of moderate activity, ≥75 min/week of vigorous activity or ≥150 min/week of a combination of moderate and vigorous activity.
¶College education or higher.
††Values are age-standardized prevalences.
**p*-values were derived from the chi square test for categorical variables and a regression model for a continuous variable.

Table 2. Multivariable adjusted odds ratio and 95% CI values for metabolic syndrome components according to noodle consumption in overall population

	Noodle consumption				*p*-trend
	Quartile 1	Quartile 2	Quartile 3	Quartile 4	
Metabolic syndrome					
No.of cases/subjects	390/2569	410/2640	438/2707	413/2589	
Median intake, servings/week	0.3	1.0	2.0	4.2	
Model 1†	1.00	1.14 (0.94-1.38)	1.31 (1.08-1.59)	1.60 (1.30-1.98)	< 0.001
Model 2‡	1.00	1.16 (0.94-1.44)	1.21 (0.96-1.51)	1.48 (1.16-1.90)	0.002
Abdominal obesity					
Model 1†	1.00	1.11 (0.96-1.28)	1.27 (1.09-1.47)	1.25 (1.07-1.46)	0.012
Model 2‡	1.00	1.30 (1.04-1.63)	1.35 (1.06-1.73)	1.33 (1.04-1.70)	0.152
Low HDL cholesterol					
Model 1†	1.00	1.05 (0.92-1.21)	1.07 (0.92-1.24)	0.95 (0.81-1.11)	0.278
Model 2‡	1.00	1.06 (0.92-1.23)	1.06 (0.91-1.25)	0.96 (0.80-1.14)	0.380
Hypertriglyceridemia					
Model 1†	1.00	1.13 (0.95-1.34)	1.35 (1.14-1.59)	1.52 (1.27-1.80)	< 0.001
Model 2‡	1.00	1.08 (0.91-1.29)	1.25 (1.05-1.48)	1.38 (1.14-1.66)	< 0.001
Hyperglycemia					
Model 1†	1.00	1.30 (1.11-1.53)	1.31 (1.10-1.55)	1.35 (1.13-1.61)	0.020
Model 2‡	1.00	1.27 (1.08-1.50)	1.20 (1.01-1.44)	1.13 (0.93-1.38)	0.840
Elevated blood pressure					
Model 1†	1.00	1.00 (0.84-1.19)	1.10 (0.93-1.31)	1.28 (1.06-1.54)	0.002
Model 2‡	1.00	0.98 (0.82-1.17)	1.01 (0.84-1.20)	1.15 (0.94-1.41)	0.098

HDL, high density lipoprotein
†Model 1 was adjusted for age and sex
‡Model 2 was adjusted for age, sex, household income, education, smoking, alcohol, total energy intake, survey year, physical activity, BMI.

1.16-1.90; *p*-trend = 0.002). In the results of the analysis for metabolic syndrome components, people in the fourth quartile of noodle intake had 33 % increased odds of having abdominal obesity (OR, 1.33; 95% CI, 1.04-1.70) and 38% increased odds of hypertriglyceridemia (OR, 1.38; 95% CI, 1.14-1.66; *p*-trend < 0.001) compared to those in the first quartile.

Table 3 shows relations between noodle consumption and metabolic syndrome by sex. The OR for the fourth quartile of noodle consumption for metabolic syndrome for men and women were 1.64 (95% CI, 1.18-2.29; *p*-trend= 0.004) and 1.63 (95% CI, 1.17-2.27; *p*-trend= 0.005), respectively. The association between noodle intake and hypertriglyceridemia was stronger in men (OR for Q4 vs Q1, 1.70; 95% CI, 1.34-2.17; *p*-trend <0.001) than in women (OR for Q4 vs Q1, 1.33; 95% CI, 1.02-1.74; *p*-trend = 0.044). In women, high noodle intake was related to raised odds of elevated blood pressure (OR for Q4 vs Q1, 1.50; 95% CI, 1.12-2.02; *p*-trend = 0.02).

The results for the relation between various types of noodle intake and metabolic syndrome were shown in Table 4. The OR for the fourth quartile of instant ramen

Table 3. Multivariable adjusted odds ratio and 95% CI values for metabolic syndrome components according to noodle consumption by sex

	Noodle consumption				p-trend
	Quartile 1	Quartile 2	Quartile 3	Quartile 4	
Men					
Metabolic syndrome					
No.of cases/subjects	197/1046	216/1042	210/1067	220/1012	
Median intake, servings/week	0.6	1.5	3.0	5.0	
Model 1†	1.00	1.21 (0.94-1.54)	1.29 (1.02-1.65)	1.75 (1.34-2.29)	< 0.001
Model 2‡	1.00	1.09 (0.83-1.44)	1.10 (0.82-1.47)	1.64 (1.18-2.29)	0.004
Abdominal obesity					
Model 1†	1.00	1.16 (0.93-1.46)	1.26 (1.00-1.59)	1.18 (0.92-1.50)	0.246
Model 2‡	1.00	1.19 (0.81-1.74)	1.32 (0.90-1.92)	1.25 (0.83-1.89)	0.308
Low HDL cholesterol					
Model 1†	1.00	1.14 (0.89-1.47)	1.06 (0.84-1.35)	1.01 (0.78-1.30)	0.726
Model 2‡	1.00	1.11 (0.85-1.44)	1.07 (0.83-1.39)	1.06 (0.78-1.42)	0.881
Hypertriglyceridemia					
Model 1†	1.00	1.35 (1.11-1.66)	1.43 (1.18-1.74)	1.77 (1.43-2.19)	< 0.001
Model 2‡	1.00	1.28 (1.04-1.59)	1.31 (1.06-1.62)	1.70 (1.34-2.17)	< 0.001
Hyperglycemia					
Model 1†	1.00	1.23 (0.99-1.53)	1.03 (0.83-1.29)	1.32 (1.04-1.69)	0.104
Model 2‡	1.00	1.13 (0.90-1.42)	0.87 (0.68-1.11)	1.04 (0.78-1.38)	0.742
Elevated blood pressure					
Model 1†	1.00	1.09 (0.88-1.34)	1.18 (0.94-1.47)	1.36 (1.09-1.71)	0.006
Model 2‡	1.00	1.00 (0.80-1.24)	1.00 (0.79-1.27)	1.18 (0.91-1.53)	0.201
Women					
Metabolic syndrome					
No.of cases/subjects	209/1463	221/1671	201/1624	177/1580	
Median intake, servings/week	0.2	0.8	1.6	3.8	
Model 1†	1.00	1.16 (0.90-1.50)	1.43 (1.10-1.87)	1.72 (1.31-2.27)	< 0.001
Model 2‡	1.00	1.21 (0.90-1.63)	1.41 (1.02-1.94)	1.63 (1.17-2.27)	0.005
Abdominal obesity					
Model 1†	1.00	1.07 (0.89-1.28)	1.29 (1.06-1.56)	1.41 (1.15-1.71)	< 0.001
Model 2‡	1.00	1.15 (0.88-1.51)	1.22 (0.91-1.62)	1.29 (0.94-1.78)	0.188
Low HDL cholesterol					
Model 1†	1.00	1.04 (0.88-1.24)	1.10 (0.92-1.31)	1.01 (0.83-1.22)	0.819
Model 2‡	1.00	1.09 (0.91-1.31)	1.09 (0.91-1.32)	1.02 (0.83-1.24)	0.738
Hypertriglyceridemia					
Model 1†	1.00	1.15 (0.92-1.44)	1.05 (0.82-1.36)	1.47 (1.16-1.88)	0.002
Model 2‡	1.00	1.16 (0.91-1.47)	1.02 (0.78-1.33)	1.33 (1.02-1.74)	0.044
Hyperglycemia					
Model 1†	1.00	1.36 (1.08-1.72)	1.54 (1.21-1.96)	1.43 (1.10-1.85)	0.040
Model 2‡	1.00	1.36 (1.06-1.74)	1.50 (1.15-1.94)	1.29 (0.97-1.71)	0.368
Elevated blood pressure					
Model 1†	1.00	1.24 (0.97-1.57)	1.36 (1.05-1.76)	1.53 (1.17-1.99)	0.004
Model 2‡	1.00	1.26 (0.98-1.61)	1.37 (1.05-1.79)	1.50 (1.12-2.02)	0.020

HDL, high density lipoprotein
†Model 1 was adjusted for age.
‡Model 2 was adjusted for age, household income, education, smoking, alcohol, total energy intake, survey year, physical activity, BMI.

consumption was 33% higher (OR for Q4 vs Q1, 1.33; 95% CI, 1.04-1.69) than the first quartile. Regarding for metabolic syndrome components, instant ramen consumption was positively associated with abdominal obesity (OR for Q4 vs Q1, 1.30; 95% CI, 1.01-1.68), hypertriglyceridemia (OR for Q4 vs Q1, 1.29, 95% CI, 1.08-1.53; *p*-trend = 0.007), and elevated blood pressure (OR for Q4 vs Q1, 1.23; 95% CI, 1.01-1.51; *p*-trend = 0.046). People in the fourth quartile for consumption of gugsu/ kalgugsu/ udong had 41% higher odds of having metabolic syndrome (OR for Q4 vs Q1, 1.41; 95% CI, 1.14-1.74; *p*-trend = 0.004) and 31% higher odds of having hypertriglyceridemia (OR for Q4 vs Q1, 1.31; 95% CI, 1.11-1.54; *p*-trend < 0.001) than those in the first quartile. The OR for the fourth quartile for consumption of jjajangmyeon/ jjamppong was 1.25 (95% CI, 1.02-1.52; *p*-trend= 0.024) for metabolic syndrome, 1.19 (95% CI, 1.03-1.37; *p*-trend= 0.026) for low HDL cholesterol, and 1.23 (95% CI, 1.04-1.44; *p*-trend= 0.017) for hyperglycemia, respectively.

DISCUSSION

The present study from the KNHANES 2012-2016 data suggested that noodle intake was positively related to metabolic syndrome. People with the highest noodle consumption had 48% higher odds for metabolic syndrome than those with the lowest noodle consumption after controlling for potential confounders. The higher odds for metabolic syndrome by increasing noodle consumption were also observed when we analyzed by sex. Among the metabolic syndrome components, hypertriglyceridemia was related to high noodle intake both in males and in

Table 4. Multivariable adjusted odds ratio and 95% CI values for metabolic syndrome components according to noodle consumption by the type of noodle

	Noodle consumption				*p*-trend
	Quartile 1	Quartile 2	Quartile 3	Quartile 4	
Instant ramen					
Metabolic syndrome					
Model 1†	1.00	1.38 (1.15-1.65)	1.24 (1.02-1.50)	1.56 (1.27-1.93)	< 0.001
Model 2‡	1.00	1.32 (1.08-1.61)	1.15 (0.93-1.44)	1.33 (1.04-1.69)	0.092
Abdominal obesity					
Model 1†	1.00	1.19 (1.03-1.36)	1.21 (1.05-1.40)	1.37 (1.16-1.61)	< 0.001
Model 2‡	1.00	1.15 (0.92-1.43)	1.21 (0.95-1.54)	1.30 (1.01-1.68)	0.081
Low HDL cholesterol					
Model 1†	1.00	1.09 (0.94-1.25)	1.03 (0.89-1.19)	0.92 (0.78-1.07)	0.094
Model 2‡	1.00	1.07 (0.92-1.24)	1.01 (0.87-1.18)	0.87 (0.73-1.03)	0.033
Hypertriglyceridemia					
Model 1†	1.00	1.15 (0.98-1.36)	1.27 (1.08-1.50)	1.49 (1.26-1.77)	< 0.001
Model 2‡	1.00	1.05 (0.88-1.24)	1.17 (0.99-1.39)	1.29 (1.08-1.53)	0.007
Hyperglycemia					
Model 1†	1.00	1.38 (1.18-1.62)	1.22 (1.03-1.44)	1.37 (1.14-1.64)	0.018
Model 2‡	1.00	1.31 (1.11-1.54)	1.15 (0.97-1.37)	1.16 (0.95-1.41)	0.611
Elevated blood pressure					
Model 1†	1.00	1.18 (0.98-1.41)	1.13 (0.95-1.35)	1.38 (1.15-1.66)	< 0.001
Model 2‡	1.00	1.12 (0.93-1.36)	1.05 (0.87-1.27)	1.23 (1.01-1.51)	0.046
Gugsu, kalgugsu and udong					
Metabolic syndrome					
Model 1†	1.00	1.00 (0.83-1.20)	1.04 (0.88-1.23)	1.23 (1.03-1.46)	0.017
Model 2‡	1.00	1.22 (0.99-1.49)	1.18 (0.96-1.45)	1.41 (1.14-1.74)	0.004
Abdominal obesity					
Model 1†	1.00	0.87 (0.75-1.01)	0.89 (0.77-1.02)	0.91 (0.79-1.05)	0.275
Model 2‡	1.00	1.06 (0.85-1.33)	1.07 (0.86-1.33)	1.07 (0.85-1.33)	0.578
Low HDL cholesterol					
Model 1†	1.00	1.00 (0.88-1.15)	0.97 (0.85-1.11)	0.98 (0.84-1.13)	0.654
Model 2‡	1.00	1.10 (0.95-1.27)	1.06 (0.92-1.22)	1.10 (0.94-1.29)	0.325
Hypertriglyceridemia					
Model 1†	1.00	0.94 (0.80-1.09)	1.06 (0.91-1.23)	1.19 (1.02-1.38)	0.008
Model 2‡	1.00	1.04 (0.88-1.22)	1.16 (0.98-1.37)	1.31 (1.11-1.54)	< 0.001
Hyperglycemia					
Model 1†	1.00	1.00 (0.84-1.18)	1.12 (0.96-1.30)	1.00 (0.84-1.18)	0.706
Model 2‡	1.00	1.07 (0.91-1.27)	1.15 (0.99-1.35)	0.98 (0.81-1.18)	0.995
Elevated blood pressure					
Model 1†	1.00	0.92 (0.77-1.10)	0.99 (0.84-1.16)	1.03 (0.88-1.21)	0.509
Model 2‡	1.00	0.98 (0.82-1.17)	1.02 (0.87-1.21)	1.03 (0.86-1.22)	0.674
Jjajangmyeon and jjamppong					
Metabolic syndrome					
Model 1†	1.00	0.78 (0.46-1.33)	1.05 (0.89-1.24)	1.38 (1.17-1.63)	< 0.001
Model 2‡	1.00	1.17 (0.70-1.97)	1.05 (0.86-1.27)	1.25 (1.02-1.52)	0.024
Abdominal obesity					
Model 1†	1.00	0.66 (0.47-0.94)	1.02 (0.90-1.16)	1.17 (1.03-1.33)	0.009
Model 2‡	1.00	0.93 (0.57-1.51)	1.07 (0.86-1.32)	1.10 (0.88-1.38)	0.394
Low HDL cholesterol					
Model 1†	1.00	0.94 (0.70-1.27)	1.10 (0.97-1.24)	1.14 (1.00-1.31)	0.057
Model 2‡	1.00	1.12 (0.82-1.52)	1.14 (1.00-1.30)	1.19 (1.03-1.37)	0.026
Hypertriglyceridemia					
Model 1†	1.00	1.16 (0.73-1.83)	0.98 (0.85-1.12)	1.18 (1.02-1.37)	0.011
Model 2‡	1.00	1.38 (0.91-2.10)	0.95 (0.82-1.10)	1.06 (0.91-1.25)	0.363
Hyperglycemia					
Model 1†	1.00	0.94 (0.61-1.44)	1.14 (0.98-1.31)	1.36 (1.18-1.58)	< 0.001
Model 2‡	1.00	1.08 (0.70-1.67)	1.11 (0.96-1.30)	1.23 (1.04-1.44)	0.017
Elevated blood pressure					
Model 1†	1.00	0.66 (0.40-1.08)	0.85 (0.73-1.00)	1.03 (0.88-1.21)	0.370
Model 2‡	1.00	0.77 (0.46-1.27)	0.85 (0.72-1.00)	0.93 (0.78-1.11)	0.664

HDL, high density lipoprotein

†Model 1 was adjusted for age and sex

‡Model 2 was adjusted for age, sex, household income, education, smoking, alcohol, total energy intake, survey year, physical activity, BMI.

females. Elevated blood pressure was positively related to high noodle consumption in females. When we analyzed by type of noodles, the positive relation between noodle consumption and metabolic syndrome was also found.

A study from the KNHANES 2007-2009 data suggested that women who consumed instant ramen more than twice a week had a 68% increased prevalence of metabolic syndrome than those who hardly consumed instant ramen.[21] A study targeting 3,397 university students reported that people with an intake of instant ramen more than three times a week had higher odds of hypertriglyceridemia than those with an intake of under once a month and diastolic blood pressure was also higher among female students who frequently consumed instant ramen.[22] These results were consistent with the present study's findings, which showed that with increased noodle consumption, blood pressure increased in women, and the prevalence of hypertriglyceridemia raised in men and women. There are few prior studies on the intake of noodles and the metabolic syndrome, but several studies have been conducted on carbohydrates that are high in noodles. In a sixteen-week clinical trial, dietary carbohydrate restriction improved metabolic parameters, resulting in increased fat oxidation and improved abnormal fatty acid composition.[23] In a study of 1,173 older people with diabetes, triglyceride levels increased as the proportion of carbohydrates increased in energy intake.[24] Noodles correspond to refined carbohydrates, and there have been several studies on refined carbohydrates and metabolic syndrome. The Korean cohort study, including 5,717 subjects, found that people with high refined grain consumption had a 63% raised risk of metabolic syndrome than those with low refined grain intake.[25] A study on the urban population of Tehran showed that high refined-grain consumption was related to 2.25 times increased odds of having metabolic syndrome compared to low intake, and a positive association was shown between noodle intake and metabolic syndrome components in relation to plasma triglyceride levels and blood pressure.[26] A meta-analysis, including thirteen observational studies, indicated that high refined grain intake was related to a 37% raised risk of metabolic syndrome.[27]

Several potential mechanisms can be considered in connection with the findings of this study, which suggested a positive association between noodle intake and metabolic syndrome. Noodles mainly consist of refined white wheat flour, and white wheat flour is almost free of dietary fiber and various essential micronutrients, including minerals and vitamins, as they are removed during the processing.[28, 29] Unlike whole grains which have a low glycemic index due to their slow digestion and absorption due to their physical shape and high viscosity of dietary fiber, refined carbohydrates are processed into smaller particles, and have a high glycemic index.[30, 31] Foods with a higher glycemic index raise postprandial glucose levels faster compared to foods with a lower glycemic index, which leads to higher insulin requirements in the long run.[32, 33] The glycemic load is estimated by multiplying the glycemic index by the total quantity of carbohydrates eaten. In previous observational studies, high dietary glycemic index and load were related to an increase in fasting blood sugar, fasting triacylglycerol concentrations, and BMI, and a decrease in HDL cholesterol.[34, 35] Noodles contain a large amount of sodium and are usually eaten with broth or sauce that contains salt. Thus, sodium may also affect the risk of metabolic syndrome. In fact, published data of the KNHANES 2013 to 2017, noodles ranked first among the foods that contributed to the high sodium consumption of Koreans with dumplings.[36] The meta-analysis of seventeen epidemiological studies, including 66,274 subjects, indicated that people with the highest levels of dietary or serum/urinary sodium had 37% increased odds of having metabolic syndrome than those with the lowest sodium levels.[37] Sodium consumption was positively associated with a risk of obesity,[38] and insulin resistance caused by obesity is the primary etiology of metabolic syndrome.[39]

In this present study, noodles were positively associated with metabolic syndrome in all types examined, despite differences in cooking styles, how they were eaten, and side dishes depending on the type. Therefore, when interpreting the observed positive associations between noodle consumption and metabolic syndrome, we focused on what the noodles examined in this study had in common: they were refined carbohydrates and were generally served in a broth that contained sodium. However, the impact on metabolic syndrome may vary depending on the cooking styles, how they were eaten, and the type of side dishes eaten together. Therefore, future research on the association between noodle consumption and metabolic syndrome will likely need to segment the types of noodles further and consider various factors related to noodle consumption.

Since the present study analyzed the data of the KNHANES, which is reliable and representative at the national scale, it can be used as baseline data on the association between noodle consumption and metabolic syndrome in Korean adults. No studies to date have used data of the KNHANES to explore the association between the intake of various types of noodles (i.e., gugsu, kalgugsu, udong, jjajangmyeon, jjamppong, and instant ramen) and metabolic syndrome and its components. Therefore, the findings of the present study may be helpful in hypothesizing future studies. Despite this usefulness, the current study has some limitations to consider. Firstly, the KNHANES is a cross-sectional study that does not consider temporal relationships, making it difficult to conclude the causal relationship between noodle intake and metabolic syndrome. However, the current study excluded all participants who were diagnosed with cancer, stroke, hypertension, dyslipidemia, myocardial infarction, or diabetes or who were dosing medication to cure dyslipidemia, hypertension, or diabetes when selecting subjects to minimize reverse causation bias. Secondly, the FFQ used in the current study to investigate dietary intake is a self-administered survey, so there is a possibility of misclassifying dietary intake. Still, such misclassification has the potential to leading the results to null (irrelevant). Therefore, there is little concern that the results will be exaggerated. Thirdly, although this study tried to control for confounding factors as much as possible to minimize confounding factors, we cannot be sure that there are no remaining confounders. Lastly, we could only analyze the type of noodles provided by the FFQ, not all types of noodles. In addition, we were able to only analyze by noodle type, which was classified into categories and groups provided by the FFQ.

In conclusion, high noodle consumption was positively related to the metabolic syndrome in Korean adults. A positive association between noodle intake and metabolic syndrome was observed regardless of the type of noodles. It is believed that clinical trials and well-designed prospective cohort studies targeting large populations should be conducted to identify a more accurate causal relationship between noodle consumption and metabolic syndrome.

CONFLICT OF INTEREST AND FUNDING DISCLOSURES

The authors declare no conflict of interest.

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