J Nutr Health. 2022 Apr;55(2):309-320
https://doi.org/10.4163/jnh.2022.55.2.309
eISSN 2288-3959

JNH
Journal of Nutrition and Health

Research Article

Check for updates

Frequency of steamed food consumption and risk of metabolic syndrome in Korean females: data from Korean Genome and Epidemiology Study

Young-Ran Heo [1] **and Jeong-Hwa Choi** [2]

[1]Division of Food and Nutrition, Research Institute for Human Ecology, Chonnam National University, Gwangju 61186, Korea
[2]Department of Food Science and Nutrition, Keimyung University, Daegu 42601, Korea

Received: Sep 17, 2021
Revised: Jan 25, 2022
Accepted: Mar 8, 2022
Published online: Apr 7, 2022

Correspondence to
Jeong-Hwa Choi
Department of Food Science and Nutrition, Keimyung University, 1095 Dalgubeol-daero, Dalseo-gu, Daegu 42601, Korea.
Email: jhchoi@kmu.ac.kr

ORCID iDs
Young-Ran Heo
https://orcid.org/0000-0001-5476-3714
Jeong-Hwa Choi
https://orcid.org/0000-0003-4730-6544

Funding
This study was conducted with bioresources from the National Biobank of Korea, the Centers for Disease Control and Prevention, Republic of Korea (KBN-2018-018). This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korean Government (MSIT) (No. NRF-2018R1A1A1A05019155, 2021R1A2C1008635).

ABSTRACT

Purpose: This study aimed to investigate the association between steamed food intake and risk of metabolic syndrome (MetS) in Korean females.
Methods: Using Ansan/Ansung data of Korean Genome and Epidemiology Study, general characteristics, nutritional intake and biochemical and anthropometric markers of a total of 4,056 females aged 40 to 69 years were analyzed. MetS was defined following National Cholesterol Education Program Adult Treatment Panel III with some minor modifications. Logistic regression models were established to present the association between steamed food intake and the risk of MetS. Levels of food and nutrient intake by the frequency of steamed food intake and MetS phenotype were analyzed using general linear models.
Results: A total of 38.4% of females had MetS. Among them, 24.9% of females with MetS had steamed food more than 1-3 times per week, which reduced the risk for MetS by about 25% (95% confidence interval [CI], 0.650-0.865). However, such association was not evident when various lifestyle factors were considered in statistical models. In rural residents, the benefit of having more steamed food was observed (adjusted odds ratio: 0.747; 95% CI, 0.583-0.958). The frequency of steamed food intake was associated with various food and nutritional intakes. However, trends in those did not differ by MetS phenotype.
Conclusion: Having steamed food more than 1-3 times per week may reduce the risk of MetS compared to those who had less steamed food in Korean females. This protective effect of steamed food intake may differ by lifestyle and environmental factors. Although a clear difference in food and nutritional intake was not observed in this study, steaming could be an effective cooking method for a healthy diet for disease prevention and management.

Keywords: dietary intake; food; Korean female; metabolic syndrome; steam

INTRODUCTION

Metabolic syndrome (MetS) is considered the pre-stage of a variety of chronic metabolic diseases. Earlier studies have demonstrated that having MetS is associated with a higher risk for type 2 diabetes mellitus [1,2], hypertension, vascular diseases [3-5], and certain types of

Conflict of Interest
There are no financial or other issues that might lead to conflict of interest.

cancer [6,7]. A variety of biological and milieu factors are associated with the risk of MetS. Dietary intake is known to contribute to its development and/or the risk [8-10]. Although inconsistencies exist, excess consumption of carbohydrate (refined or simple sugar), fat, and sodium is known to increase the risk for MetS [11,12]. This could support the idea that proper intake for those nutrients is decisive in the prevention and treatment of various diseases. In line with this, changes in cooking method for healthy eating are often applied in nutrition education for public health [13].

Cooking increases the hedonic pleasure of foods. It is also a critical procedure to secure sanitation and digestion. Cooking such as washing, cutting, and heating can lead to physical and/or chemical changes in texture and chemical components of foods. In the Korean culinary culture, fermenting, boiling, blanching, roasting, and seasoning (fresh/cooked vegetables and other foods with condiments) are often used for cooking [14]. Steaming, a type of cooking using hot vapour from a boiling water, is also used in Korean cooking. Compared to deep-frying and roasting, steaming may reduce the intake of fat, and better intake for other nutritional compounds. Although studies investigating associations of food prepared with different cooking methods with nutrition consumption and health outcomes are limited, earlier experimental studies have suggested that steaming is a more effective method for retaining beneficial compounds than other cooking methods [15]. A meta-analysis has also reported that steaming can increase the activity of antioxidants [16]. Deep fat frying technique can increase the intake of energy, trans fatty acids [17], and potential toxicants that are mutagenic and carcinogenic by-products from thermal processing [18]. Considering these findings, steaming is recommended for a healthy diet in the prevention and management of diseases such as MetS. However, evidences that support the association between steamed food intake and MetS are lacking.

Thus, the aim of this study was to determine the association between the frequency of steamed food consumption and the risk of MetS using data of Korean Genome and Epidemiology Study (KoGES). Additional analyses were also performed to determine food and nutritional intake, taking steamed food intake and MetS phenotype into account. Because sex-disparities exist in the aetiology of MetS, it is required to examine the role of dietary behaviour with sex-stratified approach [19,20]. Furthermore, women's diets are a significant independent risk factor for metabolic disease [21]. Therefore, this study mainly focused on dietary habits of Korean females. Results of this study could provide primary evidence about the association between dietary intervention (cooking method) and metabolic diseases.

METHODS

Description of study cohort

This study was performed with data of the KoGES project. For this study, a cross sectional design was applied using baseline Ansan/Ansung study of KoGES. Details of cohort description and data collection were described elsewhere [22,23]. Data were collected from 2001 to 2002. Among 4,658 females aged 40 to 69 years, 4,056 were finally included in this study. Subjects were excluded due to the following reasons: No data for diagnosis of MetS (n = 155), lifestyle factors (n = 270), dietary data (n = 109), implausible calorie intake (n = 42), and frequency for steamed food intake (n = 26). The study protocol of KoGES was approved by Institutional Review Board (IRB) of the Korea Centers for Disease Control and Prevention.

This study was performed after obtaining approval from the IRB (40525-201802-HR-121-07) of Keimyung University, Korea.

Data collection for general characteristics, anthropometrics, and biochemistry

Descriptive information (age, residential area, alcohol consumption, tobacco smoking, marital (cohabitation) type, education level, physical activity level and taking of any diabetes or hypertension treatments) were collected using self-administrated questionnaires. Tobacco smoking and alcohol drinking behaviour had 3 groups: never, past, and current. The 4 groups were also used to determine the degree of subjects' education, and household income. Metabolic equivalent of task was used to estimate the physical movement of participants. Anthropometric information—height, weight, and waist circumference— was also collected and used to compute the body mass index (BMI, calculated as weight in kilograms is divided by height in meters squared). Trained technicians measured systolic blood pressure and diastolic blood pressure using a conventional mercury sphygmomanometer (Baumanometer®; Baum, Copiague, NY, USA). For biochemical analyses, blood sample were collected by venepuncture from subjects after fasting for a minimum of 12 hours. Blood glucose, serum triglyceride (TG), and high-density lipoprotein (HDL) cholesterol were estimated using an enzymatic analysis technique (Hitachi 747 chemistry analyser; Hitachi, Tokyo, Japan).

Diagnosis for MetS

For the present study, diagnostic guidelines for National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) were employed with modification [9,24]. To define abdominal obesity, Asia-Pacific guidelines were applied. Finally, subjects were defined as having MetS when they met 3 or more criteria listed below:

- Blood pressure was equal to or higher than 130/85 mmHg, for systolic and diastolic blood pressures, respectively, or taking any hypertensive medicine.
- Fasting blood glucose was equal to or higher than 110 mg/dL, using insulin injection, or taking oral diabetes medicine.
- TG was equal to or higher than 150 mg/dL.
- HDL cholesterol was lower than 50 mg/dL.
- Subject's waist circumference was equal to or higher than 80 cm.

Data collection for dietary and steamed food intake information

Dietary intake was investigated using a semi-quantitative food questionnaire (semi-FFQ). A total of 103 types of foods were displayed in the semi-FFQ and investigated with 7 levels of frequency of intake ("almost never," "once a month," "2–3 times a month," "1–2 times a week," "3–4 times a week," "once a day," "twice a day," and "3 times a day") and 3 levels of average size for consumption ("small," "medium," and "large") for last year [25]. The investigated 103 foods were grouped into 16 according to their characteristics for food intake analyses in this study. Dietary intake for macro- and selected nutrients were computed with the database of the Korean Nutrition Society [26]. The frequency of steamed food intake was also defined with following question: How often do you consume the food cooked using steaming? "everyday", "4–6 times a week", "1-3 times a week", "1-2 times a month" and "almost never". To avoid the rarity issue and better statistical power, answers were then re-grouped into 2 levels: more than 1–3 times a week and less than 1–2 times a month.

Statistical analyses

To understand general characteristics of study subjects, Student's t-tests and χ^2 tests were conducted taking types of variables in account. The association between frequency of steamed food intake and MetS was analysed using logistic regression analyses with the absence (crude) or presence (adjusted) of covariates. Findings are presented as odds ratios (ORs) and 95% confidence intervals (CIs). Comparisons for food and nutritional intake between steamed food intake groups were made using 2 general linear models (crude and adjusted models with covariates). Two-sided p-value less than 0.05 was accepted for statistically significant. All statistical analyses were performed using SAS package version 9.4 (SAS Institute, Inc., Cary, NC, USA).

RESULTS

General characteristics of subjects

General characteristics of study population are described in **Table 1**. The prevalence of MetS was 38.4%. Females with MetS were more likely to be older ($p < 0.0001$) with higher BMI ($p < 0.0001$). Those with MetS were also more likely to live in a rural area ($p < 0.0001$), and to have less schooling years ($p < 0.0001$). In the MetS cases, ratio for individuals without partner/spouse was higher than controls ($p < 0.0001$). In the case of alcohol drinking behaviour, subjects with MetS showed higher ratio for never drinkers but lower ratio for current drinkers ($p < 0.0001$) compared to those without MetS. However, the smoking

Table 1. Descriptive data for study population taking account of MetS phenotype

Characteristics	MetS (−)	MetS (+)	p[1)]
Number of subjects	2,499 (61.6)	1,557 (38.4)	
Age (yrs)	49.87 ± 8.4	56.12 ± 8.5	< 0.0001
BMI (kg/m²)	23.85 ± 2.9	26.6 ± 3.0	< 0.0001
Area			< 0.0001
Rural	939 (37.6)	960 (61.7)	
Urban	1,560 (62.4)	597 (38.3)	
Cohabitation status			< 0.0001
With partner/spouse	2,195 (87.8)	1,264 (81.2)	
Single	304 (12.2)	293 (18.8)	
Education			< 0.0001
Elementary graduate/less	823 (32.9)	931 (59.8)	
Middle graduate	628 (25.1)	322 (20.7)	
High graduate	843 (33.7)	253 (16.3)	
College graduate/more	205 (8.2)	51 (3.3)	
Alcohol drinking			< 0.0001
Never	1,701 (68.1)	1,176 (75.5)	
Past	57 (2.3)	67 (4.3)	
Current	741 (29.6)	314 (20.2)	
Tobacco smoking			0.0728
Never	2,393 (95.8)	1,467 (94.2)	
Past	27 (1.1)	26 (1.7)	
Current	79 (3.1)	64 (4.1)	
Household income (10,000 won/mon)			< 0.0001
< 100	779 (31.2)	846 (54.3)	
100–199	764 (30.6)	384 (24.7)	
200–399	776 (31.1)	263 (16.9)	
≥ 400	180 (7.2)	64 (4.1)	
MET (hrs)	21.72 ± 13.4	23.85 ± 15.2	0.0334

Values presented as mean ± SD for age and BMI, otherwise number with percent of subjects.
MetS, metabolic syndrome; BMI, body mass index; MET, metabolic equivalent.
1)The p-values are from Students t-tests for age and MET, otherwise from χ^2 tests by MetS phenotype.

https://doi.org/10.4163/jnh.2022.55.2.309

Table 2. The association between the frequency of steamed food consumption and the risk of MetS

Subjects	All	MetS (−)	MetS (+)	OR_{crude} (95% CI)[1)]	$OR_{adjusted}$ (95% CI)[2)]	p[3)]
Less than 1–2 times/mon	2,904 (71.6)	1,734 (69.4)	1,170 (75.1)	Reference	Reference	
More than 1–3 times/wks	1,152 (28.4)	765 (30.6)	387 (24.9)	0.750 (0.650–0.865)	0.904 (0.760–1.074)	0.2505

Values are presented as number of subjects with percent.
MetS, metabolic syndrome; OR, odds ratio; CI, confidence interval.
1)ORs from crude logistic regression analyses. 2)ORs from adjusted logistic regressions models with age, body mass index, residential area, education level, cohabitation status, household income, alcohol drinking and tobacco smoking, metabolic equivalent, and total energy intake. 3)The p-value for adjusted model.

Table 3. The association between the frequency of steamed food consumption and the risk of MetS by residential area

Subjects	MetS (−)	MetS (+)	OR_{crude} (95% CI)[1)]	$OR_{adjusted}$ (95% CI)[2)]	p[3)]
Rural	939 (49.4)	960 (50.6)			
Less than 1–2 times/mon	692 (73.7)	768 (80.0)	Reference	Reference	
More than 1–3 times/wks	247 (26.3)	192 (20.0)	0.700 (0.565–0.868)	0.747 (0.583–0.958)	0.0214
Urban	1,560 (72.3)	597 (27.7)			
Less than 1–2 times/mon	1,042 (66.8)	402 (67.3)	Reference	Reference	
More than 1–3 times/wks	518 (33.2)	195 (32.7)	0.976 (0.798–1.193)	1.106 (0.868–1.409)	0.4144

Values are presented as number of subjects with percent.
MetS, metabolic syndrome; OR, odds ratio; CI, confidence interval.
1)ORs from crude logistic regression analyses. 2)ORs from adjusted logistic regressions models with age, body mass index, residential area, education level, cohabitation status, household income, alcohol drinking and tobacco smoking, metabolic equivalent, and total energy intake. 3)The p-values for adjusted models.

behaviour was not different by MetS phenotype. MetS cases were more likely at the lower household economic status ($p < 0.0001$). Levels of physical activity for MetS cases were putatively higher compared to normal ($p < 0.0334$).

Association between steamed food consumption and MetS

Table 2 presents steamed food intake behaviour and its association with risk for MetS. In the entire study population, 28.4% of subjects had steamed food more than 1–3 times per week. The ratio for individuals had steamed food for more than 1–3 times per week was higher in normal subjects (30.6%) than in those with MetS (24.9%). Such differential distribution of steamed food intake frequency modified the risk for MetS. Having steamed food more than 1–3 times per week reduced the risk for MetS (OR_{crude}, 0.750; 95% CI, 0.650–0.865). However, the lower likelihood for MetS became moderate when subjects' various lifestyle covariates (age, BMI, residential area, education and household income level, cohabitation status, alcohol drinking and tobacco smoking, metabolic equivalent, and total energy intake) were considered in the statistical model ($OR_{adjusted}$, 0.904; 95% CI, 0.760–1.074). It was interesting to note that the prevalence of MetS significantly differed by the residential area. In line with this, additional analyses taking individuals' living place in account. Findings suggested that the protective effect of having more steamed food was clearly evident in rural residences (**Table 3**). When all covariates were considered, having steamed food more than 1–3 times a week significantly reduced the risk for MetS approximately 25% (95% CI, 0.583–0.958).

Food and nutritional intake and steamed food consumption and MetS

Tables 4 and **5** show difference in food and nutritional intake by MetS phenotype and frequency of steamed food intake. Statistical analyses revealed that dietary intake was mainly associated with the frequency of steamed food intake. It was not associated with the presence of MetS (**Table 4**). In subjects with or without MetS, individuals who had steamed food less than 1–2 times per month had more grains that those who had steamed food more than 1–3 times per week (for those without and with MetS, $p_{adjusted} = 0.0008$ and $p_{adjusted} < 0.0001$, respectively). However, subjects with preference of having steamed food showed larger amounts of food high in protein (for beans, without MetS, $p_{adjusted} < 0.0001$ and with MetS, $p_{adjusted} = 0.0031$; for meats, without MetS, $p_{adjusted} < 0.0001$ and with MetS, $p_{adjusted} = 0.0138$;

Table 4. Food intake of study participants according to the frequency of steamed food intake and MetS phenotype (g/day)

Variables	Less than 1–2 times/mon	More than 1–3 times/wks	p_{crude} 1)	$p_{adjusted}$ 2)
MetS (−)				
Grains	650.5 ± 171.2	611.1 ± 150.0	< 0.0001	0.0008
Noodles & bread	74.07 ± 66.3	87.14 ± 64.5	< 0.0001	0.0021
Potato and others	22.2 ± 26.6	24.9 ± 29.3	< 0.0001	0.0161
Bean and others	36.8 ± 39.6	42.0 ± 38.7	< 0.0001	< 0.0001
Vegetables	280.4 ± 158.9	287.7 ± 143.9	0.0218	0.0296
White	221.8 ± 137.9	222.7 ± 126.1	0.2167	0.1124
Green	24.5 ± 23.3	27.2 ± 22.9	0.0003	0.0678
Mushrooms	8.1 ± 12.5	9.9 ± 10.6	< 0.0001	0.0009
Fruits	298.4 ± 276.4	286.8 ± 261.8	0.2402	0.9572
Meats	42.0 ± 36.7	54.4 ± 39.9	< 0.0001	< 0.0001
Eggs and others	11.8 ± 13.9	14.2 ± 14.1	< 0.0001	< 0.0001
Seafoods	34.7 ± 31.8	43.36 ± 27.2	< 0.0001	< 0.0001
Seeds	2.0 ± 2.0	2.3 ± 1.7	< 0.0001	< 0.0001
Dairy	123.7 ± 129.6	130.3 ± 132.2	0.0042	0.4601
Green tea	38.6 ± 87.1	48.42 ± 100.3	< 0.0001	0.0093
Coffee	2.6 ± 2.9	2.63 ± 3.1	0.6847	0.5701
MetS (+)				
Grains	707.9 ± 172.6	640.7 ± 164.1	< 0.0001	< 0.0001
Noodles & Bread	61.63 ± 67.9	84.58 ± 81.9	< 0.0001	0.0003
Potato and others	21.3 ± 28.4	24 ± 31.4	< 0.0001	0.0026
Bean and others	38.9 ± 42.6	42.8 ± 35.2	< 0.0001	0.0031
Vegetables	292.9 ± 167.8	309.7 ± 182.2	0.0002	0.0732
White	236.9 ± 151.7	247.2 ± 163.4	0.1164	0.1909
Green	24.2 ± 26.5	25.4 ± 19.6	< 0.0001	0.0099
Mushrooms	5.5 ± 9.0	9.0 ± 12.2	0.0089	< 0.0001
Fruits	314.7 ± 303.3	322.6 ± 277.6	< 0.0001	0.0507
Meats	34 ± 35.1	47.4 ± 43.6	< 0.0001	0.0138
Eggs and others	10.4 ± 16.6	13.3 ± 18.5	< 0.0001	0.0002
Seafoods	28.9 ± 30.1	38.1 ± 27.9	< 0.0001	0.0280
Seaweeds	2.0 ± 2.2	2.2 ± 2.2	< 0.0001	0.0071
Dairy	95.3 ± 128.0	118.8 ± 118.9	0.4344	0.0015
Green tea	28.9 ± 72.7	39.54 ± 83.2	< 0.0001	0.0388
Coffee	2.0 ± 2.7	2.43 ± 2.9	< 0.0001	0.2199

Values presented as means ± SD.
MetS, metabolic syndrome.
1)The p-values were from crude general linear models by frequency of steamed food intake levels. 2)The p-values were from statistical models adjusted with age, body mass index, residential area, education level, cohabitation status, household income, alcohol drinking and tobacco smoking, metabolic equivalent, and total energy intake as appropriate.

for eggs, without MetS, $p_{adjusted} < 0.0001$ and with MetS, $p_{adjusted} = 0.0002$; and for seafoods, without MetS, $p_{adjusted} < 0.0001$ and with MetS, $p_{adjusted} = 0.0280$). The intake of vegetables and fruits was not significantly different between subjects grouped by the frequency of steamed food intake. The consumption of few groups of food including green vegetable and dairy differed by MetS phenotype and frequency of steamed food intake (for green vegetables, with MetS, $p_{adjusted} = 0.0099$; for dairy, with MetS, $p_{adjusted} = 0.0015$).

Table 5 shows the consumption of selected nutrients in study subjects taking frequency of steamed food intake and MetS phenotype into account. The similar trend evident in dietary intake (differential level of dietary intake was mainly associated by level of steamed food consumption) was also in nutritional consumption. In subject with or without MetS, levels of nutritional intake were generally higher in subjects having steamed food intake for more than 1–3 times per week. These subjects had significantly higher intake for total energy, protein, fat, cholesterol (all $p_{adjusted} < 0.0001$), and potassium (for without and with MetS, $p_{adjusted} = 0.0059$ and $p_{adjusted} = 0.0003$, respectively). However, intake for carbohydrate was significantly higher in subjects who had steamed foods for less than 1-2 times per month (all

Table 5. Nutrient intake of study participants according to the frequency of steamed food intake and metabolic syndrome phenotype.

Variables	Less than 1–2 times/mon	More than 1–3 times/wks	p_{crude} [2)]	$p_{adjusted}$ [3)]
MetS (−)[1)]				
Total energy (kcal/day)	1,813.0 ± 597.7	1,994.2 ± 591.3	< 0.0001	< 0.0001
Carbohydrate (g/day)	333.9 ± 30.3	323.9 ± 29.7	< 0.0001	< 0.0001
Protein (g/day)	62.1 ± 10.6	65.8 ± 9.8	< 0.0001	< 0.0001
Fat (g/day)	28.9 ± 11.0	31.8 ± 10.1	< 0.0001	< 0.0001
Cholesterol (mg/day)	164.2 ± 103.5	189.3 ± 95.9	< 0.0001	< 0.0001
Potassium (mg/day)	2,472.7 ± 727.0	2,555.1 ± 644.5	0.0004	0.0059
Sodium (mg/day)	2,970.2 ± 1,312.6	3,011.3 ± 1,095.1	0.0206	0.0244
Sodium/potassium	1.2 ± 0.4	1.2 ± 0.3	0.9548	0.5788
Vitamin C (mg/day)	128.1 ± 73.8	125.8 ± 63.8	0.5095	0.7720
Folate (μg/day)	240.6 ± 85.8	249.7 ± 75.9	0.0003	0.0068
Dietary fibre (g/day)	6.9 ± 2.4	6.9 ± 2.1	0.9946	0.9450
MetS (+)				
Total energy (kcal/day)	1,803.2 ± 632.9	1,986.8 ± 673.8	< 0.0001	< 0.0001
Carbohydrate (g/day)	344.7 ± 30.3	331.9 ± 30.7	< 0.0001	< 0.0001
Protein (g/day)	59.7 ± 11.2	64.2 ± 10.9	< 0.0001	< 0.0001
Fat (g/day)	24.7 ± 10.3	29.1 ± 10.1	< 0.0001	< 0.0001
Cholesterol (mg/day)	139.5 ± 117.5	170.9 ± 110.1	< 0.0001	< 0.0001
Potassium (mg/day)	2,424.4 ± 772.3	2,602.5 ± 761.1	< 0.0001	0.0003
Sodium (mg/day)	3,014.1 ± 1,422.9	3,191.5 ± 1,463.9	0.0100	0.0130
Sodium/potassium	1.3 ± 0.4	1.2 ± 0.4	0.6622	0.8604
Vitamin C (mg/day)	130.9 ± 80.3	135.5 ± 72.9	0.0493	0.0330
Folate (g/day)	239.8 ± 92.6	252.2 ± 92.6	0.0035	0.0168
Dietary fibre (g/day)	7.2 ± 2.5	7.4 ± 2.6	0.2983	0.0719

Values presented as means ± SD.
MetS, Metabolic syndrome.
[1)]The p-values were from crude general linear models by frequency of steamed food intake levels. [2)]The p-values were from statistical models adjusted with age, body mass index, residential area, education level, cohabitation status, household income, alcohol drinking and tobacco smoking, metabolic equivalent, and total energy intake as appropriate.

$p_{adjusted}$ < 0.0001). Sodium (for without and with MetS, $p_{adjusted}$ = 0.0244 and $p_{adjusted}$ = 0.013, respectively) and folate (for without and with MetS, $p_{adjusted}$ = 0.0068 and $p_{adjusted}$ = 0.0168, respectively) intake were marginally different. Sodium/potassium ratio and dietary fibre intake were not different by the frequency of steamed food intake. Vitamin C intake showed differential trend by the phenotype of MetS. In subjects without MetS, vitamin C intake did not differ by the frequency of steamed food intake. However, in those with MetS, the frequency of steamed food intake tended to be associated with a higher intake for vitamin C ($p_{adjusted}$ = 0.0330).

DISCUSSION

The present study analysed whether the frequency for steamed food intake was associated with the risk for MetS in Korean females. Findings suggested that steamed food consumption showed a meaningful association with the development of MetS by individual's environmental factors including residential area.

Food and nutrition intake are decisive factors in health and disease. Excessive intake of sugar and carbohydrate, fat, and sodium could be negatively associated with chronic metabolic diseases [11,12]. For better health management, altering dietary habit including cooking methods such as steaming and/or blanching is recommended. Deep frying or roasting (grilling /broiling) may be associated with negative health outcomes. For instance, although the Maillard reaction by direct exposure to heat increases aromas, flavours, and

https://doi.org/10.4163/jnh.2022.55.2.309

colours, frequent consumption of deep frying may increase the consumption of fat and some intermediate chemical molecules during thermal processing such as acrylamide known to be potential carcinogens [17]. Roasting (grilling) is also a type of cooking method using direct heat treatment. It generates toxicants, including heterocyclic aromatic amines 5-hydroxymethylfufural, furan, etc [18]. By contrast, steamed foods are not in direct contact with cooking media other than water steam. Therefore, steaming may not lead to consumption of extra fat. Furthermore, the indirect exposure to cooking media preserves food tissues which minimises leaching of soluble compounds and degradation of health-beneficial molecules [27]. For these reasons, steaming is a cooking method commonly recommended in nutrition and health initiatives [13]. The current study provides supporting evidence that more frequent consumption of steamed food is associated with nutritional intake and reduced risk for MetS.

Findings suggested that the group of Korean females who consumed steamed food more than 1–3 times per week had lower grains but more intake of protein sources than those who consumed steamed food less than 1–2 times per month. Similar trend toward food intake was also evident in that those who had steamed food more frequently had lower levels of carbohydrates but higher protein intake. However, they also had higher intake of total fat and cholesterol, although there was no significant difference in vitamin C, sodium, or ratio of sodium/potassium. These observations differed from the assumption that subjects who preferred steamed food would show better nutritional intake such as lower intake of sodium and fat but higher intake of other nutritious compounds. This suggests that subjects with more frequent intake of steamed food might have more concern for their health, hence showing such dietary intake pattern rather than simple differential intake resulting from the frequency of steamed food intake. For instance, protein intake is generally positively associated with fat and cholesterol [28]. Individuals with more frequent steamed food consumption also had more intake of diary and green tea known to be beneficial for health. Korean traditional diet (high in grains and vegetables but low in fat) is known to be healthy [14]. However, Korean traditional diet also has other issues such as excessive consumption of carbohydrate and sodium with low amount or ratio for proteins [29,30]. In this study, subjects with more intake of steamed food might be more cautious for their dietary intake, which might lead to such observed food and nutritional intake. Differences in intake of vegetables and fruits were not evident by the frequency of steamed food intake. This result might be associated with the fact that middle to old aged Korean females overall have higher levels of vegetable intake, another common feature of Korean traditional dietary culture. Furthermore, as described earlier, steaming is an effective technique for preserving and protecting nutritious molecules [15,16]. Given these facts, individuals who had more steamed food showed better intake of proteins, energy, and other functional compounds with lower carbohydrate consumption, which might have improved issues of nutritional intake, which might finally lead to the trend of reduced risk for MetS by interacting and/or being influenced by/with other life style factors.

In this study, individuals who had steamed food 1–3 times per week was at 25% lower risk for MetS than those who had less steamed food, taking their lifestyle and environmental characteristics into account. As described above, recued intake of food high in carbohydrate but higher intake for protein and other nutritious compounds could contribute this beneficial effect of steaming recipe on MetS. This finding provides the evidence that steaming is effective cooking technique in the management for healthy dietary behaviour, although statistical significance was limited. Furthermore, it should be noted that the modified disease risk by steamed food intake is not only due to nutritional and/or dietary intake by consuming of steamed food, but also due to other milieu factors [31]. Individuals' concerns for health are linked to individual's socioeconomic status including residence, schooling year, smoking, and alcohol drinking status and modify their health behaviour including preferred recipe, and finally health outcome [32]. Additionally, in this Korean female population, the reduced risk for MetS by steamed food intake was more clearly evident in rural residence. This differential effect of dietary preference of cooking method by residence has not been reported earlier. Limited literature is available to support the evidence. A few possible hypotheses may explain as follows. First, the prevalence of MetS in rural area was decisively different from that in urban area. This differential prevalence of MetS by residential area has been observed in earlier reports [33,34]. The prevalence of MetS was significantly higher in rural area. Approximately 51% of rural participants had MetS. However, only 28% of urban participants had MetS. The statistical power of a large number of cases might have contributed the differential effect of steamed food intake on the disease risk. Second, disparity in various factors regarding socio-economic, lifestyle factors such as age, education, and income levels may exist between rural and urban areas. This may interactively and/or differentially influence the association between steamed food intake and the risk of MetS [34-36]. However, this effect of cooking method on health outcome has not been fully verified yet. More large-scaled replicate studies to confirm these findings should be required.

This study is the first study that examines the association between the frequency of steamed food intake and the risk of MetS. However, a few limitations still remain. Therefore, findings of this study should be interpreted with caution. First, baseline data collection of Ansan/Ansung study, KoGES was performed in 2000–2001. These data may not represent the current trend in nutritional intake and health outcome. Second, analyses were performed for data of approximately 4,000 subjects aged 40–69 from a large sized cohort. However, those may not fully represent the entire population of Korean females. Third, information about food and nutritional intake were limited. Dietary data was collected using FFQ. FFQ was developed with 103 food items most commonly consumed in Koreans. However, it did not fully cover the all the foods eaten by Koreans. Furthermore, the FFQ is known to be incapable of capturing detailed information regarding certain types of food such as condiments and oils [37,38]. The nutritional information of KoGES is also limited. It does not provide detailed repertoire of nutrient, for instance, types of carbohydrate (sucrose, monosaccharide etc.) or fat (animal and plant). Lastly, various characteristics of participants including lifestyle and environmental factors were included in statistical analyses. However, those models may not fully imply the background of participants' characteristics.

In summary, the frequency of steamed food intake was associated with the risk of MetS. The association between the risk for MetS and dietary habit was evident after taking lifestyle and environmental factors into account. Further studies are needed to extend findings of this study for better nutrition education and health management.

SUMMARY

The study examined whether the frequency of food intake using steaming was associated with the risk of MetS. A total of 4,056 Korean females in Ansan/Ansung cohort, KoGES were investigated for general background, dietary intake and behaviour, and biochemical and body measurements. MetS was determined using a modified NCEP ATP III for Asians. Findings

suggested that individuals who had steamed food for more than 1–3 time per week were at a lower risk for MetS than those who consumed steamed food for less than 1–2 time per month. This reduced risk of steamed food intake was decisively evident when subjects' living area and other lifestyle factors were taken into account. More frequent consumption of steamed food and living in rural area reduced the risk for MetS (OR, 0.747; 95% CI, 0.583–0.958). However, this positive effect of steaming was not observed in urban residents. This study provides preliminary evidence that a change in cooking methods, especially steaming, could be applied as a useful vehicle in nutrition education for better public health. However, larger studies are needed to confirm the true effect/association of intake of steamed food and health outcomes.

REFERENCES

1. Hanley AJ, Karter AJ, Williams K, Festa A, D'Agostino RB Jr, Wagenknecht LE, et al. Prediction of type 2 diabetes mellitus with alternative definitions of the metabolic syndrome: the Insulin Resistance Atherosclerosis Study. Circulation 2005; 112(24): 3713-3721.
   PUBMED | CROSSREF
2. Ley SH, Harris SB, Mamakeesick M, Noon T, Fiddler E, Gittelsohn J, et al. Metabolic syndrome and its components as predictors of incident type 2 diabetes mellitus in an Aboriginal community. CMAJ 2009; 180(6): 617-624.
   PUBMED | CROSSREF
3. Wang J, Ruotsalainen S, Moilanen L, Lepistö P, Laakso M, Kuusisto J. The metabolic syndrome predicts cardiovascular mortality: a 13-year follow-up study in elderly non-diabetic Finns. Eur Heart J 2007; 28(7): 857-864.
   PUBMED | CROSSREF
4. Ju SY, Lee JY, Kim DH. Association of metabolic syndrome and its components with all-cause and cardiovascular mortality in the elderly: a meta-analysis of prospective cohort studies. Medicine (Baltimore) 2017; 96(45): e8491.
   PUBMED | CROSSREF
5. Lambrinoudaki I, Kazani A, Armeni E, Rizos D, Augoulea A, Kaparos G, et al. The metabolic syndrome is associated with carotid atherosclerosis and arterial stiffness in asymptomatic, nondiabetic postmenopausal women. Gynecol Endocrinol 2018; 34(1): 78-82.
   PUBMED | CROSSREF
6. Park JH, Hong JY, Park YS, Kang G, Han K, Park JO. Persistent status of metabolic syndrome and risk of cholangiocarcinoma: a Korean nationwide population-based cohort study. Eur J Cancer 2021; 155: 97-105.
   PUBMED | CROSSREF
7. Shen X, Wang Y, Zhao R, Wan Q, Wu Y, Zhao L, et al. Metabolic syndrome and the risk of colorectal cancer: a systematic review and meta-analysis. Int J Colorectal Dis 2021; 36(10): 2215-2225.
   PUBMED | CROSSREF
8. Woo HD, Shin A, Kim J. Dietary patterns of Korean adults and the prevalence of metabolic syndrome: a cross-sectional study. PLoS One 2014; 9(11): e111593.
   PUBMED | CROSSREF
9. Choi JH, Woo HD, Lee JH, Kim J. Dietary patterns and risk for metabolic syndrome in Korean women: a cross-sectional study. Medicine (Baltimore) 2015; 94(34): e1424.
   PUBMED | CROSSREF
10. Bian S, Gao Y, Zhang M, Wang X, Liu W, Zhang D, et al. Dietary nutrient intake and metabolic syndrome risk in Chinese adults: a case-control study. Nutr J 2013; 12(1): 106.
    PUBMED | CROSSREF
11. Kim H, Lee K, Rebholz CM, Kim J. Plant-based diets and incident metabolic syndrome: Results from a South Korean prospective cohort study. PLoS Med 2020; 17(11): e1003371.
    PUBMED | CROSSREF
12. Song S, Lee JE, Song WO, Paik HY, Song Y. Carbohydrate intake and refined-grain consumption are associated with metabolic syndrome in the Korean adult population. J Acad Nutr Diet 2014; 114(1): 54-62.
    PUBMED | CROSSREF
13. Muñoz de Chávez M, Chávez A. Diet that prevents cancer: recommendations from the American Institute for Cancer Research. Int J Cancer Suppl 1998; 11: 85-89.
    PUBMED | CROSSREF

14. Kim SH, Kim MS, Lee MS, Park YS, Lee HJ, Kang S, et al. Korean diet: characteristics and historical background. J Ethn Foods 2016; 3(1): 26-31.
CROSSREF
15. Zeng C. Effects of different cooking methods on the vitamin C content of selected vegetables. Nutr Food Sci 2013; 43(5): 438-443.
CROSSREF
16. Murador D, Braga AR, Da Cunha D, De Rosso V. Alterations in phenolic compound levels and antioxidant activity in response to cooking technique effects: a meta-analytic investigation. Crit Rev Food Sci Nutr 2018; 58(2): 169-177.
PUBMED | CROSSREF
17. Bordin K, Kunitake MT, Aracava KK, Trindade CS. Changes in food caused by deep fat frying--a review. Arch Latinoam Nutr 2013; 63(1): 5-13.
PUBMED
18. Koszucka A, Nowak A. Thermal processing food-related toxicants: a review. Crit Rev Food Sci Nutr 2019; 59(22): 3579-3596.
PUBMED | CROSSREF
19. Cornier MA, Salzberg AK, Endly DC, Bessesen DH, Tregellas JR. Sex-based differences in the behavioral and neuronal responses to food. Physiol Behav 2010; 99(4): 538-543.
PUBMED | CROSSREF
20. Chang SH, Chang YY, Wu LY. Gender differences in lifestyle and risk factors of metabolic syndrome: do women have better health habits than men? J Clin Nurs 2019; 28(11-12): 2225-2234.
PUBMED | CROSSREF
21. Zyriax BC, Boeing H, Windler E. Nutrition is a powerful independent risk factor for coronary heart disease in women--The CORA study: a population-based case-control study. Eur J Clin Nutr 2005; 59(10): 1201-1207.
PUBMED | CROSSREF
22. Kim Y, Han BG; KoGES group. Cohort profile: the Korean Genome and Epidemiology Study (KoGES) Consortium. Int J Epidemiol 2017; 46(2): e20.
PUBMED | CROSSREF
23. Lee KW, Shin D. Prospective associations of serum adiponectin, leptin, and leptin-adiponectin ratio with incidence of metabolic syndrome: the Korean Genome and Epidemiology Study. Int J Environ Res Public Health 2020; 17(9): 3287.
PUBMED | CROSSREF
24. Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults. Executive summary of the third report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). JAMA 2001; 285(19): 2486-2497.
PUBMED | CROSSREF
25. Ahn Y, Kwon E, Shim JE, Park MK, Joo Y, Kimm K, et al. Validation and reproducibility of food frequency questionnaire for Korean genome epidemiologic study. Eur J Clin Nutr 2007; 61(12): 1435-1441.
PUBMED | CROSSREF
26. Ministry of Health and Welfare; The Korean Society for Nutrition. Dietary reference intakes for Koreans 2000. Seoul: The Korean Society for Nutrition; 2000.
27. Palermo M, Pellegrini N, Fogliano V. The effect of cooking on the phytochemical content of vegetables. J Sci Food Agric 2014; 94(6): 1057-1070.
PUBMED | CROSSREF
28. Darioli R. Dietary proteins and atherosclerosis. Int J Vitam Nutr Res 2011; 81(2-3): 153-161.
PUBMED | CROSSREF
29. Park HA. Adequacy of protein intake among Korean elderly: an analysis of the 2013-2014 Korea National Health and Nutrition Examination Survey data. Korean J Fam Med 2018; 39(2): 130-134.
PUBMED | CROSSREF
30. Ha K, Song Y. Low-Carbohydrate Diets in Korea: Why Does It Matter, and What Is Next? J Obes Metab Syndr 2021; 30(3): 222-232.
PUBMED | CROSSREF
31. Yang JJ, Yoon HS, Lee SA, Choi JY, Song M, Han S, et al. Metabolic syndrome and sex-specific socio-economic disparities in childhood and adulthood: the Korea National Health and Nutrition Examination Surveys. Diabet Med 2014; 31(11): 1399-1409.
PUBMED | CROSSREF
32. Darmon N, Drewnowski A. Does social class predict diet quality? Am J Clin Nutr 2008; 87(5): 1107-1117.
PUBMED | CROSSREF

33. Kim MJ, Park E. The prevalence and the related factors of metabolic syndrome in urban and rural community. Korean J Adult Nurs 2014; 26(1): 67-77.
CROSSREF

34. Seo JM, Lim NK, Lim JY, Park HY. Gender difference in association with socioeconomic status and incidence of metabolic syndrome in Korean adults. Korean J Obes 2016; 25(4): 247-254.
CROSSREF

35. Lee J, Sa J. Regional disparities in healthy eating and nutritional status in South Korea: Korea National Health and Nutrition Examination Survey 2017. Nutr Res Pract 2020; 14(6): 679-690.
PUBMED | CROSSREF

36. Han KT, Kim SJ. Regional factors associated with the prevalence of metabolic syndrome: focusing on the role of healthcare providers. Health Soc Care Community 2021; 29(1): 104-112.
PUBMED | CROSSREF

37. Yun SH, Kim MK. The effect of seasoning on the distribution of nutrient intakes by a food-frequency questionnaire in a rural area. Kor J Nutr 2009; 42(3): 246-255.
CROSSREF

38. Shim JS, Oh K, Kim HC. Dietary assessment methods in epidemiologic studies. Epidemiol Health 2014; 36: e2014009.
PUBMED | CROSSREF