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Relationship of Carbohydrate and Fat Intake with Metabolic Syndrome in Korean Women: The Korea National Health and Nutrition Examination Survey (2007-2016)

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한국 여성의 탄수화물/지질 섭취가 대사증후군에 미치는 영향: 국민건강영양조사(2007-2016)를 중심으로

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Abstract

The objective of the study was to examine the associations of dietary carbohydrate and fat intake with the prevalence of metabolic syndrome in Korean women. A cross-sectional study was employed based on data from the Korea National Health and Nutrition Examination (2007-2016). A total of 22,850 women aged 19 to 69 years were studied after excluding responses from pregnant or lactating women and those with missing metabolic values. Dietary intake data were collected with a 24-hour recall method. Dietary carbohydrate and fat intakes were divided into quintiles. After controlling for confounding variables, a multivariable logistic regression and general linear model were used. The findings indicated that HDL cholesterol levels were lower (p for trend<0.01), while triglyceride levels (p for trend=0.04), waist circumference (p for trend<0.01), and systolic blood pressure (p for trend<0.01) were higher among participants in the highest quintile of carbohydrate intake compared to those in the lowest quintile. Participants in the highest quintile of fat intake had lower waist circumference (p for trend=0.02), triglyceride level (p for trend<0.01), and systolic blood pressure (p for trend<0.01), while higher HDL cholesterol level (p for trend<0.01) compared to those in the lowest fat intake quintile. Metabolic syndrome was more likely to be present in the highest quintile of carbohydrates intake than in the lowest quintile (5^{th} quintile vs. 1^{st} quintile, *OR*: 1.32; 95% *CI*: 1.11 to 1.57). However, metabolic syndrome was less likely to be present in the highest quintile of fat intake than in the lowest quintile (5^{th} quintile vs. 1^{st} quintile, *OR*: 0.73; 95% *CI*: 0.61 to 0.86).

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This study revealed that high dietary carbohydrate intake and low dietary fat intake were associated with metabolic syndrome in Korean women.

Key words: 대사증후군(metabolic syndrome), 지방(dietary fat), 탄수화물(carbohydrates intake), 한국 여성(Korean women)

I. Introduction

Metabolic syndrome involves complex and interrelated factors that raise the risk of coronary heart disease (Williams, 2002). The prevalence of metabolic syndrome has become an issue worldwide, recently infiltrating Asia. Approximately 20 to 30% of the adult population (19 to 69 years) is estimated as having metabolic syndrome (Hong, 2019). Metabolic syndrome has several risk factors that associated with, including demographic characteristics, lifestyle like physical activity (Julibert et al., 2019). Diet related factors such as dietary lifestyles, individual foods, and dietary components are also important risk factors of metabolic syndrome, particularly the consumption of excessive carbohydrate and fat (Reaven, 2000). However, studies about associations of carbohydrate and fat consumption with our health have shown conflicting results (Allick et al., 2004; Freire et al., 2005; Shirani & Azadbakhat, 2011; Ye et al., 2012). According to Shirani & Azadbakhat (2011), subjects with higher intake of carbohydrate or fat revealed a higher risk of developing metabolic syndrome. According to Freire et al (2005), subjects with highest quintile of total fat intake are 5.03 times more likely to be exposed to metabolic syndrome than those with the lowest quintile. Reduction of 10% in the proportion of energy from fat was associated with a reduction in weight of 16 g/day (Bray & Popkin, 1998). Each increase of 5 percent of energy intake from saturated fat, as compared with equivalent energy intake from carbohydrates, was associated with a 17 percent increase in the risk of coronary disease (Hu et al., 1997). However, some studies support a new perspective on the role that fat plays in improving type 2 diabetes mellitus. Some studies suggest that a high-fat diet might make it possible for insulin to stimulate glycogen synthesis more effectively (Allick et al., 2004). The benefits of grain are similarly controversial; one study showed that subjects consuming 48-80 g whole grain/d had an 26% lower risk of type 2 diabetes, 21% lower risk of cardiovascular disease and consistently less weight gain during 8-13 year (Ye et al., 2012). Yet other studies suggests that high carbohydrate consumption may not be better than fat consumption; in one study, men across quintiles of the percentage of energy obtained from carbohydrates, triglyceride and fasting blood glucose levels increased (Song et al., 2014).

Over-consumption of total energy is positively associated with overweight that, in turn, deteriorates insulin sensitivity, and positively associated with metabolic syndrome (Riccardi et al., 2004). Thus, in order to reduce confounding, overall energy intake need to be adjusted as an indirect cause of unobserved determinants of their independent association with metabolic syndrome. Sex difference in dietary intake has been reported, showing that subjects with metabolic syndrome consume high percentage of carbohydrate proportions and low percentage of fat proportions than those without metabolic syndrome in women, but there was no significant difference in the fat and carbohydrate proportion of males with metabolic syndrome (Kwon et al., 2017). Moreover, women have relatively greater risk of having abdominal obesity than men (Kuk & Ardern, 2010).

According to the National Health Insurance Service (NHIS), The prevalence of metabolic syndreom increased from 19.7% in 2007 to 21.8% in 2017 among Korean women. Although the prevalence of metabolic syndrome is infiltrating Korea, little is known about its association with the amount of dietary carbohydrate or fat intake in Korean women. Therefore, the objective of this study was to examine associations of metabolic syndrome in Korea women with dietary carbohydrate intake and fat intake using a residual method based on data from the Korea National Health and Nutrition Examination.

II. Research Methods

1. Samples

This study was conducted based on data from the 4th, 5th, and 6th Korea National Health and Nutrition Examination Survey (KNHANES) in 2007-2016. Using household registries, the KNHANES stratified and collected households as sampling units through a multistage, probability-based sampling design based on sex, age, and geographic area. Among 44,683 eligible subjects aged 19 to 69 years except for those without metabolic values (*n*=7,814), women (*n*=25,167) were included after excluding pregnant or lactating women (*n*=405). In addition, participants who reported implausible energy intakes (<450 or >6,300 kcal/day) (*n*=2,317) were excluded (Welfare, 2019). Finally, a total of 22,850 women were included in data analyses. This study was approved by the Institutional Review Board of Korea Centers for Disease Control and Prevention. Informed consent was obtained from each participants.

2. Assessment of dietary intake

Dietary intake from KNHANES was assessed through a single 24-hr recall. Energy and nutrient intakes were estimated using the 7th Standard Food Composition Table (Rural Development Administration, 2006). Dietary intake variables included total carbohydrate intake (kcal/day), fat intake (kcal/day), energy from carbohydrate (%), energy from fat (%) and energy from protein (%). Energy intake from carbohydrate, fat or protein was calculated by multiplying carbohydrate intake (g/day), fat intake (g/day) or protein intake (g/day) and Atwater factors (4 kcal/g for carbohydrate and protein; 4 kcal/g; 9 kcal/g for fat).

3. Socio-demographic measurement

Socio-demographic variables (such as age, educational level, and household income) and health-related variables (such as smoking status, and alcohol intake) were obtained using a health questionnaire survey conducted by the Korea Centers for Disease Control and Prevention. We divided total income per month by the square root of the number of household members to calculate household income using formula: (total household income per month /√ the number of household members). Smoking status was categorized into the following groups: nonsmokers, ex-smokers, and current smokers. Current alcohol intake was assessed based on the average frequency of alcohol consumption during the last year and categorized into the following groups: never intake, 1 time/month, 2 to 4 times/month, 2 to 3 times/week, and 4 or more times/week.

4. Physical activity measurement

Physical activity was examined by asking subjects how often they were engaged in exercise during the last week using a Korean version of the international physical activity questionnaire (IPAQ)(Oh et al., 2007). Patterns of physical activity were classified as walking, moderate intensity activity, and vigorous activity. For each activity level, frequencies performed per week and subject's daily duration were evaluated. Using this information, exercise frequency (days per week) and duration of exercise (min per day) were calculated using formulas below and then converted to total metabolic equivalent tasks (METs/week) values representing total physical activity (Kang, 2015). Summed total time (min) spent in walking, moderate activities, or vigorous activities was multiplied by 3.3, 4.0, or 8.0 METs/week, respectively. Based on these formulas, weekly physical activity was summed by walking, moderate activities, and vigorous activities in METs/week (Ainsworth et al., 2000).

5. Anthropometric and blood pressure measurement

Height, weight, and waist circumference were measured using standardized techniques and calibrated equipment (Kweon et al., 2014). Body mass index (BMI) was calculated from measured height and weight (kg/m^2) of subject. Blood pressure was measured twice using a mercury sphygmomanometer (WA Baum Co., Inc., Copiague, New York, USA) in sitting position after at least a 10 min rest. If the first two measurements differed by 0.5 mmHg, additional checks were obtained, and the average value was used.

6. Laboratory measurement

For the blood sample, we asked them to fast for more than 8 hours. Serum levels of fasting glucose, high-density lipoprotein (HDL) cholesterol, and triglycerides were measured enzymatically at a central laboratory using an Advia 1650/2400 (Siemens, New York, USA) for subjects in 2007-2008 KNHANES and an automatic analyzer 7600 (Hitachi, Tokyo, Japan) for subjects in 2008-2016 KNHANES. Values were corrected and calibrated as needed due to differences in assay methods or equipment between 2007-2008 and 2008-2016 KNHANES. For each survey, methods were detailed to determine and compare their validity and reliability (Ko et al., 2012).

7. Metabolic syndrome components

The definition of metabolic syndrome follows modified NCEP ATP III (Williams, 2002). Metabolic syndrome was considered present when three or more of the following five criteria were met: 1) abdominal obesity defined as waist circumference≥85 cm for Korean women; 2) hypertriglyceridemia defined as serum triglyceride concentration≥150 mg/dL (1.69 mmol/L); 3) low serum HDL cholesterol defined as decreased levels of HDL cholesterol with fasting HDL cholesterol levels<50 mg/ dL (1.29 mmol/L) for women; 4) hypertension with systolic or diastolic blood pressure≥130/85 mm Hg or on a drug treatment for hypertension; and 5) hyperglycemia with fasting plasma glucose defined as a fasting blood glucose≥100 mg/dL (5.6 mmol/L) (Grundy et al., 2004).

8. Statistical analyses

To give an equal probability of being sampled, weight was assigned to each respondent, enabling results to represent the entire Korean population. Intakes of carbohydrates and fat were used as total energy adjusted values using the residual method and grouped into quintiles.

To examine the association between isocaloric substitutions of macronutrients (“carbohydrate replacement for fat” or “fat replacement for carbohydrate”) and the prevalence of metabolic syndrome, we applied substitution models (Hu et al., 1999). To assess prevalence of metabolic syndrome with carbohydrate replacement for fat, energy intake, protein intake, and carbohydrate intake and other confounding factors were simultaneously included in the model. The carbohydrate coefficients could be interpreted as the effect of substituting a certain amount of carbohydrate intake for the same amount of energy from fat intake while maintaining a constant intake of protein and total energy.

Age (years, continuous), household income (low-income, middle-income, or high-income), smoking status (current, ex-, or nonsmokers), current alcohol intake (never or rarely, <1 time/ month, 1 time/month, 2 to 4 times/ month, 2 to 3 times/week, or 4 times/week), physical activity (METs/week, continuous), total energy intake (Kcal/day, continuous), body mass index (kg/m^2, continuous), and protein intake (g, continuous) were considered as possible confounding variables and controlled. Missing data values (household income, n=229; smoking status, n=1,764; current alcohol intake, n= 91; physical activity, n=2,556; body mass index, n=5) were substituted with median concentrations or common values. All analyses accounted for the complex sampling method and time series weight variables to incorporate sample weights and adjust analyses. To test differences, analysis of variance was used for continuous variables while χ^2 test was used for categorical variables for descriptive analysis of characteristics of participants. All tests of significance were two-tailed and p values<0.05 were considered statistically significant. Tests for a linear trend of these variables by quintiles of carbohydrates and fat intake were conducted using a general linear model (GLM). Multivariate logistic regression was used to estimate odds ratios (ORs) and 95% CIs. All statistical analyses were conducted using SAS software version 9.4 (SAS Institute, Cary, NC, USA).

III. Results

General characteristics of subjects by quintiles of carbohydrate intake among Korean women are presented in <Table 1>. This study included 22,850 women with mean age of 44.7 years. Energy-adjusted calorie from carbohydrate was 1222.4 kcal/day. Participants with higher carbohydrate intake were more likely to be older, consuming alcohol infrequently, and less educated (p<0.01, <Table 1>). Participants with the highest fat intake were more likely to be younger and educated (p<0.01, <Table 2>).

After adjusting for potential confounding factors, carbohydrate intake showed significant positive associations with metabolic syndrome components (see Table 3). Increasing carbohydrate intake was associated with higher waist circumference (p for trend< 0.01), triglyceride level (p for trend=0.04), and systolic blood pressure (p for trend<0.01), but lower HDL cholesterol level (p for trend<0.01).

Table 1.

General Characteristics of Participants According to Carbohydrate Intake (Calories from Carbohydrate/day) [a]

	Quintiles of dietary carbohydrate intake (Kcal/day)						***P* value**[b]
	Q1 (lowest) (*n*=4,570)	**Q2 (*n*=4,570)**	**Q3 (*n*=4,570)**	**Q4 (*n*=4,570)**	**Q5 (highest) (*n*=4,570)**	**Total (*n*=22,850)**	
Age (years)[c]	36.86±0.21	39.93±0.22	43.16±0.23	46.88±0.23	50.85±0.23	44.80±0.13	<0.01
Carbohydrate intake (Kcal/day)[c]	840.00±2.31	1,061.93±0.67	1,176.67±0.52	1,278.46±0.5	1,421.49±1.39	1,221.44±1.37	<0.01
Energy from carbohydrate (%)[c]	48.86±0.14	62.17±0.06	68.94±0.06	74.85±0.06	82.16±0.08	71.30±0.07	<0.01
Educational level[c]							<0.01
Elementary	356(5.67)	532(9.08)	799(14.06)	1,247(21.59)	1,893(34.68)	4,827(15.83)	
Junior high	324(6.51)	382(7.85)	526(11.02)	588(12.34)	708(15.67)	2,528(10.30)	
Senior high	1,959(45.13)	1,831(42.04)	1,725(40.79)	1,601(38.62)	1,244(31.89)	8,361(40.28)	
College or more	1,904(42.68)	1,799(40.64)	1,494(33.11)	1,116(27.43)	704(17.74)	7,017(33.57)	
Household income[c]							<0.01
High-income	1,007(23.38)	956(22.64)	1,068(25.02)	1,149(25.95)	1,238(27.16)	5,418(24.65)	
Middle-income	2,286(50.32)	2,320(51.26)	2,256(50.08)	2,306(50.56)	2,254(49.97)	11,422(50.46)	
Low-income	1,234(26.29)	1,246(26.08)	1,206(24.88)	1,060(23.47)	1,034(22.86)	5,780(24.87)	
Smoking status[c]							<0.01
Current smokers	411(9.93)	245(6.26)	207(5.48)	181(4.58)	131(3.26)	1,175(6.15)	
Ex-smokers	357(8.60)	266(6.60)	237(5.55)	189(4.93)	125(3.04)	1,174(5.96)	
Nonsmokers	3,794(81.46)	4,048(87.12)	4,109(88.95)	4,190(90.48)	4,302(93.69)	20,443(87.88)	

Table 1.
Continued

	Quintiles of dietary carbohydrate intake (Kcal/day)						*P* value[b]
	Q1 (lowest) (*n*=4,570)	Q2 (*n*=4,570)	Q3 (*n*=4,570)	Q4 (*n*=4,570)	Q5 (highest) (*n*=4,570)	Total (*n*=22,850)	
Alcohol intake[c]							<0.01
Never intake	1,798(37.65)	2,416(50.94)	2,681(56.59)	2,933(62.19)	3,279(69.59)	13,102(54.15)	
1 time/month	614(14.13)	652(14.78)	602(13.45)	555(12.78)	482(11.26)	2,905(13.41)	
2 to 4 times/month	1,244(28.74)	1,023(23.43)	891(20.96)	766(18.33)	576(13.14)	4,500(21.52)	
2 to 3 times/week	705(15.43)	375(8.95)	308(7.58)	249(5.65)	181(4.80)	1,818(8.88)	
4 or more times/week	190(4.02)	86(1.88)	62(1.40)	52(1.02)	43(1.18)	433(2.01)	
Physical activity (METs/week)[c]	1,927.46±51.74	1,736.36±44.43	1,837.59±47.59	1,996.35±59.11	2,224.29±71.84	1,930.41±30.12	<0.01

[a] All analyses accounted for the complex sampling design effect and appropriate sampling weights of the national survey.
[b] P values were obtained from analysis of variance for continuous variables and χ^2 test for categorical variables.
[c] Continuous variables are reported as mean ± standard error (SE) while categorical variables are reported as No. (%).

Table 2.
General Characteristics of Participants According to Fat Intake [a]

	Quintiles of dietary fat intake (Kcal/day)						*P* value[b]
	Q1 (lowest) (*n*=4,570)	Q2 (*n*=4,570)	Q3 (*n*=4,570)	Q4 (*n*=4,570)	Q5 (highest) (*n*=4,570)	Total (*n*=22,850)	
Age (years)[c]	51.23±0.24	46.23±0.24	43.48±0.22	39.94±0.23	36.71±0.22	41.32±0.13	<0.01
Fat intake (Kcal/day)[c]	128.03±0.69	220.70±0.4	296.28±0.37	382.92±0.5	554.60±1.95	373.19±1.32	<0.01
Energy from fat (%)[c]	7.24±0.04	12.50±0.03	16.91±0.03	21.91±0.04	31.19±0.11	21.16±0.07	<0.01
Educational level[c]							<0.01
Elementary	2,098(38.49)	1,134(19.33)	754(13.49)	500(8.74)	341(5.34)	4,827(15.83)	
Junior high	711(15.83)	621(13.03)	545(11.64)	367(7.37)	284(5.67)	2,528(10.30)	
Senior high	1,170(30.86)	1,662(40.59)	1,768(40.70)	1,828(42.67)	1,932(44.18)	8,361(40.28)	
College or more	565(14.79)	1,128(27.03)	1,482(34.14)	1,854(41.20)	1,988(44.79)	7,017(33.57)	
Household income[c]							<0.01
High-income	919(20.70)	1,125(24.60)	1,206(25.54)	979(22.98)	1,258(22.44)	5,780(24.87)	
Middle-income	2,238(50.06)	2,292(49.63)	2,310(50.26)	2,273(51.05)	2,309(51.05)	11,422(50.46)	
Low-income	1,360(29.22)	1,101(25.75)	1,021(24.18)	979(22.98)	957(22.44)	5,418(24.65)	
Smoking status[c]							<0.01
Current smokers	181(4.78)	206(5.42)	225(5.59)	244(6.34)	319(8.03)	1,175(6.15)	
Ex-smokers	155(3.98)	173(4.62)	247(5.84)	270(6.73)	329(7.85)	1,174(5.96)	
Nonsmokers	4,216(91.22)	4,176(89.95)	4,091(88.56)	4,046(86.92)	3,914(84.10)	22,443(87.88)	
Alcohol intake[c]							<0.01
Never intake	3,031(63.55)	2,787(58.19)	2,578(53.09)	2,394(49.83)	2,312(48.19)	13,102(54.15)	
1 time/month	475(11.14)	522(11.55)	608(13.42)	640(14.41)	660(15.62)	2,905(13.41)	
2 to 4 times/month	659(15.31)	809(19.68)	908(21.21)	1,038(24.53)	1086(24.97)	4,500(21.52)	
2 to 3 times/week	285(7.42)	340(8.34)	378(9.45)	401(9.30)	414(9.50)	1,818(8.88)	
4 or more times/week	98(2.56)	92(2.22)	80(1.81)	83(1.91)	80(1.70)	433(2.01)	

Table 2.
Continued

	Quintiles of dietary fat intake (Kcal/day)						*P* value[b]
	Q1 (lowest) (*n*=4,570)	Q2 (*n*=4,570)	Q3 (*n*=4,570)	Q4 (*n*=4,570)	Q5 (highest) (*n*=4,570)	Total (*n*=22,850)	
Physical activity (METs/week)[c]	2,202.05±70.81	2,066.19±58.62	1,839.29±48.15	1,764.26±48.04	1,854.11±47.78	1,875.61±27.35	<0.01

[a] All analyses accounted for the complex sampling design effect and appropriate sampling weights of the national survey.
[b] P values were obtained from analysis of variance for continuous variables and χ^2 test for categorical variables.
[c] Continuous variables are reported as mean ± standard error (SE) while categorical variables are reported as No. (%).

Table 3.
Metabolic Syndrome Components and Body Mass Index According to Carbohydrate Intake [a]

	Quintiles of Dietary Carbohydrate intake (Kcal/day) [b]					*P* for trend[c]
	Q1 (lowest) (*n*= 4,570)	Q2 (*n*=4,570)	Q3 (*n*=4,570)	Q4 (*n*=4,570)	Q5 (highest) (*n*=4,570)	
Metabolic syndrome components, LS means (95% CI) [d]						
Waist circumference (cm)	78.68(78.50-78.86)	78.67(78.50-78.86)	78.77(78.58-78.96)	78.99(78.80-79.18)	79.21(79.01-79.42)	<0.01
Median (IQR)	75.50(69.70, 82.30)	75.80(70.00, 82.70)	76.90(70.90, 83.60)	78.50(72.10, 85.30)	80.40(74.00, 86.90)	
Triglyceride (mg/dL)	122.57(119.60-125.55)	122.83(119.85-125.91)	123.73(120.68-126.78)	122.10(118.98-125.21)	127.75(124.41-131.08)	0.04
Median (IQR)	82.00(58.00, 121.00)	85.50(61.00, 126.00)	90.00(63.00, 133.00)	95.00(67.00, 139.00)	105.00(73.00, 156.00)	
HDL cholesterol (mg/dL)	56.00(55.54-56.46)	55.06(54.60-55.53)	54.33(53.86-54.80)	53.90(53.42-54.38)	52.25(51.74-52.77)	<0.01
Median (IQR)	54.40(46.80, 63.00)	52.50(45.30, 60.90)	51.60(44.30, 59.40)	50.40(43.40, 58.40)	48.70(41.30, 56.40)	
Fasting blood glucose (mg/dL)	96.24(95.44-97.04)	96.07(95.25-96.89)	96.47(95.65-97.29)	96.17(95.33-97.01)	95.79(94.90-96.69)	0.47
Median (IQR)	90.00(85.00, 97.00)	91.00(86.00, 97.00)	91.00(86.00, 98.00)	92.00(87.00, 100.00)	93.00(87.00, 101.00)	
Systolic blood pressure (mm Hg)	114.85(114.27-115.42)	114.73(114.14-115.32)	115.18(114.76-115.77)	115.36(114.76-115.97)	115.84(115.20-116.49)	<0.01
Median (IQR)	108.00(100.00, 118.00)	109.00(101.00, 119.00)	110.00(102.00, 123.00)	114.00(104.00, 127.00)	117.50(106.00, 131.00)	
Diastolic blood pressure (mm Hg)	74.48(74.10-74.85)	74.42(74.04-74.81)	74.64(74.26-75.03)	74.57(74.18-74.96)	74.38(73.96-74.80)	0.71
Median (IQR)	72.00(66.00, 79.00)	72.00(67.00, 79.00)	73.00(68.00, 80.00)	74.00(68.00, 81.00)	74.00(69.00, 81.00)	
Body Mass Index, LS means (95% CI) [d]	23.55(23.42-23.69)	23.46(23.32-23.59)	23.40(23.26-23.54)	23.43(23.29-23.57)	23.54(23.39-23.69)	0.47
Median (IQR)	22.40(20.50, 24.90)	22.50(20.50, 24.90)	22.80(20.80, 25.20)	23.20(21.10, 25.60)	23.80(21.70, 26.00)	

[a] All analyses accounted for the complex sampling design effect and appropriate sampling weights of the national survey.
[b] All dietary carbohydrate intake variables were energy adjusted using the residual method and categorized into quintiles.
[c] P for trend was obtained from a multivariate linear analysis after adjusting for age (years, continuous), household income (low-income, middle-income or high-income), smoking status (current, ex-, or nonsmokers), current alcohol intake (never or rarely, <1 time/month, 1 time/month, 2 to 4 times/month, 2 to 3 times/week, or 4 times/week) and physical activity (METs/week, continuous), total energy intake (kcal/day, continuous), body mass index (kg/m^2, continuous) and protein intake (g/day, continuous) where missing data values were substituted with median concentrations or common value by using the median value of each quintile category as a continuous variable.
[d] LS least-squares, CI confidence interval

Carbohydrate intake showed no significant association with other metabolic syndrome components. On the other hand, fat intake showed significant associations with waist circumference, triglyceride level, HDL cholesterol level, and systolic blood pressure (see Table 4). Body mass index (*p* for trend=0.02), waist circumference (*p* for trend<0.01), triglyceride level (*p* for trend<0.01), and systolic blood pressure (*p* for trend<0.01) decreased across quintiles of fat intake while HDL cholesterol level (p for trend<0.01) increased across quintiles of fat intake. However, dietary fat intake had no significant association with fasting blood glucose level or diastolic blood pressure.

<Table 5> presents OR of prevalence for metabolic syndrome by quintiles of dietary carbohydrate intake in Korea women. After adjusting for potential confounding variables, metabolic syndrome

Table 4.

Metabolic Syndrome Components According to Fat Intake [a]

	Quintiles of Dietary Fat intake (Kcal/day) [b]					*P* for trend[c]
	Q1 (lowest) (*n*=4,570)	Q2 (*n*=4,570)	Q3 (*n*=4,570)	Q4 (*n*=4,570)	Q5 (highest) (*n*=4,570)	
Metabolic syndrome components, LS means (95% CI) [d]						
Waist circumference (cm)	79.30(79.10-79.49)	78.93(78.74-79.12)	78.67(78.49-78.86)	78.74(78.56-78.93)	78.52(78.34-78.71)	<0.01
Median (IQR)	81.10(74.70, 87.60)	78.40(72.30, 85.10)	76.80(70.90, 83.70)	75.80(70.20, 82.50)	75.00(69.10, 82.00)	
Triglyceride (mg/dL)	128.67(125.53-131.80)	124.26(121.23-127.30)	122.01(119.00-125.01)	122.63(119.60-125.65)	120.50(117.46-123.53)	<0.01
Median (IQR)	109.00(75.00, 159.00)	95.00(67.00, 139.00)	90.00(63.00, 132.00)	85.00(60.00, 126.00)	79.00(57.00, 118.00)	
HDL cholesterol (mg/dL)	53.08(52.60-53.57)	53.98(53.51-54.45)	54.88(54.42-55.34)	55.16(54.70-55.63)	55.75(55.28-56.22)	<0.01
Median (IQR)	48.70(41.70, 56.50)	50.40(38.20, 58.40)	51.60(44.30, 60.10)	52.50(45.30, 61.10)	53.90(46.10, 62.00)	
Fasting blood glucose (mg/dL)	96.36(95.51-97.21)	96.19(95.38-97.00)	96.15(95.34-96.97)	96.15(95.34-96.97)	96.01(95.19-96.83)	0.62
Median (IQR)	93.00(57.00, 102.00)	93.00(87.00, 100.00)	91.00(86.00, 98.00)	91.00(86.00, 97.00)	90.00(85.00, 96.00)	
Systolic blood pressure (mm Hg)	116.12(115.52-116.73)	115.55(115.52-116.73)	115.00(114.42-115.58)	114.46(113.87-115.58)	114.56(113.97-115.15)	<0.01
Median (IQR)	110.00(107.50, 132.00)	113.00(104.00, 127.00)	110.00(102.00, 122.00)	109.00(101.00, 119.00)	107.00(100.00, 117.00)	
Diastolic blood pressure (mm Hg)	74.46(74.06-74.85)	74.84(74.46-75.22)	74.67(74.29-75.04)	74.42(74.04-74.80)	74.17(73.78-74.55)	0.06
Median (IQR)	75.00(69.00, 82.00)	74.00(69.00, 81.00)	73.00(68.00, 80.00)	72.00(67.00, 79.00)	71.00(66.00, 78.00)	
Body Mass Index, LS means (95% CI) [d]	23.67(23.53-23.81)	23.51(23.37-23.65)	23.41(23.27-23.50)	23.37(23.23-23.50)	23.47(23.34-23.61)	0.02
Median (IQR)	23.90(21.80, 26.20)	23.20(21.20, 25.60)	22.80(20.70, 25.10)	22.50(20.50, 24.80)	22.30(20.30, 24.80)	

[a] All analyses accounted for the complex sampling design effect and appropriate sampling weights of the national survey.
[b] All dietary carbohydrate intake variables were energy adjusted using residual method and categorized into quintiles.
[c] P for trend was obtained from a multivariate linear analysis after adjusting for age (years, continuous), household income (low-income, middle-income or high-income), smoking status (current, ex-, or nonsmokers), current alcohol intake (never or rarely, <1 time/month, 1 time/month, 2 to 4 times/month, 2 to 3 times/week, or 4 times/week) and physical activity (METs/week, continuous), total energy intake (kcal/day, continuous), body mass index (kg/m^2, continuous) and protein intake (g/day, continuous) where missing data values were substituted with median concentrations or common value by using the median value of each quintile category as a continuous variable.
[d] LS least-squares, CI confidence interval

Table 5.

Odds Ratios and 95% CIs for Metabolic Syndrome According to Carbohydrate Intake

	Quintiles of Dietary Carbohydrate intake (Kcal/day)					*P* for trend
	Q1 (lowest)	Q2	Q3	Q4	Q5 (highest)	
No. of case/total	765/4,570	953/4,570	1,177/4,570	1,365/4,570	1,764/4,570	
Metabolic syndrome [a] OR (95% CI)						
Model 1[b]	1.00	1.13(0.99-1.28)	1.16(1.02-1.32)	1.07(0.94-1.22)	1.30(1.08-1.48)	<0.01
Model 2[c]	1.00	1.14(1.00-1.30)	1.15(1.01-1.32)	1.06(0.93-1.20)	1.27(1.12-1.45)	<0.01

Table 5.
Continued

	Quintiles of Dietary Carbohydrate intake (Kcal/day)					P for trend
	Q1 (lowest)	Q2	Q3	Q4	Q5 (highest)	
No. of case/total	765/4,570	953/4,570	1,177/4,570	1,365/4,570	1,764/4,570	
Model 3[d]	1.00	1.21(1.05-1.42)	1.25(1.07-1.46)	1.10(0.94-1.30)	1.32(1.11-1.57)	0.02

[a] Metabolic syndrome was considered present when three or more of the following five criteria were met: 1) abdominal obesity, defined as a waist circumference≥85 cm for women; 2) hypertriglyceridemia, defined as a serum TG concentration≥150 mg/dL (1.69 mmol/L); 3) low serum HDL cholesterol, defined as decreased level of high density lipoprotein (HDL) cholesterol with fasting HDL cholesterol level≤50 mg/ dL for women; 4) hypertension with systolic or diastolic blood pressure≥130/85 mm Hg; and 5) hyperglycemia with fasting plasma glucose, defined as a fasting serum glucose≥100 mg/dL

[b] Model 1: Adjusted for age (years, continuous)

[c] Model 2: Adjusted for household income (high-income, middle-income and low-income), smoking status (current, ex-, or nonsmokers) and current alcohol intake (never or rarely, <1 time/month, 1 time/month, 2 to 4 times/month, 2 to 3 times/week, or 4 times/week) in addition to model 1.

[d] Model 3: Adjusted for physical activity (METs/week, continuous), total energy intake (kcal/day, continuous), body mass index (kg/m^2, continuous) and protein intake (g/day, continuous) in addition to model 2 where missing data values were substituted with median concentrations by using the median value as a continuous variable or common value as a category variable.

Table 6.
Odds Ratios and 95% CIs for Metabolic Syndrome According to Fat Intake

No. of case/total	Quintiles of Dietary Fat intake (Kcal/day)					P for trend
	Q1 (lowest)	Q2	Q3	Q4	Q5 (highest)	
	1,908/4,570	1,343/4,570	1,124/4,570	902/4,570	747/4,570	
Metabolic syndrome [a] OR (95% CI)						
Model 1[b]	1.00	0.76(0.67-0.85)	0.74(0.65-0.84)	0.70(0.61-0.79)	0.68(0.59-0.78)	<0.01
Model 2[c]	1.00	0.77(0.69-0.87)	0.76(0.68-0.87)	0.72(0.63-0.82)	0.71(0.62-0.82)	<0.01
Model 3[d]	1.00	0.80(0.70-0.91)	0.83(0.72-0.95)	0.74(0.64-0.86)	0.73(0.62-0.86)	<0.01

[a] Metabolic syndrome was considered present when three or more of the following five characteristics were met: 1) abdominal obesity, defined as a waist circumference≥85 cm for women; 2) hypertriglyceridemia, defined as a serum TG concentration≥150 mg/dL (1.69 mmol/L); 3) low serum HDL cholesterol, defined as decreased level of high density lipoprotein (HDL) cholesterol with fasting HDL cholesterol level≤50 mg/ dL for women; 4) hypertension with systolic or diastolic blood pressure≥130/85 mm Hg; and 5) hyperglycemia with fasting plasma glucose, defined as a fasting serum glucose≥100 mg/dL

[b] Model 1: Adjusted for age (years, continuous)

[c] Model 2: Adjusted for household income (high-income, middle-income and low-income), smoking status (current, ex-, or nonsmokers) and current alcohol intake (never or rarely, <1 time/month, 1 time/month, 2 to 4 times/month, 2 to 3 times/week, or 4 times/week) in addition to model 1.

[d] Model 3: Adjusted for physical activity (METs/week, continuous), total energy intake (kcal/day, continuous), body mass index (kg/m^2, continuous) and protein intake (g/day, continuous) in addition to model 2 where missing data values were substituted with median concentrations by using the median value as a continuous variable or common value as a category variable.

was more likely to be present in the highest quintile of dietary carbohydrates intake than that in the lowest quintile (the highest quintile vs. the lowest quintile: *OR*=1.32; 95% *CI*: 1.11 to 1.57; *p* for trend=0.02). There was a 27% decrease in the prevalence of metabolic syndrome in women with the highest quintile of dietary fat intake compared to that in those with the lowest quintile of dietary fat intake (the highest quintile vs. the lowest quintile: *OR*=0.73; 95% *CI*: 0.62 to 0.86; *p* for trend=0.02) (see Table 6).

IV. Discussion

Results of our study revealed positive associations between dietary carbohydrate intake and metabolic syndrome components except for HDL cholesterol but inverse associations between dietary fat intake and metabolic syndrome components. Participants in the highest quintile of carbohydrate intake were more likely to have higher triglyceride level but lower HDL cholesterol level compared to those in the lowest quintile. Our results are consistent with those of previous studies showing association of low carbohydrate intake with decreased serum levels of triglycerides but increased HDL cholesterol levels (Choi et al., 2012; Nordmann et al., 2006; Song et al., 2004). In a meta-analysis reviewing 27 controlled trials, replacement of dietary carbohydrates by fat (saturated and unsaturated fat) has been found to elevate HDL cholesterol level but lower serum triglyceride level (Mensink & Katan, 1992). Recent studies have indicated that the ratio of triglyceride/ HDL cholesterol level as a subset of metabolic syndrome is a valuable clinical indicator to identify subjects with insulin resistance (Kang et al., 2012; McLaughlin et al., 2005). According to Volek and Feinman (2005), this ratio can be reliably decreased by carbohydrate restriction while it is aggravated by high carbohydrate intake.

This study revealed that higher intake of carbohydrate and lower intake of fat were associated with higher waist circumference. These findings are in agreement with those of previous studies demonstrating that there is a positive association between carbohydrate intake and waist circumference in Korean women (Park et al., 2008). Abdominal fat through carbohydrate intake could increase insulin secretion which can facilitate fatty acid mobilization from adipose tissue and induce accumulation of excess body fat (Park et al., 2008). Insulin is the hormone that pushes fat into storage in adipose tissue to drive most cells to oxidize carbohydrates for energy. Metabolically active tissues such as heart, muscle and liver can intentionally lead to a perceived state of internal starvation (Park et al., 2008).

In this study, we found that increasing fat intake was associated with an increasing HDL cholesterol level but decreasing triglyceride level. High-fat diet can enhance insulin sensitivity as demonstrated by reduction in serum insulin level while reducing or maintaining serum glucose level (Westman et al., 2005). Westman et al. (2005) have suggested a possible mechanism underlying why insulin resistance is not observed on a low carbohydrate, high-fat diet. Low-carbohydrate/high-fat diet can change insulin resistance; fat oxidation became a predominant source of acetyl CoA, due to relatively low glucose appearance and uptake with lower glycolytic pressure (Cornier et al., 2005) have reported that participants with insulin-resistance show significant change in triglyceride level: 42% decrease among participants with lower dietary carbohydrate intake but 27% increase among participants with higher dietary carbohydrate intake.

High-fat and low-carbohydrate diet can significantly decrease insulin resistance compared to high-carbohydrate and low-fat diet (Entezari et al., 2017). Insulin resistance is a key feature of obesity with central or upper-body fat distribution characterized by a large waist circumference (Bradley et al., 2009). Obesity reduces insulin action and strains β-cell, thereby promoting the insulin resistance to the genesis of hyperglycemia (Esser et al., 2020). As reported previously, a higher prevalence of metabolic syndrome is particularly common in subjects with insulin resistance (Bray, 1999). Reducing carbohydrate and protein intake can decrease serum insulin level and increase serum glucagon level, thus lowering the ratio of insulin/glucagon, a key determinant of glucagon-mediated lipolysis (Westman et al., 2003). Some studies have suggested that a high-fat diet might make it possible for insulin to stimulate glycogen synthesis more effectively (Allick et al., 2004). Fat intake can decrease insulin-stimulated muscle glucose uptake through reductions in both glycolysis and glycogen synthesis because glucose-fatty acid activity and fat oxidation by a high-fat diet caused muscle insulin resistance (Petersen & Shulman, 2018). These metabolic events are responsible for increased ketone body production induced by relatively high fat intake, thus decreasing insulin levels but increasing glucagon levels, leading to glucagon-mediated lipolysis (Foster, 1984).

In our study, systolic blood pressure was higher in those with higher intake of carbohydrates but lower intake of fat. In a systematic review and meta-analysis considering 23 reports, low carbohydrate diet has been found to be associated with significant decrease in systolic blood pressure (-4.81 mm Hg, 95% *CI*: -5.33 to -4.29) (Santos et al., 2012). The higher blood pressure after carbohydrate diet might be due to hyperinsulinemia. It has been suggested that hyperinsulinemia can enhance sympathetic nervous system activity and increase heart rate, cardiac output, vascular resistance, and sodium retention, thus increasing blood pressure (Shah et al., 2007).

Our study has several limitations. Firstly, due to its cross-sectional study design, the causality of the relationship between nutrient composition and metabolic syndrome was not calculated for this study. Second, diet intake was assessed by 24-hr recall. There might be day to day variations in these measures as well as under-reporting or over-reporting. Secondly, the exact amount by the type of carbohydrates and fat could not be determined. Information regarding glycemic index, glycemic load, saturated, monounsaturated, poly unsaturated fatty acids, and dietary patterns could not be calculated. In addition, this study did not consider men. Therefore, they may differ with respect to other factors that cannot be measured. However, several studies have reported that metabolic syndrome is more positively associated with dietary components consumption and metabolic syndrome in women than in men (Volek et al., 2003). Despite these limitations, this study used data from a nationally representative Korean adult women population. Our data could be useful for preventing metabolic syndrome in healthy Korean women.

Ⅴ. Conclusion

This study revealed that high dietary carbohydrate intake and low dietary fat intake were associated with metabolic syndrome in Korean women. The prevalence of metabolic syndrome proportionally increased with higher intake of dietary carbohydrates in Korean women. On the other hand, the prevalence of metabolic syndrome decreased with higher intake of dietary fat. Future studies are needed to explore a wide range of evidence for the effect of various types of fat and carbohydrate on metabolic diseases and mechanism involved.

Declaration of Conflicting Interests

The author declares no conflict of interest with respect to the authorship or publication of this article.

References

Ainsworth, B. E., Haskell, W. L., Whitt, M. C., Irwin, M. L., Swartz, A. M., Strath, S. J.,...Emplaincourt, P. O. (2000). Compendium of physical activities: An update of activity codes and MET intensities. *Medicine and Science in Sports and Exercise, 32*(9), 498-504.

Allick, G., Bisschop, P. H., Ackermans, M. T., Endert, E., Meijer, A. J., Kuipers, F.,...Romijn, J. A. (2004). A low-carbohydrate/high-fat diet improves glucoregulation in type 2 diabetes mellitus by reducing postabsorptive glycogenolysis. *Journal of Clinical Endocrinology & Metabolism, 89*(12), 6193-6197.

Bradley, U., Spence, M., Courtney, C. H., McKinley, M. C., Ennis, C. N., McCance, D. R.,...Hunter, S. J. (2009). Low-fat versus low-carbohydrate weight reduction diets: effects on weight loss, insulin resistance, and cardiovascular risk: A randomized control trial. *Diabetes, 58*(12), 2741-2748.

Bray, G. A. (1999). Etiology and pathogenesis of obesity. *Clinical Cornerstone, 2*(3), 1-15.

Bray, G. A., & Popkin, B. M. (1998). Dietary fat intake does affect obesity! *The American Journal of Clinical Nutrition, 68*(6), 1157-1173.

Choi, H., Song, S., Kim, J., Chung, J., Yoon, J., Paik, H.-Y., & Song, Y. (2012). High carbohydrate intake was inversely associated with high-density lipoprotein cholesterol among Korean adults. *Nutrition Research, 32*(2), 100-106.

Cornier, M. A., Donahoo, W. T., Pereira, R., Gurevich, I., Westergren, R., Enerback, S.,...Eckel, R. H. (2005). Insulin sensitivity determines the effectiveness of dietary macronutrient composition on weight loss in obese women. *Obesity*

Research, 13(4), 703-709.

Entezari, M. H., Salehi, M., Rafieian-Kopaei, M., & Kafeshani, M. (2017). Fat and carbohydrate proportions influence on the insulin resistance; A systematic review and meta-analysis on controlled clinical trials. *Journal of Preventive Epidemiology, 2*(1), e02.

Esser, N., Utzschneider, K. M., & Kahn, S. E. (2020). Early beta cell dysfunction vs insulin hypersecretion as the primary event in the pathogenesis of dysglycaemia. *Diabetologia, 63*(10), 2007-2021.

Foster, D. W. (1984). From glycogen to ketones—and back. *Diabetes, 33*(12), 1188-1199.

Freire, R. D., Cardoso, M. A., Gimeno, S. G., & Ferreira, S. R. (2005). Dietary fat is associated with metabolic syndrome in Japanese Brazilians. *Diabetes Care, 28*(7), 1779-1785.

Grundy, S. M., Brewer, H. B., Cleeman, J. I., Smith, S. C., & Lenfant, C. (2004). Definition of metabolic syndrome. *Circulation, 109*(3), 433-438.

Hong, S. (2019). Association of relative handgrip strength and metabolic syndrome in Korean older adults: Korea national health and nutrition examination survey VII-1. *Journal of Obesity & Metabolic Syndrome, 28*(1), 53-60.

Hu, F. B., Stampfer, M. J., Rimm, E., Ascherio, A., Rosner, B. A., Spiegelman, D., & Willett, W. C. (1999). Dietary fat and coronary heart disease: a comparison of approaches for adjusting for total energy intake and modeling repeated dietary measurements. *The American Journal of Epidemiology, 149*(6), 531-540.

Hu, F. B., Stampfer, M. J., Manson, J. E., Rimm, E., Colditz, G. A., Rosner, B. A.,...Willett, W. C. (1997). Dietary fat intake and the risk of coronary heart disease in women. *New England Journal of Medicine, 337*(21), 1491-1499.

Julibert, A., Bibiloni, M. d. M., Mateos, D., Angullo, E., & Tur, J. A. (2019). Dietary Fat Intake and Metabolic Syndrome in Older Adults. *Nutrients, 11*(8), 1901, 1-16.

Kang, H.-T., Yoon, J.-H., Kim, J.-Y., Ahn, S.-K., Linton, J., Koh, S.-B., & Kim, J.-K. (2012). The association between the ratio of triglyceride to HDL-C and insulin resistance according to waist circumference in a rural Korean population. *Nutrition, Metabolism and Cardiovascular Diseases, 22*(12), 1054-1060.

Kang, S.-J. (2015). The association of physical activity and colorectal and breast cancer: The fifth Korea national health and nutrition examination survey (2008-2011). *Journal of Exercise Rehabilitation, 11*(3), 155-160.

Ko, S.-H., Kwon, H.-S., Song, K.-H., Ahn, Y.-B., Yoon, K.-H., Yim, H. W.,...Park, Y.-M. (2012). Long-term changes of the prevalence and control rate of hypertension among Korean adults with diagnosed diabetes: 1998-2008 Korean national health and nutrition examination survey. *Diabetes Research and Clinical Practice, 97*(1), 151-157.

Kuk, J. L., & Ardern, C. I. (2010). Age and sex differences in the clustering of metabolic syndrome factors: association with mortality risk. *Diabetes Care, 33*(11), 2457-2461.

Kweon, S., Kim, Y., Jang, M.-j., Kim, Y., Kim, K., Choi, S.,... Oh, K. (2014). Data resource profile: The Korea national health and nutrition examination survey (KNHANES). *International Journal of Epidemiology, 43*(1), 69-77.

Kwon, Y.-J., Lee, H.-S., & Lee, J.-W. (2017). Association of carbohydrate and fat intake with metabolic syndrome. *Clinical Nutrition, 37*(2), 746-751.

McLaughlin, T., Reaven, G., Abbasi, F., Lamendola, C., Saad, M., Waters, D.,...Krauss, R. M. (2005). Is there a simple way to identify insulin-resistant individuals at increased risk of cardiovascular disease? *The American Journal of Cardiology, 96*(3), 399-404.

Mensink, R. P., & Katan, M. B. (1992). Effect of dietary fatty acids on serum lipids and lipoproteins. A meta-analysis of 27 trials. *Arteriosclerosis, Thrombosis, and Vascular Biology, 12*(8), 911-919.

Nordmann, A. J., Nordmann, A., Briel, M., Keller, U., Yancy, W. S., Brehm, B. J., & Bucher, H. C. (2006). Effects of low-carbohydrate vs low-fat diets on weight loss and cardiovascular risk factors: a meta-analysis of randomized controlled trials. *Archives of Internal Medicine, 166*(3), 285-293.

Oh, J. Y., Yang, Y. J., Kim, B. S., & Kang, J. H. (2007). Validity and reliability of Korean version of international physical activity questionnaire (IPAQ) short form. *Journal of the Korean Academy of Family Medicine, 28*(7), 532-541.

Park, S., Park, M. S., & Ko, J. A. (2008). The association between carbohydrate intake and waist circumference. *The Korean*

Journal of Obesity, 17(4), 175-181.

Petersen, M. C., & Shulman, G. I. (2018). Mechanisms of insulin action and insulin resistance. *Physiological Reviews, 98*(4), 2133-2223.

Reaven, G. M. (2000). Diet and syndrome X. *Current Atherosclerosis Reports, 2*(6), 503-507.

Riccardi, G., Giacco, R., & Rivellese, A. A. (2004). Dietary fat, insulin sensitivity and the metabolic syndrome. *Clinical Nutrition, 23*(4), 447-456.

Rural Development Administration (2006). *Food composition table 7th revision.* Suwon: Author.

Santos, F., Esteves, S., da Costa Pereira, A., Yancy Jr, W., & Nunes, J. (2012). Systematic review and meta-analysis of clinical trials of the effects of low carbohydrate diets on cardiovascular risk factors. *Obesity Reviews, 13*(11), 1048-1066.

Shah, M., Adams-Huet, B., & Garg, A. (2007). Effect of high-carbohydrate or high-cis-monounsaturated fat diets on blood pressure: A meta-analysis of intervention trials. *The American Journal of Clinical Nutrition, 85*(5), 1251-1256.

Shirani, F., & Azadbakhat, L. (2011). The association between carbohydrate intake and metabolic syndrome. *Journal of Isfahan Medical School, 29*(157), 1563-1574.

Song, S., Lee, J. E., Song, W. O., Paik, H.-Y., & Song, Y. (2014). Carbohydrate intake and refined-grain consumption are associated with metabolic syndrome in the Korean adult population. *Journal of the Academy of Nutrition and Dietetics, 114*(1), 54-62.

Volek, J. S., & Feinman, R. D. (2005). Carbohydrate restriction improves the features of Metabolic Syndrome. Metabolic Syndrome may be defined by the response to carbohydrate restriction. *Nutrition & Metabolism, 2*(1), 1-17.

Volek, J. S., Sharman, M. J., Gomez, A. L., Scheett, T. P., & Kraemer, W. J. (2003). An isoenergetic very low carbohydrate diet improves serum HDL cholesterol and triacylglycerol concentrations, the total cholesterol to HDL cholesterol ratio and postprandial lipemic responses compared with a low fat diet in normal weight, normolipidemic women. *The Journal of Nutrition, 133*(9), 2756-2761.

Ministry of Health and Welfare, The Korean Nutrition Society (2019). *Welfare and family welfare dietary reference intakes for Koreans 2015.* https://www.mohw.go.kr.

Westman, E. C., Mavropoulos, J., Yancy, W. S., & Volek, J. S. (2003). A review of low-carbohydrate ketogenic diets. *Current Atherosclerosis Reports, 5*(6), 476-483.

Westman, E. C., Yancy Jr, W. S., Haub, M. D., & Volek, J. S. (2005). Insulin resistance from a low carbohydrate, high fat diet perspective. *Metabolic Syndrome and Related Disorders, 3*(1), 14-18.

Williams, L. (2002). 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) final report. *Circulation, 106*(25), 3143-3143.

Ye, E. Q., Chacko, S. A., Chou, E. L., Kugizaki, M., & Liu, S. (2012). Greater whole-grain intake is associated with lower risk of type 2 diabetes, cardiovascular disease, and weight gain. *The Journal of Nutrition, 142*(7), 1304-1313.

<국문요약>

본 연구는 2007~2016 국민건강영양조사 자료를 이용하여 한국 여성의 탄수화물과 지방 섭취 수준에 따른 대사증후군 유병율에 대한 연관성을 파악하고자 실시하였다. 연구대상은 만 19~69세의 여성으로 임신 또는 수유중인 경우를 제외한 총 22,850명을 중심으로 분석하였다. 식이 섭취 조사는 24 시간 회상법을 이용하여 탄수화물과 지방의 섭취량에 따라 5가지 군으로 구분하였다. 교란 변수(연령, 가구소득, 흡연, 음주, 운동, 에너지 섭취량, 체질량 지수, 단백질 섭취량)을 통제한 후, 들을 통제한 후, 회귀분석과 일반 선형 모형으로 탄수화물 및 지방 섭취율에 따른 대사증후군 구성요소와의 관계를 분석하였다. 탄수화물을 가장 많이 섭취하는 군은 가장 적게 섭취하는 군에 비해 중성지방(p for trend=0.04), 허리둘레(p for trend$<$0.01), 그리고 수축기 혈압(p for trend$<$ 0.01) 이 유의하게 높았으며, HDL 콜레스테롤(p for trend$<$0.01)은 낮았다. 지방을 가장 많이 섭취하는 군은 적게 섭취하는 군에 비해 허리둘레(p for trend=0.02), 중성지방(p for trend$<$0.01), 그리고 수축기 혈압(p for trend$<$0.01)은 낮았던 반면, HDL 콜레스테롤 (p for trend$<$0.01)은 더 높았다. 또한 탄수화물을 가장 많이 섭취하는 군에서 대사증후군 유병율이 나타났으며(5^{th} quintile vs. 1^{st} quintile, *OR*: 1.32; 95% *CI*: 1.11 to 1.57) 지방을 가장 많이 섭취한 군에서는 대사증후군 유병율이 더 적게(5^{th} quintile vs. 1^{st} quintile, *OR*: 0.73; 95% *CI*: 0.61 to 0.86) 나타났다. 연구 결과, 한국 여성에 있어서 과도한 탄수화물의 섭취와 적은 지방의 섭취는 대사증후군의 유병율과의 관계가 있음을 확인할 수 있었다.

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