Association of dietary intakes of total and subtypes of fat substituted for carbohydrate with metabolic syndrome in Koreans

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Abstract. Amount of fat consumption has gradually increased among Koreans, which is relatively lower than western countries. In the current study, we examined the association between dietary fat and metabolic syndrome (MetS) prevalence among Korean adults. 3,212 participants who are aged 30-74 years from the Korea National Health and Nutritional Examination Survey (KNHANES) VI (2013) were included for cross-sectional analyses. Dietary intake data was assessed using 24-hour recall method, and MetS was defined using guideline of the National Cholesterol Education Program Adult Treatment panel III (NCEP-ATP III). Multivariate logistic regression analysis was used to estimate MetS odds ratios, using nutrient density model, according to 5% percent unit of dietary fat intake. The prevalence of MetS was significantly associated with dietary intake of total fat and saturated fatty acid (SFA) after adjustment (odds ratio [OR] 0.984 95% confidence interval [CI] 0.972–0.996; OR 0.946 95% CI 0.915–0.979). When dietary intake of total fat and SFA were substituted for carbohydrate (CHO), ORs for MetS were 0.985 (95% CI 0.972–0.998) and 0.948 (95% CI 0.907–0.990), respectively, after adjusting for potential covariates. In summary, MetS was significantly associated with dietary intakes of total fat and SFA, and when substituting dietary fat for carbohydrate among Koreans.

Key words: Dietary fat, Metabolic syndrome, Nutrient density model, Korea

THE PREVALENCE of metabolic syndrome (MetS) has increased drastically in the last 20 years [1] such that 25% of world’s adult population is estimated to have MetS [2]. One of the distinct lipid-metabolic features of Koreans is the wide prevalence of hypertriglyceridemia concomitant with low high-density lipoprotein cholesterol (HDL-C) [3], reflecting a rapid increase of MetS observed in Korea from 24.9% in 1998 to 31.3% in 2007 [4]. Additionally, the prevalence of MetS is high even in patients with a relatively low body mass index (BMI) [5]. MetS, a constellation of several metabolic abnormalities, has been shown to be associated with further development of type 2 diabetes (T2DM) and cardiovascular disease (CVD) [6]. Dietary factors such as dietary carbohydrate (CHO), fish oil supplement, several micronutrients, high saturated fatty acid (SFA) and trans fatty acid diet have been considered the major dietary risk factors for improvement of public health, including MetS risk factors [7-9]. However, the association between dietary fat intake and risk of metabolic diseases is not accurately established among Koreans.
According to the reports from the Korea National Health and Nutrition Examination Survey (KNHANES) [10], fat intakes have gradually increased, accompanied by reductions in CHO intake, in the Korean population over the past 50 years. Despite rapid transitions in dietary patterns over time in Korea, dietary CHO are still the major source of energy intake. Simultaneously, fat-derived energy intake gradually increased throughout the whole period to 21.2% in 2013 [10], however, dietary fats intake have maintained relatively lower in Koreans than expected amount. While the associations between dietary CHO intakes and metabolic abnormalities have accumulated, the association between total fat and subtypes of fat and MetS has not extensively studied in this population. Therefore, we first aimed to examine the association between the energy intake from total dietary fat and the major types of dietary fat substituted for CHO and the prevalence of MetS in Korean adults whose fat intake is relatively lower than that of Western societies [11]. In order to further understand the role of dietary fat intake in the prevention of MetS, we tested the hypothesis whether substitution of a specific amount of energy from fat for the same amount of energy from CHO is associated with MetS prevalence.

**Materials and Methods**

**Study population**

To determine the association between dietary total fat and MetS, cross-sectional analysis was performed with data which were obtained from the KNHANES VI (2013). Individual dietary fatty acid was also included in variables of interest. The KNHANES is a national representative survey conducted by the Korea Centers for Disease Control and Prevention (KCDC) to assess the health and nutritional status of the Korean population. Detailed information on the KNHANES is provided elsewhere [12]. Briefly, the KNHANES included national representative samples using a stratified multi-stage probability sampling method. The participants responded to the health interview, health examination, and nutrition survey (response rate: higher than 80% for age ≥1 year). Among the 8,018 individuals who participated in the examination, we limited analysis to adults aged 30–74 years old. Subjects with missing values for important variables such as MetS risk factors and nutrient intake were excluded. Furthermore, subjects with implausible data on energy intake (<500 kcal or >5,000 kcal) or total fat intake (0 g) were excluded. We also excluded subjects diagnosed with severe diseases such as cancer, stroke, myocardial infarction, and angina pectoris. Pregnant or lactating women were excluded because of their hormonal changes. Finally, 3,212 subjects were included in the statistical analysis. We used KNHANES dataset which is available to the public and approved by the Institutional Review Board (IRB) of the KCDC. All participants were provided with a written consent form.

**General characteristics of the subjects**

We obtained data from the KNHANES including socio-demographic, anthropometric, health behavior, and medical history data. Socio-demographic traits consisted of education status and household income status. BMI was calculated as weight (kg)/height squared (m²), measured to the nearest 0.1 kg and 0.1 cm. Blood pressure was measured using a mercury sphygmomanometer (Baumanometer; NY, USA) on the right arm. Waist circumference (cm) was measured at the narrowest part between the lower rib and the iliac crest to the nearest 0.1 cm. Education level was classified into 4 categories: elementary school, middle school, high school, or university. Monthly income was reported in South Korean currency and divided into 4 groups: the lowest, lower-middle, upper-middle, or the highest. Subjects who consumed alcoholic beverages at least once in a month were regarded as current alcohol users. Additionally, subjects who smoked at time of enrollment into this study were considered current smokers. Physical activity was grouped into exercise or non-exercise according to participation in any of following 3 types of activities: intensive exercise for 20 min at least 3 days a week, moderate exercise for 30 minutes at least 5 days a week, or walking for 30 minutes at least 5 days a week. Subjects who took nutrient supplements for at least 2 weeks during the last year were considered nutrient supplement users. Diagnoses of hypertension, diabetes, and dyslipidemia were based on self-reported medical history.

**Biochemical measurements**

Data on biochemical markers were obtained from the health examination section of the KNHANES. To analyze biochemical markers, overnight fasting blood samples were collected. Serum concentration of FBG (mg/dL), TG (mg/dL), TC (mg/dL), HDL-C (mg/dL),
Dietary fat and metabolic syndrome

Dietary data were collected from the KNHANES using a 24-hour recall. Intake of macronutrients was calculated based on 24-hour recall data. Intakes of individual fatty acids including SFA, monounsaturated fatty acid (MUFA), polyunsaturated fatty acid (PUFA), omega 3 (omega 3 fatty acid) and omega 6 (omega 6 fatty acid) were also derived from 24-hour recall within the available dataset (KNHANES VI, 2013). The ratio of energy from each macronutrient and fatty acid was calculated.

Definition of metabolic syndrome
MetS was defined using the guideline of the National Cholesterol Education Program Adult Treatment panel III (NCEP-ATP III) [14]. In detail, subjects who met at least 3 of following criteria were considered MetS patients: 1) blood pressure ≥130/85 mmHg or antihypertensive drug use, 2) TG ≥150 mg/dL and taking TG lowering medications, 3) HDL-C concentration ≤40 mg/dL in men and ≤50 mg/dL in women or taking HDL-C-raising drugs, 4) WC ≥90 cm in men and ≥80 cm in women according to World Health Organization Asian specific cut off value [15], and 5) FBG ≥100 mg/dL or use of antidiabetic medication (insulin or oral agents).

Statistical analyses
Statistical analyses were performed using SPSS statistical software, version 21.0 (IBM, Chicago, USA). Continuous and categorical variables were expressed as means ± standard errors and numbers and percentages of subjects. The distribution of continuous variables was inspected to detect outliers and non-normal distribution before statistical analysis. Then, the values of FBG, TG, TC, AST, and ALT were log-transformed. To obtain representative estimates, sampling weights were used in analysis. Differences in basal characteristics, biochemical measurements, and nutrient intake according to MetS status were determined using the Student t-test and a general linear model (GLM) with Bonferroni correction for continuous variables and Chi-square test for categorical variables. The association between dietary fat intake and MetS was estimated through logistic regression with a multivariate nutrient density model. The model removes the effect of total energy intake, and provides interpretation as substituting fat for CHO, an iso-caloric substitution. In brief, models were constructed to include total energy intake, variable of interest as the percentage of energy from fat, other major types of fatty acid and protein. This allows substitution of dietary fat for same energy of CHO [16, 17]. Model 1 included the variable of interest as the percentage of energy from fat, total energy intake, and potential covariates such as age, sex, education level, physical activity, tobacco use, alcohol use, and use of nutritional supplements. Models 2 and 3 were constructed to analyze the association between dietary fat for CHO and MetS. Model 2 included the variable of interest as the percentage of energy from fat, total energy intake, and percentage of energy from protein. Model 3 included the variables of model 2 and potential covariates. Since the Odds ratio (OR) and 95% confidence intervals (95% CIs) for model 1 were interpreted as risk difference of MetS for a 5 percent-higher level of energy from fat or a major type of fatty acid, for which the same complementary amount of energy is from unspecified sources of energy. In addition, results of model 2 and model 3 were interpreted as difference in MetS risk according to 5 percent-higher level of energy from fat for the same amount of energy from CHO. P values <0.05 were considered significant.

Results

General characteristics and biochemical measurements
Basal characteristics of study subjects are presented in Table 1. Student t-test and Chi-square test was used to determine differences of basic characteristics between groups of diagnosis of MetS for continuous variables and categorical variables, respectively (p <0.05). In KNHANES VI (2013), number of missing data was 2,392 for MetS components and 676 for nutrition. Subjects with MetS were significantly older, had higher BMI, and participated more in physical activity than those without MetS (p <0.05). Subjects without MetS were more highly educated and earned higher...
**Table 1** Basic characteristics, biochemical markers and intakes of macronutrients of the study population according to metabolic syndrome status from KNHANES 2013

|                                | Total subjects (n=3,212) | Without MetS (n=2,013) | With MetS (n=1,199) | p-value 2 | p'-value 3 |
|--------------------------------|--------------------------|------------------------|---------------------|-----------|-----------|
| **Male n, (%)**                | 1,305 (9.76)            | 777 (47.5)             | 528 (53.7)          | 0.002     |           |
| **Age (years)**                | 48.6 ± 0.3              | 45.7 ± 0.3             | 53.8 ± 0.4          | <0.001    |           |
| **BMI (kg/m²)**                | 24.0 ± 0.1              | 23.0 ± 0.1             | 26.1 ± 0.1          | <0.001    |           |
| **Current drinker n, (%)**    | 1,725 (58.0)            | 1,122 (59.0)           | 603 (56.1)          | 0.123     |           |
| **Current smoker n, (%)**     | 631 (54.8)              | 391 (23.9)             | 240 (26.6)          | 0.148     |           |
| **Physical activity n, (%)**  | 1,424 (45.2)            | 922 (46.7)             | 502 (42.3)          | 0.040     |           |
| **Education n, (%)**          |                          |                        |                     |           | <0.001    |
| ≤ Elementary school           | 662 (15.9)              | 264 (10.3)             | 398 (26.3)          |           |           |
| ≤ Middle school               | 357 (10.4)              | 191 (37.6)             | 166 (13.7)          |           |           |
| ≤ High school                 | 1,120 (37.0)            | 730 (37.6)             | 390 (36.0)          |           |           |
| ≥ University                  | 1,070 (36.6)            | 827 (43.5)             | 243 (24.0)          |           |           |
| **Income status n, (%)**      |                          |                        |                     |           | <0.001    |
| Lowest                        | 494 (12.6)              | 220 (9.5)              | 274 (18.3)          |           |           |
| Lower middle                  | 840 (25.4)              | 516 (24.8)             | 324 (26.3)          |           |           |
| Upper middle                  | 906 (30.5)              | 583 (30.7)             | 323 (30.1)          |           |           |
| Highest                       | 958 (31.6)              | 684 (35.0)             | 274 (25.3)          |           |           |
| **Physician diagnosis n, (%)**|                          |                        |                     |           |           |
| Hypertension                  | 610 (19.0)              | 25 (1.3)               | 585 (43.7)          | <0.001    |           |
| Diabetes                      | 260 (8.1)               | 54 (2.5)               | 206 (15.1)          | <0.001    |           |
| Dyslipidemia                  | 438 (13.6)              | 146 (6.2)              | 292 (22.0)          | <0.001    |           |
| **Biochemical markers**       |                          |                        |                     |           |           |
| FBG (mg/dL)                   | 99.9 ± 0.5              | 94.9 ± 0.7             | 108.2 ± 1.0         | <0.001    | <0.001    |
| TG (mg/dL)                    | 146.2 ± 2.8             | 111.6 ± 0.5            | 216.6 ± 5.3         | <0.001    | <0.001    |
| TC (mg/dL)                    | 191.8 ± 0.8             | 189.6 ± 1.1            | 196.2 ± 1.9         | <0.001    | 0.001     |
| HDL (mg/dL)                   | 47.5 ± 0.2              | 40.5 ± 0.3             | 42.4 ± 0.4          | <0.001    | <0.001    |
| LDL (mg/dL)                   | 116.4 ± 0.7             | 128.4 ± 2.8            | 170.9 ± 9.8         | <0.001    | <0.001    |
| AST (IU/L)                    | 22.3 ± 0.3              | 21.7 ± 0.4             | 24.7 ± 0.6          | <0.001    | <0.001    |
| ALT (IU/L)                    | 22.9 ± 0.5              | 20.9 ± 0.6             | 29.2 ± 1.0          | <0.001    | <0.001    |
| SBP (mmHg)                    | 117.5 ± 0.4             | 113.4 ± 0.5            | 125.9 ± 0.7         | <0.001    | <0.001    |
| DBP (mmHg)                    | 76.6 ± 0.3              | 74.0 ± 0.4             | 81.4 ± 0.5          | <0.001    | <0.001    |
| **Nutrient intakes**          |                          |                        |                     |           |           |
| Total energy (kcal)           | 2,073.6 ± 17.7          | 2,074.9 ± 29.6         | 2,051.7 ± 34.9      | 0.068     | 0.511     |
| Carbohydrate (%)              | 63.8 ± 0.3              | 64.2 ± 0.4             | 63.9 ± 0.6          | <0.001    | 0.610     |
| Protein (%)                   | 13.9 ± 0.1              | 13.7 ± 0.1             | 13.6 ± 0.2          | 0.003     | 0.404     |
| Fat (%)                       | 17.9 ± 0.2              | 17.6 ± 0.3             | 16.7 ± 0.3          | <0.001    | 0.013     |
| SFA (%)                       | 5.1 ± 0.1               | 5.2 ± 0.1              | 4.8 ± 0.1           | <0.001    | <0.001    |
| MUFA (%)                      | 5.6 ± 0.1               | 5.5 ± 0.1              | 5.2 ± 0.1           | <0.001    | 0.016     |
| PUFA (%)                      | 4.5 ± 0.1               | 4.4 ± 0.1              | 4.2 ± 0.1           | <0.001    | 0.336     |
| Omega 6 (%)                   | 3.86 ± 0.05             | 3.71 ± 0.07            | 3.61 ± 0.09         | <0.001    | 0.332     |
| Omega 3 (%)                   | 0.69 ± 0.02             | 0.67 ± 0.02            | 0.65 ± 0.03         | 0.517     | 0.615     |

1 The values of age, body mass index, biochemical markers and nutrient intake were represented as means ± standard errors. The values of males, alcohol use, tobacco use, physical activity, education status, income status, physician diagnosis, and use of nutrient supplementation were represented as the percentage of total subjects.

2 Differences of basic characteristics between groups of diagnosis of metabolic syndrome were determined using Student t-test for continuous variables, and Chi-square test for categorical variables (p<0.05).

3 Statistical significance of biochemical markers and nutrient intake difference were determined by the general linear model (GLM) with the Bonferroni’s multiple correction (p <0.05) after adjusting for sex, alcohol use (non-drinkers/current drinkers), tobacco use (non-smokers/current smokers), physical activity (non-exercised/exercised), education status (≤elementary/middle school/high school/≥University), and intake of nutrient supplementation (non-user/user).

4 Macronutrients to energy was calculated as the ratio of energy from each macronutrient to total energy.

AST, aspartate transaminase; ALT, alanine transaminase; DBP, diastolic blood pressure; FBG, fasting blood glucose; MUFA, monounsaturated fatty acid; omega 3, omega 3 fatty acid; omega 6, omega 6 fatty acid; PUFA, polyunsaturated fatty acid; SBP, systolic blood pressure; SFA, saturated fatty acid; TG, triglyceride; TC, total cholesterol.
income than those with MetS ($p <0.001$). Prevalence of hypertension, diabetes, and dyslipidemia was higher in participants diagnosed with MetS. Biochemical measurements and intake of major macronutrients were also compared by using GLM with the Bonferroni’s multiple correction, which are shown in Table 1. Subjects with MetS had significantly higher FBG, TG, TC, HDL-C, LDL-C, AST, ALT and blood pressure than those without MetS before and after adjustment ($adjusted \ p <0.01$). Additionally, the subjects with MetS consumed less total fat, SFA, and MUFA ($adjusted \ p <0.05$). Potential confounders used in the analysis were sex, alcohol use, tobacco use, physical activity, education status, and intake of nutrient supplementation, which were considered to affect both exposure and outcome variables.

**Association between dietary fat intake and metabolic syndrome prevalence**

Cross-sectional estimates of dietary fat for MetS are presented in Table 2 using binary logistic regression analysis. In the analysis, fat, CHO and protein were grouped in 5% unit. Energy from total fat was associated with lower prevalence of MetS in total and in male subjects before and after adjustment which was prominent in middle-aged subjects. Furthermore, a 5% increase of energy from fat, which is substituted for the same energy from dietary CHO, was significantly associated with lower prevalence of MetS in total and in male subjects after adjusting for potential covariates. On the basis of significant association between dietary fat and MetS, we further analyzed the association of individual fatty acid with the prevalence of MetS using the available dataset, the KNHANES VI (2013). Energy from SFA and MUFA was negatively associated with risk of MetS in total and in male subjects before and after adjusting confounders. Similarly, a 5% increment of energy from SFA for CHO was associated with decreased prevalence of MetS in total subjects and in men. This association was stronger in middle-aged men; no significant association was found in older subjects and women (Table 3).

**Table 2** Odds ratio of metabolic syndrome according to intake of 5% higher level of energy from dietary fat

|                  | Total (n=3,212) | Men (n=1,305) | Women (n=1,907) |
|------------------|----------------|--------------|-----------------|
|                  | OR (95% CI) 1 | OR (95% CI) | OR (95% CI)     |
| **Total fat**    |               |              |                 |
| Model 1 2        | 0.984 (0.972, 0.996) | 0.976 (0.958, 0.994) | 0.997 (0.980, 1.014) |
| Total fat for CHO| Model 2       |              |                 |
|                  | 0.894 (0.867, 0.922) | 0.886 (0.944, 0.978) | 0.911 (0.877, 0.946) |
|                  | Model 3       |              |                 |
|                  | 0.985 (0.972, 0.998) | 0.976 (0.957, 0.994) | 0.999 (0.981, 1.017) |
| **SFA**          |               |              |                 |
| Model 1          | 0.946 (0.915, 0.979) | 0.910 (0.864, 0.958) | 0.995 (0.952, 1.040) |
| SFA for CHO      | Model 2       |              |                 |
|                  | 0.894 (0.867, 0.922) | 0.886 (0.842, 0.932) | 0.911 (0.877, 0.946) |
|                  | Model 3       |              |                 |
|                  | 0.948 (0.907, 0.990) | 0.897 (0.838, 0.961) | 1.016 (0.961, 1.073) |
| **MUFA**         |               |              |                 |
| Model 1          | 0.964 (0.935, 0.994) | 0.952 (0.911, 0.994) | 0.982 (0.945, 1.021) |
| MUFA for CHO     | Model 2       |              |                 |
|                  | 0.913 (0.887, 0.939) | 0.925 (0.886, 0.964) | 0.907 (0.872, 0.944) |
|                  | Model 3       |              |                 |
|                  | 1.001 (0.960, 1.044) | 1.021 (0.961, 1.085) | 0.978 (0.930, 1.028) |
| **PUFA**         |               |              |                 |
| Model 1          | 0.983 (0.952, 1.015) | 0.980 (0.936, 1.026) | 0.982 (0.936, 1.031) |
| PUFA for CHO     | Model 2       |              |                 |
|                  | 0.948 (0.918, 0.978) | 0.925 (0.886, 0.964) | 0.952 (0.911, 0.994) |
|                  | Model 3       |              |                 |
|                  | 0.995 (0.961, 1.031) | 0.993 (0.944, 1.045) | 0.993 (0.942, 1.046) |

1 Differences were tested using binary logistic regression analysis adjusting for the variables of each model.  
2 Model 1 included the variable of interest as the percentage of energy from fat, total energy intake, and potential covariates such as age, sex, alcohol use (non-drinkers/current drinkers), tobacco use (non-smokers/current smokers), physical activity (non-exercised/exercised), education status (≤elementary/middle school/high school/≥University), and intake of nutrient supplementation (non-user/user). Model 2 included the variable of interest as the percentage of energy from interested fat, total energy intake, and percentage of energy from protein. Model 3 included the variables of model 2 plus the potential covariates.  
$P$ values $<0.05$ were considered significant. CHO, carbohydrate; CI, confidence interval; MUFA, monounsaturated fatty acid; OR, odds ratio; PUFA, polyunsaturated fatty acid; SFA, saturated fatty acid; yrs, years.
In the present study, we found that higher levels of energy intake from total fat and SFA were associated with a lower prevalence of MetS in Korean adults. In addition, substituting a specific amount of energy from fat for the same amount of energy from CHO was negatively associated with MetS prevalence. These observations were the strongest in men aged 30–64 years old.

It has been reported that dietary fat is associated with the risk of diabetes and CVD [18] mainly through the raising effect on circulating LDL [19]. However, association between dietary fat intake and metabolic abnormalities such as MetS and T2DM has been inconsistently reported in both cross-sectional [20, 21], prospective studies [22-24] and intervention study [25]. A meta-analysis of controlled trials showed that effects of dietary fat on CVD are less clear [26]. Conflicting results may be attributed to different study designs, populations, food sources, and possible interaction with other nutritional factors. Especially with regard to the health effect of SFA, it has been widely accepted that SFA intake is one of the risk factors for CVD. The Multi-Ethnic Study of Atherosclerosis showed that intake of SFA from meat was positively associated with atherosclerosis [27]. Another cross-sectional study showed that SFA consumption was positively associated with MetS [28].

However, recent observations have suggested fewer adverse health effects of SFA on metabolic health than previous speculated. Interestingly, Siri-Tarino et al. observed no relationship between SFA and CHD, stroke, and CVD in a meta-analysis of 21 prospective studies [29]. In line with this, a meta-analysis of prospective studies found no significant relation-

| Table 3 | Odds ratio of metabolic syndrome according to intake of 5% higher level of energy from dietary fat by sex and age group |
|---------|--------------------------------------------------------------------------------------------------|
|         | Total (n=3,212)                                                                                   |
|         | Total fat                                                                                         |
|         | Model 1                                            | OR (95% CI) |
|         | 0.975 (0.962, 0.989)                                                                               |
|         | Model 2                                            | OR (95% CI) |
|         | 0.958 (0.945, 0.971)                                                                               |
|         | Model 3                                            | OR (95% CI) |
|         | 0.974 (0.960, 0.988)                                                                               |
|         | Total fat for CHO                                                                                 |
|         | Model 1                                            | OR (95% CI) |
|         | 0.908 (0.873, 0.946)                                                                               |
|         | Model 2                                            | OR (95% CI) |
|         | 0.870 (0.816, 0.928)                                                                               |
|         | Model 3                                            | OR (95% CI) |
|         | 0.884 (0.829, 0.942)                                                                               |
|         | SFA                                                                                               |
|         | Model 1                                            | OR (95% CI) |
|         | 0.908 (0.905, 0.975)                                                                               |
|         | Model 2                                            | OR (95% CI) |
|         | 1.011 (0.951, 1.075)                                                                               |
|         | Model 3                                            | OR (95% CI) |
|         | 1.030 (0.969, 1.096)                                                                               |
|         | MUFA                                                                                              |
|         | Model 1                                            | OR (95% CI) |
|         | 0.940 (0.905, 0.975)                                                                               |
|         | Model 2                                            | OR (95% CI) |
|         | 1.011 (0.951, 1.075)                                                                               |
|         | Model 3                                            | OR (95% CI) |
|         | 1.030 (0.969, 1.096)                                                                               |
|         | PUFA                                                                                              |
|         | Model 1                                            | OR (95% CI) |
|         | 0.977 (0.936, 1.020)                                                                               |
|         | Model 2                                            | OR (95% CI) |
|         | 0.982 (0.936, 1.030)                                                                               |
|         | Model 3                                            | OR (95% CI) |
|         | 0.995 (0.947, 1.046)                                                                               |

1 Differences were tested using binary logistic regression analysis adjusting for the variables of each model.
2 Model 1 included the variable of interest as the percentage of energy from fat, total energy intake, and potential covariates such as age, sex, alcohol use (non-drinkers/current drinkers), tobacco use (non-smokers/current smokers), physical activity (non-exercised/exercised), education status (≤elementary/middle school/high school/≥University), and intake of nutrient supplementation (non-user/user). Model 2 included the variable of interest as the percentage of energy from interested fat, total energy intake, and percentage of energy from protein. Model 3 included the variables of model 2 plus the potential covariates.
P values <0.05 were considered significant. CHO, carbohydrate; CI, confidence interval; MUFA, monounsaturated fatty acid; OR, odds ratio; PUFA, polyunsaturated fatty acid; SFA, saturated fatty acid; yrs, years.

Discussion

In the present study, we found that higher levels of energy intake from total fat and SFA were associated with a lower prevalence of MetS in Korean adults. In addition, substituting a specific amount of energy from fat for the same amount of energy from CHO was negatively associated with MetS prevalence. These observations were the strongest in men aged 30–64 years old.

It has been reported that dietary fat is associated with the risk of diabetes and CVD [18] mainly through the raising effect on circulating LDL [19]. However, association between dietary fat intake and metabolic abnormalities such as MetS and T2DM has been inconsistently reported in both cross-sectional [20, 21], prospective studies [22-24] and intervention study [25]. A meta-analysis of controlled trials showed that effects of dietary fat on CVD are less clear [26]. Conflicting results may be attributed to different study designs, populations, food sources, and possible interaction with other nutritional factors. Especially with regard to the health effect of SFA, it has been widely accepted that SFA intake is one of the risk factors for CVD. The Multi-Ethnic Study of Atherosclerosis showed that intake of SFA from meat was positively associated with atherosclerosis [27]. Another cross-sectional study showed that SFA consumption was positively associated with MetS [28].

However, recent observations have suggested fewer adverse health effects of SFA on metabolic health than previous speculated. Interestingly, Siri-Tarino et al. observed no relationship between SFA and CHD, stroke, and CVD in a meta-analysis of 21 prospective studies [29]. In line with this, a meta-analysis of prospective studies found no significant relation-
ship between SFA intake and cardiovascular mortality, total CVD, ischemic stroke, and T2DM [21]. It is well known that reductions in SFA intake usually are accompanied by an increased proportion of CHO intake [30]. Replacement of SFA with a higher CHO intake, particularly refined CHO, can exacerbate the atherogenic dyslipidemia that includes increased TG, small LDL particles, and reduced HDL-C [31]. Consistent with the current perspective on the role of dietary fat [32], our results showed negative associations between both dietary fat and SFA intake and MetS prevalence in a Korean population whose fat consumption is lower than Western people [11]. Among the dietary options that can be implemented to replace CHO, CHO substituted with SFA showed inverse relation to MetS in this study. Similar to our results, Park et al. [33] very recently found that higher prevalence of MetS was associated with low dietary fat intake in Korean population. However, they did not observe which individual fatty acid contributed to the result. In addition, this is further supported by the observations from KNHANES 2008-2011 that the participants with higher consumptions of eggs, fish, seafood, and milk showed negative association with MetS prevalence (data not shown). According to a study conducted in 2013, egg and milk were known as main contributors to dietary fat and SFA in Koreans aged 30 years and over [34]. Our finding is in line with the results of a randomized cross-over clinical trial that moderate replacement of CHO by dietary fats resulted in lower prevalence of MetS [35]. It was also reported that substitution of SFA for CHO exhibited increases in HDL-C with no noticeable effect on the total HDL-C ratio increases in TC to HDL-C [9]. It is well established that high CHO intake induces atherogenic dyslipidemia. Dietary CHO and excess calories have been shown to increase hepatic TG stores, thereby driving the secretion of large TG-enriched particles that undergo intravascular lipolysis and remodeling, ultimately giving rise to small dense LDL [36]. In the present study, we observed gender and age related difference in the association of dietary total fat and saturated fat with the MetS. Significance in the observed associations disappeared in women and older participants. While no exact underlying pathway can be clarified, it is possible that the association of dietary SFAs with MetS in this study may be that lower intakes of SFAs were accompanied by compensatory increases in CHO, of which main food sources were white rice, glutinous rice and bread in Korean population [10]. More interestingly, we found that people aged 65–74 years old and women in the study population showed significantly higher intake of CHO than those aged less than 65 years old and men, respectively (data not shown). This may imply that association between fat intake, specifically SFA, and MetS is modified by the amount of CHO among Koreans. Also, the qualities of CHO substituted with dietary fat were possibly different among the gender age group, which was not proven in this study. Alternatively, there may exist underlying biological interaction in hormonal regulation and metabolic pathway according to age and gender. Further study is needed to elucidate the underlying biological pathways.

There are some limitations in the current study. First, there is a possibility of misclassification as the data are derived from nutritional data surveyed using a one-day 24-hour recall method. Second, we were not able to specify the types of CHO, because types of CHO were not available in the KNHANES data. Third, since the KNHANES provided data of major types of fatty acids only in the KNHANES VI (2013), a relatively small population was available for the individual fatty acid investigation. Despite these limitations, we have several strengths in this study. To our knowledge, this is the first study to investigate the association of MetS with individual fatty acids in Korean population. Second, we used a nutrition density model, which may account for practical dietary nutrition intake. Third, we used KNHANES data which to provides representative results of the entire Korean population. Finally, various potential confounding factors were considered in model construction for the Korean population.

In summary, we report that dietary intakes of total fat and SFA were negatively associated with the prevalence for MetS and the substitution of these fats for CHO displayed metabolic health benefits in Korean adults. Further research on the underlying pathway of dietary fat and MetS based on physiological mechanism is warranted. We speculate that modification of macronutrient composition is effective in reducing the risk of MetS and relevant metabolic abnormalities in Koreans.

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Disclosure

The authors declare no conflicts of interest in this article.

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