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Original Article

Carbohydrate Composition Associated with the 2-Year Incidence of Metabolic Syndrome in Korean Adults

Nam H. Cho,[1] Ara K. Cho,[1] Hyun Kyu Kim,[1] Jong Bae Kim,[1] Kyung Eun Lee,[1] Sung Soo Kim,[2] Yeon-Jung Kim,[2] Hak C. Jang,[3] Inkyung Baik[4]

[1]Department of Preventive Medicine, Ajou University School of Medicine, Suwon 16499, Korea
[2]Division of Epidemiology and Health Index, Center for Genome Science, Korea National Institute of Health, Korea Centers for Disease Control and Prevention, Cheongwon 28159, Korea
[3]Department of Internal Medicine, Seoul National University Bundang Hospital, Seongnam 13620, Korea
[4]Department of Foods and Nutrition, Kookmin University College of Science and Technology, Seoul 02707, Korea

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Correspondence to
Nam H. Cho
Department of Preventive Medicine, Ajou University School of Medicine, 164 World cup-ro, Yeongtong-gu, Suwon 16499, Korea.
Tel: +82-31-219-5083
Fax: +82-31-219-5084
E-mail: chnaha@ajou.ac.kr

Correspondence to
Inkyung Baik
Department of Foods and Nutrition, Kookmin University College of Science and Technology, 77 Jeongneung-ro, Seongbuk-gu, Seoul 02707, Korea.
Tel: +82-2-910-4774
Fax: +82-2-910-5249
E-mail: ibaik@kookmin.ac.kr

ORCID
Nam H. Cho
http://orcid.org/0000-0003-4187-0929
Inkyung Baik
http://orcid.org/0000-0002-9524-4344

ABSTRACT

The aim of this study was to investigate the association between macronutrient composition and metabolic syndrome (MetS) incidence in Korean adults. Data were obtained from a cohort of 10,030 members aged 40 to 69 years who were enrolled from the 2 cities (Ansung and Ansan) between 2001 and 2002 to participate in the Korean Genome Epidemiology Study. Of these members, 5,565 participants, who were free of MetS and reported no diagnosis of cardiovascular disease at baseline, were included in this study. MetS was defined using the criteria of the National Cholesterol Education Program-Adult Treatment Panel III and Asia-Pacific criteria for waist circumference. MetS incidence rate were identified during a 2-year follow-up period. Baseline dietary information was obtained using a semi-quantitative food frequency questionnaire. Multivariate logistic regression analysis was used to evaluate the association between the quartiles of percentages of total calorie from macronutrients consumed and MetS incidence. In analyses, baseline information, including age, sex, body mass index, income status, educational status, smoking status, alcohol drinking status, and physical activity level was considered as confounding variables. Participants with the second quartile of the percentages of carbohydrate calorie (67%–70%) had a 23% reduced odds ratio (95% confidence interval, 0.61–0.97) for MetS incidence compared with those with the fourth quartile after adjusting for confounding variables. The findings suggest that middle aged or elderly Korean adults who consume approximately 67%–70% of calorie from carbohydrate have a reduced risk of MetS.

Keywords: Metabolic syndrome; Macronutrient composition; Carbohydrate; Korean adults; Prospective cohort study

INTRODUCTION

The term of metabolic syndrome (MetS) was first described in 1988 by Reaven [1] and is characterized by dyslipidemia, high blood pressure (BP), glucose intolerance (or diabetes), and visceral obesity. According to the National Cholesterol Education Program-Adult Treatment Panel III (NCEP-ATP III), untreated MetS increases mortality and the risk of chronic diseases [2]. In recent years, the rising prevalence of MetS has posed a grave social

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Conflict of Interest

The authors declare that they have no competing interests.

problem in most countries, including South Korea. The age-adjusted prevalence of MetS has increased significantly over the years, 24.9% in 1998, 29.2% in 2001, 30.4% in 2005, and 31.3% in 2007. Over the last 10 years in Korea, a 13.8% decrease in high-density lipoprotein (HDL) cholesterol levels has been the most significant change among the 5 diagnostic components of MetS, followed by abdominal obesity and hypertriglyceridemia with 8.7% and 4.9% increases, respectively [3]. A number of risk factors, such as age, social-economic status, educational level, alcohol consumption, smoking, exercise, stress, and dietary factors have been reported to have significant associations with MetS [4-8].

The Korea National Health and Nutrition Examination Survey (KNHANES) listed carbohydrate-rich foods such as rice as a major energy source for Korean people. Some studies reported that a high percentage of total calorie from carbohydrate is associated with the prevalence of MetS [9,10] whereas others observed no or an inverse association between carbohydrate intake and the prevalence of MetS [11-13]. These discrepancies may be partly due to a higher percentage of total calorie from carbohydrate in a typical Korean diet than that in a typical Western diet. Currently, 55%–65% for carbohydrate, 7%–20% for protein, and 15%–30% for fat are recommended as calorie proportions for Korean adults, whereas 45%–65% for carbohydrate, 10%–35% for protein, and 20%–35% for fat are suggested for adults according to the US dietary guideline; higher ranges of protein and fat composition and a lower limit of the carbohydrate percentage are set as a recommended macronutrient composition for US adults [14,15]. Thus, directions of the association between macronutrient composition and MetS may vary depending on macronutrient consumption in a typical diet. In addition, because earlier studies observed the prevalence of MetS [9-13] and there are no prospective studies on the association between macronutrient composition and MetS incidence, its causal relationship is still unclear.

The present study evaluated whether macronutrient composition is associated with the incident risk of MetS and what percentages of calorie from macronutrients are optimal to significantly reduce the MetS risk in a Korean adult population. Particularly, we examined 2-year MetS incident cases in an ongoing, prospective, community-based cohort study because dietary habits are less likely to be changed in this short-term period.

MATERIALS AND METHODS

Study population

A total of 10,030 (4,757 men and 5,273 women) participants from 2 communities, Ansung as a rural community and Ansan as an urban community, were recruited from 2001 to 2002. Eligibility criteria were as follows: age of 40–69 years, residence within the borders of the survey area for at least 6 months before testing, and having sound mental and physical abilities. Of the 7,192 eligible subjects in the rural farming community of Ansung, 5,018 subjects were recruited (response rate of 70%) using a cluster sampling method. For the Ansan community, which included a population of 554,998 in the year 2000, a random sample of 5,012 subjects was successfully recruited from the 124,775 eligible subjects using the local telephone directory. For this study, we excluded 285 participants who reported the diagnosis of cardiovascular diseases because these diseases are considered to be associated with MetS and are likely to modify a usual dietary habit after diagnosis. In addition, 2,789 participants were excluded due to the diagnosis of MetS at baseline because this study investigated MetS incidence. Furthermore, 1,391 participants with missing values of weight

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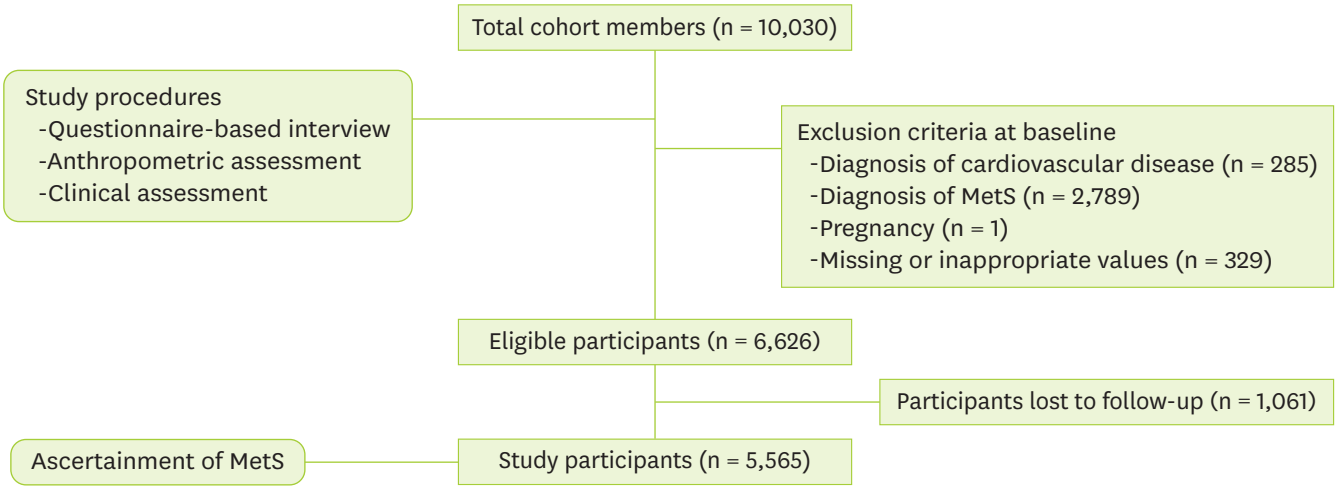

Figure 1. Flowchart of the study participants and procedures.
MetS, metabolic syndrome.

and total calorie intake, inacceptable values of total calorie intake (> 5,000 kcal/day), or pregnancy at baseline or those who were not followed-up after 2 years were excluded. Finally, 5,565 participants were included in the present study (**Figure 1**).

The study protocol was approved by the Ethics Committee of the Korea Center for Disease Control and Institutional Review Board either at the Ajou University School of Medicine or at the Korea University Ansan Hospital.

Study procedures

All participants visited a community clinic to take questionnaire-based interviews and anthropometry and clinical assessments (**Figure 1**). Demographic and socioeconomic information and data of lifestyle factors, such as smoking status, alcohol drinking status, and physical activity, were collected using a standard questionnaire during a face-to-face interview.

Height and body weight were measured by standard methods while wearing light clothing. Body mass index (BMI) was calculated as weight divided by height squared (kg/m^2). Waist circumference (WC) was measured using a flexible measuring tape at the most slender point of the trunk, or the middle point between the 10th rib and the iliac crest, with the tape parallel to the floor and under normal tension. The average value was used after measuring 3 times at the same site using the same measurement method.

Repeated measurements of BP were performed for the left and right arms of each subject in a sitting position using a mercury sphygmomanometer. The measurements were recorded to the nearest 2 mmHg and its average was calculated for systolic and diastolic BP.

All participants fasted for at least 8 hours before blood collection. Serum samples were collected for assays of triglycerides and HDL cholesterol, which were assessed enzymatically using an autoanalyzer (ADVIA® 1650 Chemistry System; Siemens, Deerfield, IL, USA). For the evaluation of glucose metabolism, fasting levels of plasma glucose were measured. Plasma glucose levels were determined using the hexokinase method (Linco Research, St. Charles, MO, USA).

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Dietary assessment was conducted using a semi-quantitative food frequency questionnaire (FFQ), which includes 103 food items and has been validated earlier [16]. The FFQ was administered by trained researchers. Consumption frequency was classified as followed: never or seldom, once a month, 2–3 times a month, 1–2 times a week, 3–4 times a week, 5–6 times a week, once a day, twice a day, or 3 or more times a day. After converting the amount of macronutrients, including carbohydrate, protein and fat, to calories, percentages of total calorie from each macronutrient were calculated.

Diagnosis of MetS

MetS was defined in accordance with the NCEP-ATP III guidelines and the Asia-Pacific criteria for WC. Participants with 3 of the 5 diagnostic components were considered to have MetS and the criteria for the components are as follows: WC, ≥ 90 cm for men and ≥ 80 cm for women; systolic BP/diastolic BP, 130/85 mmHg or greater or treatment with anti-hypertensive drugs; HDL-cholesterol, < 40 mg/dL for men and < 50 mg/dL for women; triglycerides, 150 mg/dL or greater; and fasting plasma glucose, 100 mg/dL or greater or treatment with anti-diabetic drugs.

Statistical analysis

All statistical analyses were performed with Statistical Package for Social Science software (SPSS ver. 12.0; SPSS Inc., Chicago, IL, USA). Descriptive statistics such as mean ± standard deviation (SD) and percentages were obtained.

Potential confounding variables including age (continuous variable), sex, income status (monthly family income < 1,000,000 vs. ≥ 1,000,000 won), educational status (< high school graduation vs. ≥ high school graduation), smoking status (never smoking, former smoking, current smoking ≤ 10, 11–20, > 20 cigarettes/day), alcohol consumption status (never drinking, former drinking, current drinking < 16, 16–30, > 30 g/day of alcohol), BMI (< 21, 21–22, 23–24, 25–26, 27–28, > 28 kg/m^2), and physical activity level (quartiles) were considered in the analysis.

The comparison of these variables and total calorie and macronutrient intake between participants without MetS and incident cases of MetS were evaluated using the χ^2 test for categorical variables and the Student's t-test for continuous variables. To evaluate associations of the percentage of total calorie from each macronutrient with the 2-year risk of MetS and the baseline MetS components, multivariate logistic regression analysis was conducted considering potential confounding variables. Statistical significance was defined as $p < 0.05$ for 2-sided tests.

RESULTS

Table 1 demonstrates the comparison between baseline characteristics among participants without MetS and incident cases of MetS. MetS cases were likely to be older and females, to have low economic and educational status, greater BMI, and higher physical activity levels, and to consume less amounts of fat and greater percentages of total calorie from carbohydrate. However, total calorie and carbohydrate intake were not significantly different between the 2 groups.

Table 2 shows the results regarding the association of the percentages of total calorie from macronutrients consumed with the MetS risk. These percentages were classified into quartiles and the fourth quartile was used as a reference to estimate odds ratio (OR) and its 95% confidence interval (CI) of the MetS risk for other quartile groups. Participants in

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Table 1. Baseline characteristics according to MetS incidence in 5,565 participants

Variables	No MetS (n = 4,744)	MetS incidence cases (n = 821)	p value
Age, yr	50.6 ± 8.6	53.5 ± 8.8	< 0.001
Male	53.2	42.1	< 0.001
Low income status	27.9	41.1	< 0.001
Low educational status	48.6	66.4	< 0.001
Current smoker	27.0	24.6	0.15
Current alcohol drinker	52.2	48.4	0.04
BMI, kg/m^2	23.5 ± 2.8	25.5 ± 2.9	< 0.001
Total calorie intake, kcal	1,881.7 ± 582.8	1,870.1 ± 606.5	0.61
Carbohydrate, g	329.4 ± 96.6	333.8 ± 108.0	0.28
Protein, g	64.4 ± 25.3	62.9 ± 24.4	0.11
Fat, g	31.4 ± 17.5	28.9 ± 17.1	< 0.001
Carbohydrate*	70.6 ± 6.5	71.7 ± 7.0	< 0.001
Protein*	13.5 ± 2.3	13.4 ± 2.4	0.12
Fat*	14.5 ± 5.1	13.5 ± 5.4	< 0.001
Physical activity, MET-hours	31.2 ± 15.3	32.4 ± 16.1	0.04

Data are expressed as mean ± SD or percentage.

MetS, metabolic syndrome; BMI, body mass index; MET-hours, metabolic equivalent values; SD, standard deviation.

*Percentages of total calorie from a specific macronutrient.

Table 2. OR and 95% CI for the association between the percentages of total calorie from macronutrients and MetS incidence

Macronutrients	OR (95% CI) for MetS risk according to the quartiles of macronutrient composition			
	1st quartile	2nd quartile	3rd quartile	4th quartile
Carbohydrate range, %	34–66	67–70	71–75	76–89
MetS cases/non-cases, No.	190/1,201	162/1,229	206/1,186	263/1,128
Model 1	0.84 (0.68–1.05)	0.68 (0.55–0.85)	0.84 (0.69–1.03)	Reference
Model 2	0.87 (0.70–1.09)	0.69 (0.55–0.86)	0.85 (0.69–1.05)	Reference
Model 3	0.97 (0.77–1.23)	0.77 (0.61–0.97)	0.91 (0.73–1.13)	Reference
Protein range, %	7–11	12	13–14	15–28
MetS cases/non-cases, No.	246/1,145	188/1,203	193/1,199	194/1,197
Model 1	1.11 (0.90–1.37)	0.90 (0.73–1.12)	0.96 (0.77–1.19)	Reference
Model 2	1.22 (0.98–1.52)	0.94 (0.75–1.18)	0.99 (0.79–1.25)	Reference
Model 3	1.10 (0.87–1.38)	0.91 (0.72–1.14)	0.99 (0.79–1.25)	Reference
Fat range, %	1–10	11–13	14–17	18–44
MetS cases/non-cases, No.	256/1,135	210/1,181	185/1,207	170/1,221
Model 1	1.28 (1.03–1.60)	1.15 (0.92–1.43)	1.07 (0.85–1.33)	Reference
Model 2	1.22 (0.97–1.54)	1.10 (0.87–1.38)	1.02 (0.81–1.29)	Reference
Model 3	1.11 (0.87–1.41)	1.05 (0.83–1.33)	1.03 (0.82–1.31)	Reference

In model 1, data were adjusted for age; model 2, data were adjusted for age, sex, and BMI (< 21, 21–22, 23–24, 25–26, 27–28, > 28 kg/m^2); model 3, data were adjusted for age (continuous), sex, BMI (< 21, 21–22, 23–24, 25–26, 27–28, > 28 kg/m^2), income status (monthly family income < 1,000,000 vs. ≥ 1,000,000 won), educational status (< high school graduation vs. ≥ high school graduation), smoking status (never smoking, former smoking, current smoking ≤ 10, 11–20, > 20 cigarettes/day), alcohol consumption status (never drinking, former drinking, current drinking < 16, 16–30, > 30 g/day of alcohol), and physical activity level (quartiles).

OR, odds ratio; CI, confidence interval; MetS, metabolic syndrome; BMI, body mass index.

the second quartile for carbohydrate (range, 67%–70%) had a 23% reduced OR (95% CI, 0.61–0.97) compared with the reference group (range, 76%–89%) even after adjusting for all potential confounding variables. However, other multivariate ORs were not significant.

Furthermore, we evaluated the association between the percentage of total calorie from carbohydrate consumed and the baseline prevalence of the MetS diagnostic components (**Table 3**). The results show that the associations between the second quartile of carbohydrate composition and the MetS components were not significant. Those in the first quartile (range, 34%–66%) had a 19% reduced OR (95% CI, 0.66–0.99) for low HDL cholesterol level and those in the third quartile (range, 71%–75%) showed a 22% (95% CI, 0.66–0.93) reduced OR for high BP compared with the reference group.

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Table 3. Multivariate OR and 95% CI for the association between the percentages of total calorie from carbohydrate and the baseline MetS components

MetS components	No. of cases (%)	OR (95% CI) for MetS components according to the quartiles of carbohydrate composition			
		1st quartile	2nd quartile	3rd quartile	4th quartile
Large WC	1,286 (23.1)	0.98 (0.76–1.26)	0.84 (0.65–1.07)	0.93 (0.73–1.17)	Reference
High triglyceride level	1,163 (20.9)	0.85 (0.69–1.05)	0.95 (0.77–1.16)	1.05 (0.86–1.28)	Reference
Low HDL cholesterol level	1,305 (23.5)	0.81 (0.66–0.99)	0.85 (0.70–1.03)	1.16 (0.97–1.39)	Reference
High BP	1,617 (29.1)	0.92 (0.77–1.11)	0.94 (0.79–1.13)	0.78 (0.66–0.93)	Reference
High glucose level	443 (8.0)	1.19 (0.87–1.62)	1.32 (0.98–1.78)	1.11 (0.82–1.50)	Reference

Data were adjusted for age (continuous), sex, BMI (< 21, 21–22, 23–24, 25–26, 27–28, > 28 kg/m^2), income status (monthly family income < 1,000,000 vs. ≥ 1,000,000 won), educational status (< high school graduation vs. ≥ high school graduation), smoking status (never smoking, former smoking, current smoking ≤ 10, 11–20, > 20 cigarettes/day), alcohol consumption status (never drinking, former drinking, current drinking < 16, 16–30, > 30 g/day of alcohol), and physical activity level (quartiles).

OR, odds ratio; CI, confidence interval; MetS, metabolic syndrome; WC, waist circumference; HDL, high-density lipoprotein; BP, blood pressure; BMI, body mass index.

DISCUSSION

The present study evaluated the association between the percentages of total calorie from macronutrients consumed and the 2-year MetS incidence. We found that approximately 67%–70% of calorie from carbohydrate consumed significantly reduced the MetS risk.

Based on data from the KNHANES, the MetS prevalence has gradually increased over 10 years [3]. During this period, socioeconomic factors, lifestyle, and dietary habits may have been changed in Korea. In terms of macronutrient composition in total calorie intake, average percentages of total calorie from carbohydrate percentages were changed from 66.9% to 64.6% over 14 years while those for fat were changed from 17.3% to 20.0% for the same periods in Korean adults [17]. Although, the diet of Korean adults has been westernized, carbohydrate intake is still a large part of the diet.

Several epidemiologic studies reported data on the association between macronutrient intake and the MetS prevalence [9-13]. Two studies analyzed data from the KNHANES and found a positive association for carbohydrate intake [9,10] and one of them also showed an inverse association for fat intake [10] whereas other studies analyzed data from Western populations and found no or an inverse association for carbohydrate [11-13]. These discrepancies in the findings might be partly due to difference in ethnicities, dietary habits, or physiology in the occurrence of MetS. The most potential speculation is that because carbohydrate consumption is higher in a typical Korean diet than in a typical Western diet, the directions of the association between carbohydrate consumption and the MetS prevalence seem to be opposite. Thus, it is warranted to determine an optimal percentage of total calorie from carbohydrate contributing to MetS occurrence. In addition, because a major limitation of earlier studies was the use of a cross-sectional data, a causal relationship between macronutrient composition and MetS incidence has not yet been clarified.

Our findings suggest that approximately 67%–70% for carbohydrate composition is associated with a reduced MetS risk and this reduced risk may be partly due to the 2 diagnostic components, large WC and low HDL cholesterol level. However, because the associations for these components were not significant and there was a positive trend for high glucose level, further data regarding the associations of carbohydrate composition with each MetS component are warranted. On the basis of our results, carbohydrate composition lower than 67% may be more advantageous for HDL cholesterol level while 71%–75% for high BP.

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It was suggested that the components of large WC and low HDL cholesterol level are responsible for the increasing prevalence of MetS in Korean adults [18]. Rice is a staple food and a major energy source in a typical Korean diet and thus consumption of excessive calories from carbohydrate for Koreans results in an accumulation of stored fat in the body. A positive association between carbohydrate intake and WC was observed in a previous study [19], but carbohydrate composition related to WC has not been analyzed. Because large WC seems to reflect visceral obesity and individuals with visceral obesity have dyslipidemia characterized by high triglyceride and low HDL cholesterol, which are diagnostic components of MetS [18,20], data regarding a positive association between carbohydrate intake and the MetS prevalence are reasonable. In addition, there are data on an inverse association between carbohydrate consumption and HDL cholesterol levels [21]. However, data on an optimal carbohydrate composition to reduce the MetS risk have been limited so far.

In this study, dietary intake was assessed using the FFQ. It is known that the FFQ method is more suitable for determining a relationship between chronic diseases and dietary factors in a large population than a 24-hour recall method is, but it has a drawback in estimating absolute amounts of nutrients and foods consumed [22,23]. Thus, macronutrient composition percentages might be under- or over-estimated in this study, although carbohydrate consumption is known to be more accurately estimated than other nutrients' amounts consumed [23].

The strengths of our study include a large sample size, investigation in a general population, and a prospective cohort study, in which we were able to observe incidence cases. However, the findings are generalizable only to middle aged or older Korean adults. To the best our knowledge, this is a sole study regarding the association between macronutrient composition and the MetS incidence in a Korean population. Further studies need to confirm the findings.

In conclusion, we found that carbohydrate composition is associated with the MetS risk in Korean adults; those consuming approximately 67%–70% of calorie from carbohydrate had a 23% reduced MetS risk compared with those consuming carbohydrate composition greater than 75%. Based on these findings, we suggest that excessive carbohydrate consumption may need to be replaced with protein or fat to reduce the risk of MetS.

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