



Carbohydrate Intake and Refined-Grain Consumption Are Associated with Metabolic Syndrome in the Korean Adult Population

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ABSTRACT

Background Metabolic syndrome is prevalent in the Asian population, but little is known about its associations with sources or types of dietary carbohydrates.

Objective We examined relationships between metabolic syndrome prevalence and dietary carbohydrate intake, including total carbohydrate, energy from carbohydrates, dietary glycemic index, dietary glycemic load, total grains, refined grains, and white rice in Korean men and women.

Design This cross-sectional study was based on data from the Fourth Korea National Health and Nutrition Examination Survey (KNHANES 2007-2009) and a nationally representative sample.

Participants/setting A total of 6,845 adults (2,631 men, 4,214 women) aged 30 to 65 years with no diagnosed diabetes, hypertension, or dyslipidemia were selected. Dietary intake data were obtained using the 24-hour recall method and all dietary carbohydrate intakes were divided into quintiles by sex.

Main outcome measures Metabolic syndrome and its components were defined using the National Cholesterol Education Program Adult Treatment Panel III criteria.

Statistical analyses performed All statistical analyses accounted for the complex sampling design effect and used appropriate sample weights. Multivariate adjusted logistic regression was used to estimate odds ratios and 95% CIs for metabolic syndrome across quintiles of dietary carbohydrate intake.

Results After controlling for potential confounding variables, the determinants of metabolic syndrome were the percentage of energy from carbohydrates in men and intakes of refined grains, including white rice, in women. Triglyceride, high-density lipoprotein cholesterol, and fasting blood glucose levels were associated with the percentage of energy from carbohydrates in men and white rice intake in women.

Conclusions Our findings suggest that the sources and types of carbohydrates were differentially associated with metabolic syndrome according to sex in the Korean adult population. The percentage of energy from carbohydrates in men and intake of refined grains, including white rice, in women were associated with metabolic syndrome.

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DIETARY CARBOHYDRATE INTAKE HAS RECEIVED considerable research attention because of proposed associations between diets with high glycemic index (GI) or glycemic load (GL), or those with low whole grains, and increased risks of obesity, metabolic syndrome, diabetes, and coronary heart disease.¹⁻⁴ However, studies have produced conflicting evidence about the relationships between sources or types of dietary carbohydrates and metabolic disease.

Several prospective studies⁵⁻⁷ have shown that dietary GI or GL were associated with high incidences of coronary heart disease, type 2 diabetes, and stroke. However, the results for total carbohydrate intake have been less clear.^{1,6} Extensive studies in Western populations have suggested that whole grains help to prevent diabetes, cardiovascular disease, and metabolic syndrome.^{1,8}

Because Asians traditionally consume large amounts of rice as a staple food, dietary carbohydrate intake can play a substantial role in the development of metabolic disease in Asian populations. Diabetes and metabolic syndrome have recently become more prevalent in Asia, reaching levels similar to those in Western countries.^{9,10}

Positive associations between total carbohydrate or rice intake and the incidence of diabetes have been reported in Chinese¹¹ and Japanese women.¹² Metabolic syndrome has

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been associated with total carbohydrate intake and GL in obese Korean women¹³ and high refined-grain consumption in a south Indian population.¹⁴ In addition, several studies have demonstrated stronger associations between dietary carbohydrate intake and metabolic disease in women than in men.^{12,13,15,16}

However, few studies have examined the combined associations of all sources and types of dietary carbohydrates with metabolic syndrome in Asian populations. Dietary carbohydrates account for a considerable part of daily energy intake in Asian populations, and examination of the sources and types of dietary carbohydrates associated with metabolic syndrome is important. Metabolic syndrome is characterized by abdominal obesity, high triglyceride and low high-density lipoprotein (HDL) cholesterol levels, high blood pressure, and high fasting blood glucose level. Assessment of the contributions of these metabolic syndrome components offers the opportunity to prevent the progression of chronic diseases, such as type 2 diabetes and cardiovascular disease.¹⁷

We examined associations between the sources and types of dietary carbohydrates and the prevalence of metabolic syndrome in Korean men and women using data from the Korea National Health and Nutrition Examination Survey.

METHODS

Subjects

This study was based on data from the Fourth Korea National Health and Nutrition Examination Survey, which was a cross-sectional and nationally representative survey carried out by the Korea Centers for Disease Control and Prevention in 2007-2009.

Among 10,618 eligible subjects aged 30 to 65 years, subjects were excluded if they had prior diagnoses and treatment for diabetes, hypertension, or dyslipidemia ($n=2,257$). In addition, subjects who had incomplete information on sociodemographic, anthropometric, biochemical, or health-related variables ($n=1,346$), reported implausible energy intakes (<500 or $>5,000$ kcal/day) ($n=71$), or were pregnant or breastfeeding women ($n=99$) were excluded. A total of 6,845 adults (2,631 men and 4,214 women) were included in the final data analyses.

This study was approved by the Korea Centers for Disease Control and Prevention Institutional Review Board, and informed written consent was obtained from each subject.

Assessment of Dietary Intake

Dietary intake data were obtained through a single 24-hour recall. Energy and nutrient intakes for each subject were calculated using the seventh food composition table by Korean National Rural Resources Development Institute.¹⁸

The average dietary GI and GL based on a glucose standard were calculated for each subject using the table of GI values for common Korean foods established in a previous study.¹⁹ The GI values in this table were obtained from published estimates or inputted when necessary by matching similar foods based on calorie and carbohydrate content of each food. The dietary GL was calculated by multiplying the carbohydrate content of each food by its GI value, and this value was summed for all food items. The

dietary GI was calculated by dividing the dietary GL by the total carbohydrate intake.²⁰

Refined grains were classified by the methods of Jacobs and colleagues²¹ and Liu and colleagues.²² Refined grains included white rice, spaghetti, noodles, and white-flour products, such as cookies, biscuits, white bread, crackers, muffins, waffles, bagels, and pizza.

Dietary carbohydrate intake variables included total carbohydrate (g/day), energy from carbohydrate (%), dietary GI, dietary GL, total grains (servings/day), refined grains (servings/day), and white rice (servings/day).

Assessment of Other Variables

Sociodemographic variables such as age, living area, and education, and health-related variables such as smoking status, alcohol intake, physical activity, medical history, and medication use, were obtained by general questionnaire. Smoking status was categorized into the following groups: nonsmokers, ex-smokers, or current smokers. Current alcohol intake was assessed based on the average frequency of alcohol drinking during the last year. Vigorous physical activity was examined based on the frequency of high intensity exercise during the last week.

Height, weight, and waist circumference were measured using standardized techniques and calibrated equipment. Body mass index was calculated from the measured heights and weights (kg/m^2) of the subjects. Blood pressure was measured by standard methods three times, and the average value was used.

Blood samples were collected after having fasted for at least 8 hours. Fasting blood glucose, triglyceride level, and HDL cholesterol were analyzed in a certified clinical laboratory.²³

Assessment of Metabolic Syndrome

Metabolic syndrome was diagnosed based on the National Cholesterol Education Program Adult Treatment Panel III criteria¹⁷ with a modified waist circumference cutoff for Korean adults²⁴ if any three or more of the following components were present: high waist circumference, as defined by a waist circumference ≥ 90 cm in men and ≥ 85 cm in women; elevated triglycerides as defined by triglyceride level ≥ 150 mg/dL (≥ 1.695 mmol/L); low HDL cholesterol as defined by HDL cholesterol < 40 mg/dL (< 1.036 mmol/L) in men and < 50 mg/dL (< 1.295 mmol/L) in women; elevated fasting blood glucose as defined by fasting blood glucose ≥ 100 mg/dL (≥ 5.6 mmol/L); and elevated blood pressure as defined by systolic blood pressure ≥ 130 mm Hg or diastolic blood pressure ≥ 85 mm Hg.

Statistical Analyses

All statistical analyses were conducted using SAS software version 9.3 (2011, SAS Institute). All analyses accounted for the complex sampling design effect and appropriate sampling weights of the national survey using PROC SURVEY in SAS program.

Values of sociodemographic and health-related variables were expressed as mean \pm standard error of mean for continuous variables or percentages for categorical variables; the *t*-test (for continuous variables) and χ^2 test (for categorical variables) were used to test differences by sex. All statistical analyses were conducted by sex because carbohydrate

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