Review Article

Nutritional risk and metabolic syndrome in Korean type 2 diabetes mellitus

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The prevalence of diabetes mellitus (DM) and the metabolic syndrome (MetS) are rapidly increasing in Asia including Korea. In 2005, the Third Korea National Health and Nutrition examination survey (KNHANES III) reported that the prevalence of DM and MetS in adults was estimated to be 8.7% and 32.6%, respectively. In our study of 688 type 2 DM patients, MetS prevalence was 46.9 % for males, and 65.1% for females. Patients with T2DM and MetS showed significantly higher insulin resistance than T2DM without MetS, confirming that insulin resistance is an important feature of MetS in T2DM patients. Patients with T2DM and MetS showed higher BMI, waist circumference, blood triglycerides, atherogenic index, C-reactive protein and lower HDL-cholesterol. In recent years, concerns with regard to the association of diet with MetS have grown. In our study with non-DM elderly people, higher % energy from carbohydrate, and lower intakes of antioxidant vitamins were considered to be associated with the risk of MetS. Patients with T2DM and MetS showed significant positive correlations between intakes of energy, carbohydrate, protein and lipids with BMI, weight, as well as waist circumference. These associations were not found in patients with T2DM without MetS. Nutritional risk factors for MetS among middle-aged T2DM subjects would be excessive carbohydrate intake with low intakes of fat, protein, vitamins, and minerals.

Key Words: metabolic syndrome, type 2 diabetes mellitus, nutritional risk factor, cardiovascular disease

INTRODUCTION

The metabolic syndrome (MetS) is characterized by a cluster of several metabolic and cardiovascular disease risk factors, such as insulin resistance, abdominal obesity, atherogenic dyslipidemia, hypertension, a proinflammatory state, and a prothrombotic state.[1] The MetS has become a subject of great interest because of its association with the development of type 2 diabetes mellitus (T2DM) and atherosclerotic cardiovascular disease (CVD). The prevalence of diabetes mellitus (DM) and the MetS are rapidly increasing in Asia including Korea. In the 2005 Korea National Health and Nutrition examination survey (KNHANES) reports, the prevalence of DM and the MetS in adults older than 30 years is estimated to be 8.7% and 32.6%, respectively.[2] The MetS prevalence is even higher in DM patients and insulin resistance is believed to be the underlying cause for both T2DM and the MetS.[3] T2DM patients with the MetS faces increased risk of DM complications including CVD compared to T2DM without MetS.[4] It is important to evaluate the characteristic of diabetic patients with the MetS with regards to CVD, since CVD is a leading cause of death of DM patients.

Diet and the metabolic syndrome

It is known that diet plays an important role in the development and management of the MetS. In general excessive intakes of energy, fats, and cholesterol are considered to be dietary risk factors for the MetS.[5]

However, studies with Korean populations do not always support the reported results.

In our study with 400 elderly Korean people, subjects with MetS showed a tendency of consuming a higher % energy from carbohydrate and lower % energy from fat.[6] Intakes of protein, fat, vitamins A, C, and E were inversely associated with the risk of the MetS, especially in female subjects. Female subjects with the MetS showed lower intakes of protein, fat, Ca, Fe, Zn, Vitamins A, C, and E than female subjects without the MetS. The MetS prevalence has increased across increasing quartiles of carbohydrate intake. When nutrition adequacy ratios were calculated, the highest quartile of carbohydrate intake had the lowest nutrition adequacy ratios (diet quality) of most vitamins and minerals. These results imply that subjects with the MetS had inadequate nutrient intakes with excess intake of carbohydrate. To identify the nutritional variables associated with MetS, the elderly subjects were classified into quartile groups based on nutrient intakes. Male subjects in the higher carbohydrate quartile group had a higher odds ratio for MetS than the lowest quartile group.

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Manuscript received 9 September 2007. Accepted 3 December 2007.

In women, the subjects in the highest quartile groups of protein, fat, vitamin A, and Vitamin E had a lower risk for MetS than those in the lowest quartile groups. Another study related dietary pattern to the MetS in middle aged people, we found that the prevalence of the MetS was lower in participants with a "vegetable and fish" dietary pattern, the most balanced and healthy dietary pattern, compared to "meat and alcohol", and "rice and kimchi" diets.[7] This suggests that inadequate nutrition /unbalanced nutrition is a dietary risk factor for the MetS in middle aged Koreans.

Several other studies have also reported that healthy dietary pattern was associated with lower risks of the MetS. In a study with Tehrani female teachers aged 40-60 years, the healthy dietary pattern was associated with lower risks of insulin resistance and the MetS, whereas the western dietary pattern was associated with higher risks of insulin resistance and the MetS.[8] In the Framingham Offspring Study, higher prevalence of abdominal obesity and the MetS was found in women with an "empty calorie" dietary pattern, on the other hand, women with a "wine and moderate eating" dietary pattern showed lower prevalence.[9] The MetS was more prevalent in women with the "white-bread" dietary pattern and less prevalent in women with the "milk-fat"pattern in the Malmö Diet and Cancer Cohort.[10]

In a study to evaluate the diet of DM patients, we found that DM patients had a higher cereal consumption leading to higher carbohydrate intake and lower consumption of fruits and vegetables, especially in women of 50 years and older compared to non-DM subjects.[11]

Discriminant analysis showed that BMI was the most important risk factor for diabetes for both men and women. Cereal intake, undesirable food habits such as heavy drinking as well as unbalanced diets resulted in high BMIs and in diabetes mellitus. Energy and fat intake was not associated with the incidence of DM. Therefore high carbohydrate/cereal intake, not energy or fat, seemed to be a contributing factor for both the MetS and DM in Korea. We also reported that alcohol consumption was associated with the MetS in Korea.[12]

Characteristics of type 2 DM subjects with the MetS

To document the nutritional risk and the MetS in T2DM, we studied 688 (356 males, 332 females) T2DM patients recruited from DM clinic in the Seoul area. The MetS was identified according to The National Cholesterol Education Program-Adult Treatment Panel III (NCEP-ATP III) criteria (triglycerides≥150mg/dl, HDL cholesterol<40mg/dl for men, <50mg/dl for women, blood pressure ≥130/85 mm-Hg, and high fasting blood glucose≥110mg/dl) and by applying the Asia-Pacific waist circumference (≥90 cm for men, and ≥80 cm for women). Because all of the study subjects were diabetic with high FBS, those who fulfilled two or more of criteria were classified as in the MetS group. People on antihypertensive drug therapy were included in the category with raised blood pressure. Medication use for hyperlipidemia was not considered in diagnosis of the MetS in this study.

Components of the Metabolic Syndrome

The prevalence of the MetS was 46.9% for males and 65.1% for females in this study with T2DM subjects. Considering that the MetS prevalence among non-DM elderly patients was 35.6% for males and 47.9% for females[6], the result of this study confirms that the MetS prevalence is higher in DM patients and higher in women in Korea. Among the 5 MetS components, the prevalence of high blood pressure (73%) was the most frequent in T2DM patients for both genders. Female T2DM subjects had a higher prevalence of abdominal obesity (50.6%) and low HDL-cholesterol (45.5%) than male T2DM patients. In non-DM elderly men, the most frequent MetS component was high blood pressure (74.6%) followed by abdominal obesity (44.1%) and high triglycerides concentration (40.7%), whereas in women, abdominal obesity (72.7%) was the most frequent followed by high blood pressure (66.1%) and low HDL-cholesterol (48.3%). Therefore high blood pressure and abdominal obesity are important MetS components among middle-aged Koreans with or without DM. Abdominal obesity is especially important for women over the age of 50 years (Table 1).

Anthropometry, blood variables and diet

Table 2 shows the comparisons between T2DM subjects with the MetS and T2DM without the MetS. T2DM subjects with the MetS showed significantly higher BMIs and waist circumferences, serum triglycerides concentrations, and lower HDL-cholesterol than those without the MetS. T2DM subjects with the MetS also showed significantly higher insulin resistance and atherogenic indexes, and higher C-reactive protein concentrations. No differences

Table 1. Prevalence of metabolic syndrome among DM and non-DM subjects

	DM		Non-DM	
variables	Men (n=356)	Women (n=332)	Men (n=118)	Women (n=286)
Age (year)	54.0±0.6 ‡	58.3±0.5	68.7±0.7	67.3±0.5
High fasting blood glucose (%)	100	100	23.7	20.3
High blood pressure (%)	73.3	72.6	74.6	66.1
High triglyceride (%)	30.6	32.0	40.7	34.3
Low serum HDL-cholesterol (%)	29.8	45.5	29.7	48.3
Abdominal obesity (%)	24.7	50.6	44.1	72.7
Metabolic syndrome (%)†	46.9	65.1	35.6	47.9

† In DM subjects, the diagnosis of metabolic syndrome is made if 2 or more criteria are present, besides fasting blood glucose. In non-DM subjects, the diagnosis of metabolic syndrome is made if 3 or more criteria are present out of 5 components. ‡ Mean ± S.E.

Table 2. Characteristics of the type 2 DM subjects with and without metabolic syndrome

	Men		Women	
	With MetS	Without MetS	With MetS	Without MetS
Age(year)	54.1±0.84[1)]	53.9±0.76	59.6±0.67	56.5±0.87
Anthropometric variables				
BMI (kg/m^2)	26.4±0.62	23.3±0.16***[2)]	25.5±0.21	22.2±0.22***
Waist circumference (cm)	88.9±0.61	81.3±0.46***	83.4±0.15	73.7±0.53***
Blood profiles				
Triglyceride (mg/dl)	187±7.55	102±3.70***	170±6.52	97.3±4.04***
HDL-cholesterol (mg/dl)	40.1±0.83	52.5±0.87***	47.7±0.87	63.0±1.21***
C-reactive protein (mg/dl)	2.65±0.50	1.95±0.53	2.13±0.36	1.37±0.40
Atherogenic index[4)]	3.90±0.10	2.55±0.07***	3.31±0.36	2.35±0.21***
HbA_{1c}(%)	8.72±0.38	8.21±0.16	8.50±0.13	8.13±0.16
K_{ITT} (%/min)[5)]	1.88±0.08	2.28±0.07**	1.91±0.07	2.56±0.09***
Diet intake (per 1000kcal/day)[3)]				
Energy (Kcal)	2521±83.9	2327±59.3*	1919±52.7	1991±66.1
Protein (g)	42.8±0.55[3)]	43.3±0.54	41.5±0.54	44.5±0.65**
Lipid (g)	27.6±0.59	27.9±0.57	25.1±0.60	28.7±0.72
Carbohydrate (g)	138±1.66	137±1.71	154±1.68	144±1.99**
Calcium (mg)	318±8.74	332±8.87	367±9.97	398±11.8*
Zinc (mg)	5.6±0.07	5.5±0.06	5.5±0.07	5.8±0.07
Vitamin A (μgRE)	468±15.8	486±16.7	516±17.4	543±21.6
Vitamin B_2 (mg)	0.7±0.03	0.9±0.04*	0.8±0.03	0.8±0.04
Vitamin C (mg)	59.7±2.40	56.6±1.91	73.9±2.49	70.0±2.63
Vitamin E (mg)	7.7±0.24	7.9±0.22	8.1±0.25	8.7±0.30
Folate (μg)	1521±4.16	1541±3.94	1761±4.01	181±5.74

[1] All values are mean ± S.E. [2] The value in with MetS group is significantly different from that of without MetS group at *** p<0.0001, **p<0.001, *p<0.05 by student's t-test for each gender. [3] Diet intakes were assessed by FFQ and except energy, diet intakes were calculated per 1000kcal/day. [4] Atherogenic index: (total cholesterol – HDL-cholesterol)/HDL-cholesterol. [5] Index of insulin resistance

Table 3. Odds ratios for metabolic syndrome in relation to CVD risk variables

Variables		OR† (95%CI‡)s	
		Men	Women
BMI (kg/m^2)	Quartile1	1.0	1.0
	Quartile2	2.6 (1.3-5.1)	1.7 (0.93-3.2)
	Quartile3	5.0 (2.5-9.7)	12.0 (5.9-24.5)
	Quartile4	14.2 (7.0-28.9)	13.2 (6.4-27.1)
Waist circumference (cm)	Quartile1	1.0	1.0
	Quartile2	2.4 (1.2-4.7)	3.6 (1.8-7.4)
	Quartile3	1.9 (1.9-7.3)	48.9 (20.0-119)
	Quartile4	25.7 (11.9-55.5)	39.5 (16.9-92.4)
Atherogenic index	Quartile1	1.0	1.0
	Quartile2	2.7 (1.3-5.8)	1.7 (0.93-3.2)
	Quartile3	8.3 (4.0-17.1)	12.0 (5.9-24.5)
	Quartile4	28.5 (12.9-63.0)	13.2 (6.4-27.1)
C-reactive protein (mg/dl)	Quartile1	1.0	1.0
	Quartile2	2.5 (1.3-4.8)	2.7 (1.4-5.2)
	Quartile3	2.3 (1.2-4.5)	2.6 (1.4-5.0)
	Quartile4	6.9 (3.4-14.1)	3.9 (2.1-7.5)
K_{ITT} (%/min)	Quartile1	1.0	1.0
	Quartile2	0.90 (0.51-1.6)	0.80 (0.42-1.54)
	Quartile3	0.79 (0.45-1.4)	0.39 (0.21-0.74)
	Quartile4	0.37 (0.20-0.68)	0.20 (0.10-0.37)
Carbohydrate Intake (g) per 1000kcal	Quartile1	1.0	1.0
	Quartile2	1.4 (0.8-2.5)	1.1 (0.64-2.1)
	Quartile3	1.6 (0.89-2.8)	2.1 (1.1-3.8)
	Quartile4	1.2 (0.67-2.1)	3.0 (1.6-5.6)

† OR: odds ratio. ‡ 95% CI: confidence interval in parentheses(all such values)

were found in HbA1c.concentrations. This confirms that DM patients with the MetS are at increased risk for CVD as indicated by their anthropometric measurements, blood indices, and inflammatory status.

Dietary intake was assessed by admistering a Food Frequency Questionnaire (FFQ) that composed of 144 food items. Compared with T2DM subjects without MetS, male T2DM subjects with MetS, but not females, showed higher energy intakes. When nutrients intake was expressed per 1000 kcal, lower vitamin B_2 intake was seen in males. On the other hand, female T2DM subjects with MetS showed lower intakes of protein, fat, Ca, Zn and higher carbohydrate intake than female T2DM subjects without MetS.

To document the association between nutrient intakes and the prevalence of the MetS, the MetS prevalence was analysed by quartiles for each nutrient intake. In male subjects, no significant differences were found according to quartiles for any nutrient. However, in female T2DM patients, MetS prevalence increased across increasing quartiles of carbohydrate intake, and decreased across increasing quartiles of protein and fat intakes. Patients with T2DM and MetS showed a significant positive correlation between intakes of energy, carbohydrate, protein and lipids, with BMI, weight, as well as waist circumference. A significant association was also found between energy and carbohydrate intakes with HbA_{1C}, fasting glucose and LDL-cholesterol. These associations were not found in T2DM subjects without the MetS (data not shown). Therefore nutritional risk factors seem to play a more important role in subjects with the MetS than those without.

When T2DM subjects were divided into quartiles for CVD risk variables, the odd ratios for the MetS increased across increasing quartiles of BMI, waist circumference, AI, and CRP. This finding confirms that known CVD risk factors are important features for the MetS in T2DM patients. Also higher odds ratios for the MetS were found in the highest quartile of insulin resistance and carbohydrate intakes, especially in females subjects (Table 3).

CONCLUSION

The higher MetS prevalence in women in our study is similar to that of previous reports. In a study of age and gender specific prevalence of the MetS in Koreans, the prevalence was higher in men than in women under the age of 50 years, however, this gender difference was reversed in an older population of over 50 years.[13] It has been suggested that the gender differences in the prevalence of the MetS after age 50 may be related to the higher prevalence of abdominal obesity associated with menopause.[13]

Our study with DM and non-DM subjects showed that MetS subjects had higher carbohydrate intakes and lower fat intakes. High carbohydrate intake in middle aged Koreans is probably due to excessive rice intake with few side dishes containing meats and vegetables, and results in inadequate intakes of vitamins and minerals. In the 2005 KNHANES reports, Korean women over 50 years of age had higher % energy from carbohydrate than men, and rice supplied about 50% of daily energy. In recent years, health risks associated with high carbohydrate intake have been reported. By analysing the US NHANES III data, a positive association between high carbohydrate intake of over 60% of total energy and CHD risk was suggested.[14] It has also been suggested that increased intakes of refined carbohydrate concomitant with decreasing intakes of fiber was associated with the increasing prevalence of DM observed in the US during the 20th century.[15] In postmenopausal women, high carbohydrate intake with relatively low total fat intake was associated with a greater progression of coronary atherosclerosis.

Women have a propensity to adhere simple and, traditional food choices. Many studies in Korea have repeatedly reported that diet quality of middle-aged women was poor compared to men.[2, 6] This may increase the vulnerability of female subjects, with or without DM, to under- and unbalanced nutrition in normal. Therefore poor nutritional status, along with age-related abdominal obesity, may explain the higher MetS prevalence in female subjects. In conclusion, for our middle-aged T2DM subjects, especially females, age-related abdominal obesity and high carbohydrate intake (>60% energy) are contributing risk factors for the MetS. Nutritional risk factors for the MetS among T2DM subjects are excessive carbohydrate intakes with low intakes of fat, protein, vitamins, and minerals. Therefore it would be advisable to reduce carbohydrate intakes and increase protein and fat intakesof these subjects. A well- planned and balanced diet is the prerequisite to the control T2DM as well as the MetS.

ACKNOWLEDGMENT

This study was supported by Seoul R&BD. Program, No.10526 and second stage of BK 21 project in 2007.

AUTHOR DISCLOSURES

Wha Young Kim, Jung Eun Kim, Young Joo Choi and Kap Bum Huh, no conflicts of interest.

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