The cross-sectional relationship between dietary calcium intake and metabolic syndrome among men and women aged 40 or older in rural areas of Korea

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BACKGROUND/OBJECTIVES: Studies conducted in Western populations have suggested that dietary calcium may protect against metabolic abnormalities, but there is little evidence of this effect in Asians, who have relatively low calcium intake. We evaluated the cross-sectional relationship between dietary calcium and metabolic syndrome among Korean men and women aged 40 years and over.
SUBJECTS/METHODS: A total of 6,375 subjects aged 40 years and over and were recruited between January 2005 and February 2010 from the baseline study of the Multi-Rural Communities Cohort Study in Rural Communities (MRCohort). A food frequency questionnaire was used to collect dietary information. Metabolic syndrome was defined using the modified criteria published in the Third Report of the National Cholesterol Education Program Adult Treatment Panel.
RESULTS: Calcium intake was related inversely to metabolic syndrome in women (P-value = 0.0091), but not in men (P = 0.1842). Among metabolic components, high waist circumference (WC) (P = 0.0426) and high blood glucose (P = 0.0027) in women and hypertriglyceridemia (P = 0.0017) in men were inversely correlated with calcium intake. Excluding those who used calcium or multinutrient supplements did not attenuate the relationship between dietary calcium and metabolic abnormalities.
CONCLUSION: Dietary calcium intake from foods may be inversely related to metabolic syndrome, WC, and blood glucose among women in rural areas of Korea.

INTRODUCTION

Metabolic syndrome is defined by a cluster of clinical features including obesity, dyslipidemia, hypertension, and insulin resistance [1] and it is a well-known risk factor for type 2 diabetes and cardiovascular diseases (CVD) [2].

The development of metabolic syndrome is influenced by genetic, metabolic, and environmental factors including diet [3]. However, the role of diet in the progression of metabolic syndrome is poorly understood and most researches have focused on fat [4]. A growing body of epidemiologic research suggests that calcium [5-7] may have beneficial effects against metabolic syndrome, but findings were not consistent [8,9]. The effect of dietary calcium on metabolic syndrome could be partially mediated by body fat, blood pressure (BP), and insulin sensitivity [10,11]. A recent study in the United States suggested that various dairy products may have differential associations with metabolic disorders and that ethnic differences in dairy consumption may explain some ethnic disparities in metabolic disorders [8]. In many Asian countries, milk and dairy products, which are major dietary calcium sources, are not commonly used in traditional foods [12], possibly due to the high prevalence of lactose intolerance [13]. Thus, Asian populations have a relatively low calcium intake compared to Western populations [13,14]. Most previous studies on the association between calcium and metabolic syndrome have been conducted in Western populations, with only limited evidence in Asian populations, despite a steadily increasing prevalence of metabolic syndrome over the past decade [15].

The present study examines the cross-sectional relationship

between calcium and the risk of metabolic syndrome in middle-aged and elderly populations in the Multi-Rural communities Cohort study (MRCohort) in South Korea whose calcium intake is relatively low.

SUBJECTS AND METHODS

Study population

Study subjects were participants of the Multi-Rural Communities Cohort Study in Rural Communities (MRCohort) to identify risk factors for CVD as part of the Korean Genomic Epidemiology Study (KoGES). A total of 9,696 subjects aged $\geq$ 40 years were recruited from three centers located in Yangpyeong, Namwon and Goryeong between January 2005 and February 2010. Among these 9,696 subjects, those who did not complete the food frequency questionnaire were excluded (n = 76). Subjects were also excluded if they had myocardial infarction (n = 607), stroke (n = 334), cancer (n = 224) or non-response to medical history (n = 3); or if they had taken medicine for hypertension (n = 1,754) or diabetes (n = 578); or had hyperlipidemia (n = 148). In addition, subjects were excluded if their records were missing data related to BP or metabolic syndrome (n = 12). Thus, a total of 6,375 subjects (2,491 men, 3,884 women) were used in the final analyses. This study was conducted in accordance with the Declaration of Helsinki and the protocol was approved by the Institutional Review Boards (IRB) of Hanyang University (HYUH 2005-15, 2006-32, 2007-04, 2008-09), Chonnam National University Hospital (CNUH 06-062) and Keimyung University (KU 06-40, 07-39, 09-50). Written informed consent was obtained from all subjects.

General characteristics, anthropometrics and biochemical variables

Data were collected using standard protocols for a questionnaire and for each examination procedure including measurements of anthropometry, clinical examination, and blood sampling to overcome the limitations of the multicenter studies. All interviewers and technicians were trained with the same protocol by the same trainers from the coordinating center.

The structured questionnaire was administered by trained interviewers and included information on demographics (age, sex, education, occupation, marital status, and income), smoking habits, alcohol intake, exercise, medical history and female reproductive history (menopause, oral contraceptive use). Height was measured with a standard height scale to the nearest 0.1 cm and weight was measured with a metric weight scale to the nearest 0.01 kg while the subjects were wearing light clothing without shoes. Body mass index (BMI) was calculated as weight (kg) / height (m^2) and waist circumference (WC) was measured at the smallest horizontal trunk circumference between the lowest rib margin and the iliac crest. BP was measured from the right arm by auscultation using a standard sphygmomanometer and a standard cuff after each subject had been sitting for at least 5 min. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) measurements were recorded to the nearest 2 mmHg. If two systolic or diastolic BPs differed by more than 5 mmHg, an additional measurement was performed, and the mean value of the closest two measurements was used.

Blood samples were collected to measure plasma total cholesterol, triglyceride, fasting blood glucose and HDL-cholesterol after at least $\geq$ 8 hr of fasting. Triglyceride, fasting blood glucose and Total and HDL-cholesterol were analyzed by the ADVIA1650 Automatic Analyzer (Siemens, New York, NY, USA). LDL-cholesterol was calculated as described by Friedewald *et al.* [16], unless triglyceride concentrations were above 400 mg/dl.

Definition of metabolic syndrome

Metabolic syndrome was defined using modified criteria proposed by the Third Report of the National Cholesterol Education Program Adult Treatment Panel. Subjects were diagnosed with metabolic syndrome if they met three of the following five criteria: WC $\geq$ 90 cm in men and $\geq$ 85 cm in women [17], triacylglycerol $\geq$ 150 mg/dL, HDL cholesterol < 40 mg/dL in men and < 50 mg/dL in women, SBP and DBP $\geq$ 130/85 mmHg or antihypertensive treatment, and fasting blood glucose $\geq$ 100 mg/dL or treatment of type 2 diabetes [18].

Dietary measurements

Dietary intake was assessed with a semi-quantitative food frequency questionnaire (FFQ) that asked each participant to provide his or her usual intake of 106 food items during the previous year. The FFQ consisted of a list of foods with three portion sizes and nine frequency categories ranging from 'never or rare' to '3 times/d'. For food items with different seasonal availability, participants were also asked to estimate how many months out of the year (3, 6, 9, or 12 months) they had eaten each seasonal food. The validity and reproducibility of the FFQ has been reported in detail elsewhere [19]. Nutrient intake and food intake were calculated by weighted frequency per day and portion size per unit in each food item. The Food Composition Table of Korean Nutrition Society was used as the nutrient database [20]. Total calcium intake was estimated by totaling calcium intake derived from all food items. All nutrient intakes were adjusted for total energy intake by the residual method.

Statistical analysis

All data were analyzed separately for men and women. Subjects were categorized into quartiles by relative intake of dietary calcium. General characteristics of subjects according to calcium intake were assessed using the general linear model for continuous variables and the Cochran-Mantel-Haenszel analysis for categorical variables. Age and variables with significantly different means or distributions according to calcium intake quartiles were considered potential confounders in multivariable models. Multiple logistic regression models were used to evaluate odds ratios (ORs) and corresponding 95% confidence intervals (CIs) for metabolic syndrome according to each category of calcium, compared with the lowest intake as a reference group. The test of linear trend was conducted by assigning the median values of the quartiles of calcium as a continuous variable. Multiple logistic regression modeling and linear trend tests were repeated after excluding those who used calcium and supplements to address the potential effects of those supplements. All statistical analyses were performed with SAS software (Version 9.2; SAS Institute Inc).

RESULTS

General characteristics of the study population

General characteristics of study subjects are shown in Table 1. The mean ages of men and women were 61.5 years and 59.7 years, respectively. A greater proportion of men was farmers, was married, was highly educated, and regularly exercised compared with women. Also, the proportions of current smokers and current drinkers were higher in men than in women. Mean WC was higher in men than in women, whereas BMI was higher in women than in men. Mean fasting glucose, triglyceride, SBP, and DBP were higher in men than in women, whereas total cholesterol, LDL cholesterol and HDL cholesterol were higher in women than men. All daily dietary intakes were higher in men than women. Average daily intake of energy-adjusted calcium for men and women were 351.3

Table 1. General characteristics of study subjects

Characteristics	Men (n = 2,491)	Women (n = 3,884)
Age (yrs)	61.5 ± 9.8	59.7 ± 10.0
Education (≥ High-school, %)	28.4	15.8
Farmer (%)	64.3	49.6
Married (%)	94.2	75.6
Regular exercise (≥ 22.5 MET-h/week, %)[1]	27.3	21.4
BMI (kg/m^2)	23.7 ± 3.0	24.2 ± 3.2
Current smoker (%)	37.8	3.6
Current drinker (%)	66.8	32.4
Alcohol consumption (g/d)	30.3 ± 56.7	2.6 ± 12.4
Hormonal factors (women only)		
Menopause (yes, %)	-	80.2
Oral contraceptive use (yes, %)	-	0.31
Total cholesterol (mg/dL)	192.1 ± 35.0	204.5 ± 36.4
LDL cholesterol (mg/dL)	117.9 ± 31.4	131.3 ± 32.2
Daily dietary intake		
Total energy (kcal)	1,729.5 ± 508.7	1,508.9 ± 437.6
Carbohydrate (g)	307.1 ± 32.2	278.6 ± 28.0
Protein (g)	50.5 ± 9.4	42.3 ± 8.1
Fat (g)	21.8 ± 8.9	15.3 ± 7.3
Fiber (g)	5.0 ± 1.9	4.7 ± 1.8
Cholesterol (mg)	122.7 ± 93.4	93.2 ± 82.8
Sodium (mg)	2,658.5 ± 1293.7	2,199.2 ± 1182.4
Potassium(mg)	1,915.1 ± 609.7	1,725.0 ± 617.6
Calcium(mg)	351.3 ± 161.6	331.0 ± 162.7
Glycemic load	178.7 ± 22.4	162.1 ± 21.0
Calcium supplement use (%)	0.6	4.2
Multinutrient supplement use (%)	10.1	11.0
Metabolic syndrome components		
Waist circumference (cm)	84.7 ± 8.2	82.5 ± 9.0
Triglyceride (mg/dL)	159.0 ± 117.4	139.3 ± 82.8
HDL cholesterol (mg/dL)	44.4 ± 11.7	45.9 ± 10.3
SBP (mmHg)	124.9 ± 16.6	121.8 ± 18.0
DBP (mmHg)	80.1 ± 10.4	77.7 ± 10.2
Fasting glucose (mg/dL)	100.6 ± 22.3	95.6 ± 15.3

Values are expressed as mean ± SD or percentage. All nutrient intakes were adjusted for total energy intake (kcal/d) by the residual method.
[1] MET, metabolic equivalent

mg/d and 331.0 mg/d, respectively. The proportion of calcium supplement users was low, 0.6% of men and 4.2 % of women, while multinutrient supplement users accounted for 10.1% and 11.0% of these study populations, respectively.

The potential confounders of the relationship between calcium intake and metabolic abnormalities

Age-adjusted proportions and averages of potential confounders according to quartiles of calcium intake are shown in Table 2. Men with high calcium intake tended to be more highly educated (≥ high school). Women with high calcium intake tended to be younger, highly educated, married, and exercise more, but were less likely to be farmers. The likelihood of calcium and multinutrient supplement use was likely to increase by calcium intake quartile among both men and women. Intake of protein, fat, fiber, cholesterol, sodium, and potassium increased linearly across the quartiles of calcium intake, while total energy, carbohydrate and glycemic load tended to decrease by calcium intake quartile.

The relationships of metabolic abnormalities with dietary calcium

Age-adjusted and multivariable-adjusted ORs of metabolic abnormalities are shown in Table 3. In women, dietary calcium intake was inversely related to metabolic syndrome after adjusting for potential confounders in the multivariable model 2 (4th V. 1st quartile, OR = 0.71, 95% CI: 0.54-0.94, P-value = 0.0091) as well as in an age-adjusted model. These findings were not observed in men (4th V. 1st quartile, OR = 0.82, 95% CI: 0.60-1.14, P-value = 0.1842). In terms of individual metabolic abnormalities among women, dietary calcium intake was inversely related to blood glucose (4th V. 1st quartile, OR = 0.69, 95% CI: 0.51-0.92, P-value = 0.0027) and larger WC (4th V. 1st quartile, OR = 0.81, 95% CI: 0.62-1.06, P-value = 0.0426). Although there was no significant relationship between dietary calcium intake and metabolic syndrome and the inverse relationship with triglyceride was found (4th V. 1st quartile, OR = 0.58, 95% CI: 0.43-0.79, P-value = 0.0017) in men. However, dietary calcium was positively correlated to low HDL cholesterol among men (4th V. 1st quartile, OR = 1.61, 95% CI: 1.18-2.18, P-value = 0.0158). Excluding calcium and multinutrient supplement users did not substantially attenuate the relationship between dietary calcium intake from foods and metabolic abnormalities in the remainder of the population (Table 4).

DISCUSSION

The present study found that calcium intake was inversely related to metabolic syndrome, WC, and blood glucose in women and triglyceride in men.

Mean calcium intake in the present study was 351.3 ± 161.6 mg and 331.0 ± 162.7 mg for men and women, respectively, which is lower than mean calcium intake in Americans (986.3 ± 12.0 mg for men, 752.4 ± 9.9 mg for women) [8], Europeans (909.0 ± 329.0 mg for men, 830 ± 308.0 mg for women) [21], and even the general population in Korea (584.1 ± 7.7 mg for men, 474.9 ± 6.7 mg for women) [14]. The distribution of calcium intake (37.5 mg/d to 1,371.0 mg/d in men and 32.5 to 1,150.2 mg/d in women) was shifted to the low intake

Table 2. Age-adjusted characteristics of selected factors according to quartiles of dietary calcium intake from foods

	Quartiles of Calcium intake (mg/d)									
Variables	Men (n = 2,491)					Women (n = 3,884)				
	Q1	Q2	Q3	Q4	P-value[1]	Q1	Q2	Q3	Q4	P-value
Median (min, max)	190.8 (37.5,238.8)	278.7 (238.8,322.6)	370.8 (322.6,435.2)	530.8 (435.5,1371.0)		166.2 (32.5,211.6)	252.6 (211.7,302.0)	353.6 (302.0,416.2)	516.7 (416.4,1150.2)	
N	622	623	623	623		971	971	971	971	
Age (yrs)	62.7 ± 0.4	60.6 ± 0.4	60.6 ± 0.4	62.0 ± 0.4	0.5524	62.9 ± 0.3	59.6 ± 0.3	58.3 ± 0.3	58.1 ± 0.3	< 0.0001
Education (≥ High-school, %)	20.4	27.5	30.8	31.4	< 0.0001	10.7	14.7	14.4	19.4	< 0.0001
Farmer (%)	60.1	57.5	55.3	56.4	0.1157	46.5	42.9	37.2	37.5	< 0.0001
Married (%)	89.6	89.9	90.2	91.7	0.1055	58.6	62.6	63.6	65.6	0.0002
Regular exercise (≥ 22.5 MET-h/week, %)[2]	23.6	25.8	27.1	27.0	0.2413	15.3	18.1	21.7	27.5	< 0.0001
Current smoker (%)	36.4	35.4	37.2	33.2	0.3641	5.6	6.5	5.3	5.5	0.6146
Current drinker (%)	63.9	63.4	61.9	64.6	0.9399	27.9	34.7	32.5	30.5	0.4192
Alcohol consumption (g/d)	31.7 ± 2.3	31.7 ± 2.3	29.1 ± 2.3	28.8 ± 2.3	0.2797	2.2 ± 0.4	2.6 ± 0.4	2.6 ± 0.4	2.9 ± 0.4	0.2722
Hormonal factors (only women)										
Menopause (yes, %)	-	-	-	-	-	81.4	81.0	80.1	80.1	0.1890
Oral contraceptive use (yes, %)	-	-	-	-	-	0.0	0.3	0.5	0.4	0.0838
BMI (kg/m²)	23.6 ± 0.1	23.8 ± 0.1	23.7 ± 0.1	23.7 ± 0.1	0.9711	24.2 ± 0.1	24.2 ± 0.1	24.3 ± 0.1	24.2 ± 0.1	0.6662
Total cholesterol (mg/dL)	191.8 ± 1.4	191.7 ± 1.4	193.9 ± 1.4	191.0 ± 1.4	0.8112	205.0 ± 1.2	204.0 ± 1.2	203.9 ± 1.2	205.1 ± 1.2	0.8710
LDL cholesterol (mg/dL)	116.4 ± 1.3	117.9 ± 1.3	120.0 ± 1.3	117.5 ± 1.3	0.5104	132.2 ± 1.1	130.5 ± 1.0	130.8 ± 1.0	131.5 ± 1.0	0.8913
Daily dietary intake										
Total energy (kcal)	1,736.8 ± 19.2	1,730.1 ± 19.2	1,768.0 ± 19.2	1,683.2 ± 19.2	0.0691	1,506.3 ± 13.6	1,546.3 ± 13.4	1,545.0 ± 13.4	1,438.0 ± 13.4	< 0.0001
Carbohydrate (g)	316.0 ± 1.3	311.1 ± 1.3	306.6 ± 1.3	294.9 ± 1.3	< 0.0001	291.0 ± 0.8	281.8 ± 0.8	277.3 ± 0.8	264.4 ± 0.8	< 0.0001
Protein (g)	43.2 ± 0.3	48.7 ± 0.3	51.6 ± 0.3	58.4 ± 0.3	< 0.0001	35.5 ± 0.2	40.3 ± 0.2	43.6 ± 0.2	49.8 ± 0.2	< 0.0001
Fat (g)	17.8 ± 0.3	21.2 ± 0.3	22.2 ± 0.3	26.0 ± 0.3	< 0.0001	10.8 ± 0.2	14.0 ± 0.2	16.2 ± 0.2	20.1 ± 0.2	< 0.0001
Fiber (g)	3.6 ± 0.1	4.7 ± 0.1	5.4 ± 0.1	6.4 ± 0.1	< 0.0001	3.4 ± 0.0	4.4 ± 0.0	4.9 ± 0.0	6.0 ± 0.0	< 0.0001
Cholesterol (mg)	76.0 ± 3.5	111.3 ± 3.5	128.4 ± 3.5	174.8 ± 3.5	< 0.0001	46.5 ± 2.4	79.2 ± 2.4	98.9 ± 2.4	148.1 ± 2.4	< 0.0001
Sodium (mg)	1,706.5 ± 43.8	2,397.3 ± 43.8	2,924.3 ± 43.8	3,604.5 ± 43.7	< 0.0001	1,379.6 ± 32.8	1,991.2 ± 32.4	2,342.1 ± 32.5	3,083.7 ± 32.5	< 0.0001
Potassium (mg)	1,319.6 ± 17.2	1,780.7 ± 17.1	2,050.2 ± 17.1	2,508.8 ± 17.1	< 0.0001	1,173.5 ± 13.9	1,555.7 ± 13.7	1,838.9 ± 13.7	2,331.8 ± 13.7	< 0.0001
Glycemic load	190.2 ± 0.8	182.6 ± 0.8	176.6 ± 0.8	165.4 ± 0.8	< 0.0001	176.1 ± 0.6	166.0 ± 0.6	159.7 ± 0.6	146.5 ± 0.6	< 0.0001
Calcium supplement use (%)	0.1	0.7	0.3	1.2	0.0453	2.5	3.4	4.4	5.6	0.0005
Multinutrient supplement use (%)	4.6	7.1	10.6	10.5	< 0.0001	6.8	11.5	12.6	15.2	< 0.0001
Metabolic syndrome components										
Waist circumference (cm)	84.4 ± 0.3	84.9 ± 0.3	84.7 ± 0.3	84.6 ± 0.3	0.8847	82.1 ± 0.3	82.8 ± 0.3	82.7 ± 0.3	82.5 ± 0.3	0.4415
Triglyceride (mg/dl)	164.9 ± 4.7	161.2 ± 4.7	160.4 ± 4.7	149.4 ± 4.7	0.0169	143.5 ± 2.7	140.5 ± 2.6	138.7 ± 2.6	134.5 ± 2.6	0.0152
HDL cholesterol (mg/dl)	44.9 ± 0.5	43.6 ± 0.5	43.8 ± 0.5	45.2 ± 0.5	0.3683	44.8 ± 0.3	45.6 ± 0.3	46.0 ± 0.3	47.1 ± 0.3	< 0.0001
SBP (mmHg)	125.2 ± 0.7	125.5 ± 0.7	124.4 ± 0.7	124.7 ± 0.7	0.3932	120.9 ± 0.6	122.2 ± 0.6	121.9 ± 0.6	122.1 ± 0.6	0.2262
DBP (mmHg)	79.7 ± 0.4	80.6 ± 0.4	79.9 ± 0.4	80.1 ± 0.4	0.7192	77.4 ± 0.3	77.8 ± 0.3	77.9 ± 0.3	77.9 ± 0.3	0.3369
Fasting glucose (mg/dL)	99.6 ± 0.9	101.8 ± 0.9	100.8 ± 0.9	100.3 ± 0.9	0.9218	95.3 ± 0.5	95.9 ± 0.5	95.2 ± 0.5	96.1 ± 0.5	0.3585

Values are expressed as mean ± SD or percentage. All nutrient intakes were adjusted for total energy intake (kcal/d) by the residual method.
[1] *P*-values for the linear trends were determined by Cochran-Mantel-Haenzel for categorical variables and by general linear model for continuous variables after adjustment for age.
[2] MET, metabolic equivalent

Table 3. ORs and 95% CI of metabolic syndrome and its components according to quartiles of dietary calcium intake from foods

	Quartiles of dietary calcium intake (mg/d)									
	Men (n = 2,491)					Women (n = 3,884)				
	Q1	Q2	Q3	Q4	P-value	Q1	Q2	Q3	Q4	P-value
Median (min, max)	190.8 (37.5,238.8)	278.7 (238.8,322.6)	370.8 (322.6,435.2)	530.8 (435.5,1371.0)		166.2 (32.5,211.6)	252.6 (211.7,302.0)	353.6 (302.0,416.2)	516.7 (416.4,1150.2)	
N	622	623	623	623		971	971	971	971	
High waist circumference (%)[1]	27.2	27.2	27.4	28.0		38.0	41.0	40.0	38.4	
Age adjusted OR	1.00	1.00 (0.78-1.28)	1.01 (0.79-1.30)	1.04 (0.81-1.34)	0.7061	1.00	1.14 (0.95-1.37)	1.08 (0.90-1.30)	1.02 (0.85-1.23)	0.8603
Multivariable-Model 1[2]	1.00	0.97 (0.75-1.25)	1.00 (0.78-1.29)	1.02 (0.79-1.31)	0.8261	1.00	1.22 (1.01-1.47)	1.16 (0.95-1.40)	1.10 (0.91-1.34)	0.6168
Multivariable-Model 2[3]	1.00	0.91 (0.69-1.18)	0.89 (0.67-1.18)	0.85 (0.61-1.19)	0.3992	1.00	1.08 (0.88-1.32)	0.95 (0.76-1.18)	0.81 (0.62-1.06)	0.0426
Hypertriglyceridemia (%)[1]	40.1	36.3	37.9	36.5		34.8	34.9	30.0	30.8	
Age adjusted OR	1.00	0.82 (0.65-1.03)	0.88 (0.70-1.11)	0.83 (0.66-1.04)	0.2066	1.00	1.01 (0.84-1.22)	0.80 (0.66-0.97)	0.83 (0.69-1.01)	0.0193
Multivariable-Model 1	1.00	0.82 (0.65-1.03)	0.88 (0.70-1.11)	0.81 (0.65-1.03)	0.1685	1.00	1.01 (0.83-1.23)	0.81 (0.66-0.99)	0.85 (0.69-1.04)	0.0353
Multivariable-Model 2	1.00	0.73 (0.57-0.93)	0.72 (0.55-0.93)	0.58 (0.43-0.79)	0.0017	1.00	1.02 (0.83-1.25)	0.82 (0.65-1.03)	0.86 (0.65-1.14)	0.1495

Table 3. continued

	Men (n = 2,491)					Women (n = 3,884)				
	Q1	Q2	Q3	Q4	P-value	Q1	Q2	Q3	Q4	P-value
Low HDL cholesterol (%)[1]	33.6	40.6	38.1	38.5		71.0	67.2	67.3	63.1	
Age adjusted OR	1.00	1.36 (1.08-1.71)	1.22 (0.97-1.54)	1.25 (0.99-1.57)	0.2083	1.00	0.84 (0.69-1.02)	0.84 (0.69-1.03)	0.70 (0.58-0.85)	0.0006
Multivariable-Model 1	1.00	1.33 (1.06-1.68)	1.19 (0.94-1.51)	1.20 (0.95-1.52)	0.3511	1.00	0.85 (0.69-1.04)	0.85 (0.69-1.04)	0.71 (0.58-0.87)	0.0012
Multivariable-Model 2	1.00	1.51 (1.18-1.93)	1.44 (1.11-1.88)	1.61 (1.18-2.18)	0.0158	1.00	0.91 (0.74-1.13)	0.96 (0.76-1.21)	0.89 (0.67-1.17)	0.5103
High blood pressure (%)[1]	42.7	48.0	42.5	42.9		32.1	34.7	35.9	34.9	
Age adjusted OR	1.00	1.24 (0.99-1.55)	0.99 (0.79-1.24)	1.01 (0.81-1.26)	0.5446	1.00	1.13 (0.93-1.36)	1.19 (0.98-1.44)	1.14 (0.94-1.38)	0.2210
Multivariable-Model 1	1.00	1.24 (0.99-1.55)	1.01 (0.80-1.26)	1.01 (0.80-1.26)	0.5456	1.00	1.15 (0.94-1.40)	1.22 (1.00-1.49)	1.18 (0.97-1.45)	0.1233
Multivariable-Model 2	1.00	1.21 (0.95-1.53)	0.96 (0.74-1.24)	0.94 (0.70-1.26)	0.2907	1.00	1.12 (0.91-1.38)	1.18 (0.94-1.48)	1.13 (0.86-1.49)	0.4771
High blood glucose (%)[1]	35.2	40.4	39.4	41.2		26.2	28.4	26.0	26.3	
Age adjusted OR	1.00	1.25 (0.99-1.57)	1.20 (0.95-1.51)	1.29 (1.03-1.63)	0.0616	1.00	1.12 (0.92-1.37)	0.99 (0.81-1.22)	1.00 (0.82-1.23)	0.6782
Multivariable-Model 1	1.00	1.25 (0.99-1.57)	1.20 (0.95-1.52)	1.27 (1.01-1.60)	0.0913	1.00	1.13 (0.92-1.39)	0.95 (0.77-1.18)	1.03 (0.84-1.28)	0.8342
Multivariable-Model 2	1.00	1.16 (0.91-1.48)	1.04 (0.80-1.36)	1.01 (0.75-1.37)	0.7343	1.00	0.99 (0.79-1.23)	0.76 (0.59-0.96)	0.69 (0.51-0.92)	0.0027
Metabolic syndrome (%)[1]	28.9	30.5	29.5	31.1		34.7	35.0	33.3	31.0	
Age adjusted OR	1.00	1.08 (0.85-1.39)	1.03 (0.81-1.33)	1.12 (0.88-1.43)	0.4398	1.00	1.01 (0.84-1.23)	0.94 (0.78-1.14)	0.84 (0.69-1.02)	0.0465
Multivariable-Model 1	1.00	1.07 (0.84-1.37)	1.02 (0.80-1.31)	1.09 (0.85-1.39)	0.5878	1.00	1.03 (0.85-1.26)	0.96 (0.79-1.17)	0.88 (0.72-1.08)	0.1296
Multivariable-Model 2	1.00	0.98 (0.75-1.27)	0.86 (0.65-1.14)	0.82 (0.60-1.14)	0.1842	1.00	0.96 (0.78-1.18)	0.85 (0.67-1.06)	0.71 (0.54-0.94)	0.0091

[1] Age-adjusted prevalence
[2] Multivariable-Model 1 was adjusted for age (yrs) and education (≥ High-school, yes/no) in men and age (yrs), education (≥ High-school, yes/no), farmer (yes/no), marital status (married or no), and exercise habits (≥ 22.5 MET-h/week) in women.
[3] Multivariable-Model 2 was additionally adjusted for glycemic load and daily intake of fat, fiber, and sodium in men and glycemic load, and daily intake of fat, fiber, sodium and energy in women.

Table 4. ORs and 95% CI of metabolic syndrome components according to quartiles of dietary calcium intake from foods among calcium and multinutrient non-users

	Men (n = 2,331)					Women (n = 3,473)				
	Q1	Q2	Q3	Q4	P-value	Q1	Q2	Q3	Q4	P-value
Median (min, max)	188.4 (37.5,236.3)	275.7 (236.3,318.7)	366.4 (318.8,430.8)	525.4 (430.9,1369.8)		161.9 (32.2,206.0)	247.5 (206.0,294.2)	345.1 (294.2,406.7)	506.9 (406.8,1140.2)	
N	582	583	583	583		868	868	869	868	
High waist circumference (%)[1]	26.9	27.3	27.5	30.0		38.2	41.6	40.0	37.3	
Age adjusted OR	1.00	1.02 (0.79-1.33)	1.04 (0.80-1.34)	1.15 (0.89-1.49)	0.2581	1.00	1.15 (0.95-1.40)	1.06 (0.87-1.29)	0.96 (0.79-1.17)	0.3826
Multivariable-Model 1[2]	1.00	1.00 (0.77-1.29)	1.02 (0.78-1.32)	1.12 (0.87-1.45)	0.3388	1.00	1.21 (0.99-1.48)	1.12 (0.91-1.38)	1.03 (0.84-1.27)	0.8208
Multivariable-Model 2[3]	1.00	0.94 (0.72-1.24)	0.93 (0.69-1.25)	0.98 (0.70-1.38)	0.9912	1.00	1.06 (0.86-1.31)	0.90 (0.71-1.13)	0.73 (0.55-0.98)	0.0082
Hypertriglyceridemia (%)[1]	40.4	36.6	38.2	36.8		34.8	34.7	31.8	30.8	
Age adjusted OR	1.00	0.85 (0.67-1.08)	0.91 (0.72-1.16)	0.86 (0.68-1.09)	0.3372	1.00	1.00 (0.82-1.22)	0.87 (0.71-1.07)	0.84 (0.68-1.03)	0.0432
Multivariable-Model 1	1.00	0.85 (0.67-1.08)	0.91 (0.72-1.16)	0.85 (0.67-1.08)	0.2818	1.00	1.02 (0.83-1.25)	0.88 (0.71-1.09)	0.86 (0.69-1.06)	0.0791
Multivariable-Model 2	1.00	0.77 (0.60-0.99)	0.75 (0.57-0.99)	0.62 (0.45-0.85)	0.0068	1.00	1.05 (0.84-1.30)	0.91 (0.72-1.16)	0.91 (0.68-1.22)	0.3700
Low HDL cholesterol (%)[1]	33.5	40.4	37.5	38.4		71.0	67.1	68.0	63.9	
Age adjusted OR	1.00	1.35 (1.06-1.71)	1.19 (0.94-1.52)	1.24 (0.98-1.58)	0.2379	1.00	0.83 (0.68-1.02)	0.87 (0.71-1.07)	0.72 (0.59-0.89)	0.0041
Multivariable-Model 1	1.00	1.33 (1.04-1.69)	1.16 (0.91-1.49)	1.20 (0.94-1.52)	0.3896	1.00	0.86 (0.70-1.07)	0.86 (0.69-1.07)	0.74 (0.59-0.91)	0.0078
Multivariable-Model 2	1.00	1.46 (1.13-1.88)	1.38 (1.05-1.82)	1.55 (1.31-2.12)	0.0331	1.00	0.95 (0.75-1.19)	1.00 (0.78-1.28)	0.97 (0.72-1.30)	0.9575
High blood pressure (%)[1]	42.9	47.8	42.5	43.3		32.6	34.4	35.3	34.6	
Age adjusted OR	1.00	1.22 (0.97-1.54)	0.99 (0.78-1.24)	1.02 (0.81-1.28)	0.6377	1.00	1.08 (0.89-1.33)	1.13 (0.92-1.38)	1.10 (0.89-1.35)	0.4015
Multivariable-Model 1	1.00	1.22 (0.97-1.54)	0.99 (0.79-1.26)	1.02 (0.80-1.28)	0.6291	1.00	1.12 (0.90-1.37)	1.17 (0.94-1.44)	1.16 (0.94-1.44)	0.1851
Multivariable-Model 2	1.00	1.19 (0.93-1.52)	0.95 (0.73-1.23)	0.94 (0.69-1.27)	0.3376	1.00	1.07 (0.86-1.33)	1.09 (0.86-1.39)	1.06 (0.79-1.41)	0.8002
High blood glucose (%)[1]	34.9	41.0	40.0	41.6		26.7	28.0	25.7	26.7	
Age adjusted OR	1.00	1.30 (1.02-1.64)	1.25 (0.98-1.58)	1.33 (1.05-1.69)	0.0458	1.00	1.07 (0.87-1.32)	0.95 (0.76-1.18)	1.00 (0.81-1.24)	0.7548
Multivariable-Model 1	1.00	1.30 (1.02-1.65)	1.25 (0.98-1.59)	1.31 (1.03-1.66)	0.0690	1.00	1.09 (0.88-1.36)	0.92 (0.74-1.16)	1.05 (0.84-1.31)	0.9842
Multivariable-Model 2	1.00	1.20 (0.93-1.54)	1.07 (0.81-1.40)	1.02 (0.72-1.39)	0.7300	1.00	0.93 (0.74-1.17)	0.70 (0.54-0.91)	0.66 (0.48-0.90)	0.0032
Metabolic syndrome (%)[1]	28.5	30.9	29.9	30.9		35.7	34.5	33.7	30.8	
Age adjusted OR	1.00	1.13 (0.87-1.45)	1.07 (0.83-1.39)	1.13 (0.88-1.46)	0.4541	1.00	0.95 (0.78-1.16)	0.92 (0.75-1.12)	0.80 (0.65-0.98)	0.0283
Multivariable-Model 1	1.00	1.11 (0.86-1.44)	1.06 (0.82-1.37)	1.09 (0.85-1.42)	0.6199	1.00	0.98 (0.80-1.20)	0.93 (0.76-1.15)	0.85 (0.69-1.05)	0.1087
Multivariable-Model 2	1.00	1.01 (0.77-1.32)	0.88 (0.66-1.18)	0.82 (0.58-1.14)	0.1579	1.00	0.86 (0.72-1.11)	0.80 (0.63-1.02)	0.67 (0.50-0.90)	0.0062

[1] Age-adjusted prevalence
[2] Multivariable-Model 1 was adjusted for age (yrs) and education (≥ High-school, yes/no) in men and age (yrs), education (≥ High-school, yes/no), farmer(yes/no), marital status (married or no), and exercise habits (≥ 22.5 MET-h/week) in women.
[3] Multivariable-Model 2 was additionally adjusted for glycemic load and daily intake of fat, fiber, and sodium in men and for glycemic load and daily intake of fat, fiber, sodium and energy in women.

compared to the same distribution in a Western population (value of the highest quintile > 1,372 mg/d) [22]. Nevertheless, the inverse relationships between metabolic syndrome and/or its components and calcium intake in several previous studies [5,9,23,24] were also found inthe present study population whose calcium intake was relatively low.

The inverse relationships between dietary calcium, WC [5,25,26], and blood glucose [24], and triglyceride [5,9] were also found in previous cross-sectional and intervention studies. The inverse relationship of dietary calcium intake with WC was also found with body fat [27], BMI, and body weight among women [28]. There were few previous studies on the relationship between calcium and fasting blood glucose level, but a Dutch study found an inverse relationship between calcium intake and blood glucose [24]. This inverse relation was consistent with some, but not all, of the results [9,23]. A cross-sectional study [5] and two previous cohort studies [29,30] found lower risk of type 2 diabetes with higher calcium. The lower risk of hypertriglyceridemia in the relatively high calcium intake group was consistent with the lipid-lowering effect of calcium observed in previous cross-sectional studies [5,9].

There were no significant associations between high BP and calcium intake in the present study. Previously, no relationships between dietary calcium intake and hypertension have been reported in Korea [9] or in the United States [8], and a meta-analysis of clinical trial evidence showed that calcium supplementation has a small and inconsistent effect on BP [31]. However, there are possible mechanisms for the antihypertensive effect of increased dietary calcium [5,23,32]. Thus, further studies are needed to confirm the effect of calcium on BP.

The possible mechanisms of the inverse relationship between dietary calcium intake and WC, blood glucose, and triglyceride in the present study may be as follows: low calcium intake may be related to an increase in calcium content of tissues, such as adipocytes. This may lead to the stimulation of fatty acid synthase activity and a decrease in lipolysis in adipocytes [10,11]. Calcium is essential for insulin-mediated intracellular processes in insulin-responsive tissues and may contribute to insulin sensitivity via impaired signal transduction [10]. Previous epidemiological studies have demonstrated a positive relationship between calcium intake and insulin sensitivity [22,23]. In addition, high calcium intake may increase fecal fat excretion via formation of insoluble calcium fatty acid soaps, by binding bile acids or by decreasing fat absorption in the intestine [33].

Gender-differences in the relationships between calcium and metabolic syndrome components were also observed in previous epidemiological studies [8,9,21,25]. An inverse association between calcium intake and metabolic syndrome was previously reported in post-menopausal women, but not in men or in pre-menopausal women [5,9]. The present study, in which most women were post-menopausal, also showed an inverse association. Estrogen withdrawal at menopause may lead to a decrease in intestinal calcium absorption and in renal calcium conservation [34,35]. An abrupt increase in serum calcium level has been observed around menopause in women [36]. And the sex-hormone and lifestyle differences between men and women, such as smoking, drinking habits, and dietary patterns [21,36], ultimately may lead to gender differences. In the present

study, most women were post-menopausal and thus we could not definitively assert sex-hormone as the cause for these gender differences. In the present study, smoking and drinking status were not potential confounders and some dietary factors were adjusted. However, a relatively higher proportion of smokers and drinkers may affect overall calcium metabolism results in men, via depression of the vitamin D-parathyroid hormone system among smokers [37] or by reducing bone mineral density in excessive alcohol drinkers [38]. Those effects on calcium metabolism may partially contribute to the sex-based differences observed in the association between calcium intake and metabolic syndrome in this study.

Unexpectedly, we found an inverse relationship of HDL cholesterol with calcium intake in men unlike previous cross-sectional studies [9,26] showing positive relationships. Another Korean study revealed a negative correlation between calcium intake and HDL cholesterol; however, the same study showed a positive correlation between calcium intake and triglyceride [39], unlike the present study. They suggested that calcium consumption derived from animal-based foods was positively associated with blood triglyceride in normotensive Korean subjects [39] and varying roles in lipid metabolism were suggested for calcium from animal-based and plant-based foods. However, calcium derived animal-based foods could not explain the positive relationship between dietary calcium intake and hypertrigly-ceridemia and low HDL cholesterolemia among our subjects who had relatively low animal foods. Therefore, further studies are needed using more sophisticated dietary calcium assessment tools.

There are several limitations to interpret results of the present study. First, convenient recruitment may preclude generalization of the results. Second, due to the cross-sectional nature of this study, it was not possible to establish a cause-effect relationship between calcium intake and metabolic syndrome components. Third, it was not possible to control for all potential confounders in the present study. The classical function of vitamin D is regulation for calcium homeostasis [11] and magnesium may directly regulate cellular glucose metabolism by interacting with cellular calcium homeostasis [40]. However, due to the lack of available information on magnesium and vitamin D in the Korean Food Composition Table, the regulatory effect of vitamin D and magnesium on calcium homeostasis could not be considered in the present study. In addition, potassium, which may decrease calcium excretion, could not be included in the analysis due to the high correlation coefficient with calcium intake (r > 0.80 in both men and women). Hormone replacement therapy may be another factor affecting calcium metabolism, but in the present study, just 1.6% of women had used hormone replacement therapy and we did not detect any significant effect on dietary calcium or metabolic syndrome. Regardless of these limitations, there is still a possible relationship between calcium intake and metabolic syndrome and its components. Only a few studies were conducted previously and they reported inconsistent results [6,30,41,42] concerning the effect of calcium intake in Asian populations with a relatively low overall calcium intake.

In conclusion, the findings in the present study suggest that calcium intake may be inversely related to metabolic syndrome

among middle-aged and elderly women in rural areas of Korea. This relationship in women could be mediated by WC and blood glucose.

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