Association between metabolic syndrome and coffee consumption in the Korean population by gender: a cross-sectional study in Korea

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ABSTRACT

Background and Objectives: We conducted this cross-sectional study to identify the association between coffee consumption and risk of metabolic syndrome (MetS) in the Korean population. **Methods and Study Design:** Subjects aged 30–79 years in the Fifth Korea National Health and Nutrition Examination Survey conducted in 2010 and 2011 were included (n=8,246). The self-reported frequency of coffee consumption was classified as non-drinker, <1, 1, 2, and ≥3 cups/day. **Results**: The MetS prevalence was 33.6% in men (n=1,149) and 26.1% in women (n=1,388). Among women, the level of coffee consumption was inversely associated with MetS and each component (*p* for trend 0.002 for abdominal obesity and <0.001 for others). The dose-response inverse association remained significant between coffee consumption and MetS, high triglyceride, and low high-density lipoprotein cholesterol (*p* for trend 0.001, 0.009, and <0.001, respectively; adjusted for age and body mass index). Compared with women who did not consume coffee, the adjusted odds ratio (OR) for MetS was 0.57 (95% CI, 0.38–0.86) for women who consumed ≥3 cups per day (*p* for trend 0.002). Among women, excluding those receiving medical treatments for hypertension, diabetes, and dyslipidemia, a significantly lower OR for MetS (0.53, 95% CI 0.31–0.93) was observed with coffee consumption ≥3 cups, and the dose-response inverse association remained significant (*p* for trend 0.008). In men, there were no significant associations between coffee consumption and MetS. **Conclusion**: In conclusion, coffee consumption is associated with a lower risk of MetS among Korean women. There was a dose-response inverse relationship between coffee consumption and the prevalence of MetS in Korean women.

Key Words: coffee, dose-response relationship, healthy lifestyle, KNHANES, metabolic syndrome X

INTRODUCTION

Because of the increased prevalence of metabolic syndrome (MetS) worldwide, as well as in Asian countries including South Korea,[1] it has become a major public health concern.[2] Patients with MetS are at increased risk for developing cardiovascular diseases and type 2 diabetes mellitus.[3]

A number of studies have focused on lifestyle factors such as diet and commonly consumed food, attempting to identify and modify the potential risk factors for MetS.[4-6] Coffee is one of the most commonly consumed beverages in the world. Asia, especially

South Korea, has experienced the most dynamic growth in coffee consumption globally, with approximately 91% of Korean adults reporting drinking coffee and 66% who drink coffee daily.[7] According to the Korea Customs Service, Korean adults consumed an average 338 cups of coffee in 2011, and coffee imports jumped 44% to 130,000 tons over the past 5 years.[8] Owing to the high consumption of coffee among the Korean population, there has been a recent increasing interest in the health effects of coffee consumption.

Coffee is a complex mixture of chemicals including chlorogenic acid, cafestol, magnesium, potassium, vitamin E, and caffeine.[9] Caffeine, which is the major component of coffee, stimulates the central nervous system, increases the metabolic rate, and acutely elevates blood pressure (BP).[9,10] Coffee also contains a relatively large amount of chlorogenic acids, which are an important group of dietary phenols with antioxidant, anti-hypertensive, anti-hypercholesterolemic, and anti-inflammatory effects.[11] Coffee consumption reportedly reduces the risk of type 2 diabetes mellitus.[12]

Although various effects of habitual coffee consumption on the risks of MetS have been reported, the results have been inconsistent.[13-17] In addition, the dose-response relationship between coffee consumption and MetS risk remains unknown. Moreover, there have been few studies on the relationship between coffee consumption and human health, especially MetS, in Korea. Therefore, we conducted this study to evaluate the association between coffee consumption and MetS and its components in Korean adults.

MATERIALS AND METHODS

Study population

This study is based on data acquired in the Fifth Korea National Health and Nutrition Examination Survey conducted in 2010 and 2011 (KNHANES V-1 and 2). The KNHANES has been conducted periodically since 1998 to assess the health and nutritional status of the civilian, non-institutionalized population of Korea. The KNHANES V-1 and 2 are cross-sectional, nationally representative surveys that were conducted by the Korea Centers for Disease Control and Prevention (KCDC) from 2010 to 2011. Using a complex, stratified, multistage, probability-cluster sampling method, the KCDC selected 21,527 individuals from 7,600 households for possible participation in KNHANES V-1 and 2. Of these 21,527 individuals, 17,476 agreed to participate, yielding a response rate of 81.2%. Subjects aged 30–79 years were eligible for the present study. Subjects without available data for coffee consumption and/or MetS (n=2,447), with previously diagnosed stroke and/or ischemic heart disease, or were pregnant during the study period (n=462) were

excluded. A total of 8,246 subjects were enrolled and finally analyzed. All of the subjects provided informed consent. Ethical approval from our Institutional Review Board was not required because these survey data are publicly available.

Data collection and measurements

Data were collected using standardized health examinations conducted in specially equipped mobile examination centers and via household-based face-to-face interviews. The sequence of the health survey administration involved intake, informed consent, BP measurement, anthropometric measurements, blood sampling, and questionnaire completion. A standardized questionnaire survey was performed to collect age, sex, socioeconomic characteristics, medical history, current drug use, smoking habits, and other lifestyle-related risk factors. Daily carbohydrate, fat, protein, and energy intake were obtained from the nutrition survey part. A single 24 hour dietary recall was collected from each participants via in-person interview.

In the present study, post menopause was defined as natural menopause, with a current age ≥1 year than the age at the time of the final menstrual period or a previous bilateral oophorectomy. Household equivalent income was calculated by summing the monthly income of all household members and dividing this sum by the square root of the household size. To assess smoking status, the subjects were classified as current smokers, ex-smokers, and non-smokers. High-risk alcohol consumption was defined as ≥7 drinks per day for men and ≥5 drinks per day for women, at least twice per week. Regular walking was defined as walking at least 5 times per week for ≥30 minutes per session.

BP was measured 3 times at 5-minutes intervals using a standard mercury sphygmomanometer (Baumanometer®, WA Baum Co., Inc., Copiague, New York, USA). The average of the second and third measurements was used as the final BP. Anthropometric data, including height, body weight, and waist circumference (WC), were measured according to standardized guidelines. With the subject in a stable standing position, with feet 25–30 cm apart, WC was measured in tenths of a centimeter without compression of the soft tissue along the middle horizontal line between the inferior margin of the last rib and the iliac crest. Body mass index (BMI) was calculated by dividing the body weight by the height squared (kg/m^2). Fasting plasma glucose (FPG), total cholesterol (T-C), triglyceride (TG), and high-density lipoprotein cholesterol (HDL-C) levels were measured after a fasting period of at least 8 hours using an autoanalyzer (Hitachi Automatic Analyzer 7600®, Hitachi, Tokyo, Japan).

Metabolic syndrome

The identification of MetS, except the abdominal obesity component, was based on the American Heart Association/National Heart Lung and Blood Institute (AHA/NHLBI) criteria.[18] MetS was defined as the presence of ≥3 of the following 5 risk factors: (1) abdominal obesity, (2) high BP, (3) high FPG, (4) high TG, (5) low HDL-C. Abdominal obesity was defined using ethnic-specific WC cut-offs: ≥90 cm for men and ≥85 cm for women.[19] High BP was defined as a systolic BP ≥130 mmHg, diastolic BP ≥85 mmHg, or treatment of previously diagnosed hypertension. High fasting glucose was defined as an FPG level ≥100 mg/dL (5.6 mmol/L) or use of medication for diabetes. High TG was defined as a TG level ≥150 mg/dL (1.69 mmol/L) or antidyslipidemic drug use. Low HDL-C was defined as an HDL-C level <40 mg/dL (1.03 mmol/L) for men or <50 mg/dL (1.29 mmol/L) for women.

Coffee consumption

Coffee consumption data were self-reported and obtained from the dietary interview. Subjects were asked how many cups of coffee they drank during a day, week, or month: ≥3 cups a day, 2 cups a day, 1 cup a day, 4–6 cups a week, 2–3 cups a week, 1 cup a week, 2–3 cups a month, 1 cup a month, 6–11 cups a year, or almost none. Taking into account the subject distribution, the frequency of coffee consumption was categorized into the following 5 groups: non-drinker, <1 cup/day, 1 cup/day, 2 cups/day, and ≥3 cups/day. No distinction was made between caffeinated and decaffeinated coffee or between the types of coffee (boiled, filtered, or instant).

Statistical analysis

All estimates were calculated based on sample weights, which were evaluated by taking into consideration the sampling rate, response rate, and age and sex proportions of the reference population. The analysis was adjusted for the complex sample design of the survey. Continuous variables were tested for normality using graphical tools and the Kolmogorov-Smirnov test. The values of household equivalent income, T-C level, TG level, and daily intake of total calorie, carbohydrate, fat, and protein were log transformed to improve the normality of the distribution. Continuous data are presented as means and standard errors (SE), and categorical data are presented as weighted proportion and SE, as appropriate. General characteristics were compared using the Student's *t*-test for

continuous data and the chi-square test for categorical data. Logistic regression analyses were used to analyze relations between MetS and its components and the frequency of coffee consumption by sex. A trend test was conducted by modeling the main independent values as continuous variables. In addition, multivariable logistic regression analysis was conducted to evaluate the relationship between the level of coffee consumption and the prevalence of MetS, adjusted for the continuous variables of age, BMI, household equivalent income (log-transformed value), fat intake (log-transformed value), and protein intake (log-transformed value) and for the categorical variables of marital status, education level, menopausal status (only for women), smoking status, and high-risk alcohol consumption. Further, we performed subgroup analysis among the subjects not undergoing medical treatment for hypertension, diabetes, or dyslipidemia. All tests were two-sided, and *p*-values of <0.05 were considered statistically significant. Statistical analyses were performed using IBM SPSS version 21.0 (IBM Co., Armonk, NY, USA).

RESULTS

The mean age of the study subjects was 51.2 years (SE 0.3), and 54.1% (SE 0.5; n=4,916) of the sample was women. The prevalence of MetS was 29.6% overall (SE 0.6; n=2,537), 33.6% (SE 1.0; n=1,149) in men, and 26.1% (SE 0.8; n=1,388) in women. The general characteristics of the study population are presented in Table 1. There were significant differences between subjects with and without MetS in age, sex, marital status, education level, household equivalent income, smoking status, high-risk alcohol consumption, and daily fat and protein intake. However, there were no differences between subjects with and without MetS in regular walking activity, total calorie and carbohydrate intake, and daily tea or soda consumption. The frequency of daily coffee consumption (≥1 cup/day) was higher in subjects without MetS than in those with MetS.

The frequencies of MetS and its components exhibited a significant decreasing pattern across the levels of coffee consumption among women (*p*=0.017 for abdominal obesity and <0.001 for the other components); only high FPG was significant for men (*p*=0.004; Table 2). The level of coffee consumption was inversely associated with MetS among women. In the unadjusted analysis among the women, the OR for MetS in the highest quintile of coffee consumption as compared with no coffee consumption was 0.33 (95% confidence interval [CI] 0.23–0.47), and an inverse association between coffee consumption and MetS was seen (*p* for trend <0.001). This trend was maintained after adjusting for age and BMI, and subjects in the highest quintile of coffee consumption had 46% lower odds of having

MetS compared to those in the lowest quintile (OR 0.54, 95% CI 0.36–0.81, *p* for trend 0.001). In addition, there were inverse dose-response associations between coffee consumption and each component of MetS among women (*p* for trend 0.002 for abdominal obesity and <0.001for the other components). The inverse dose-response association remained significant between coffee consumption and high TG level and low HDL-C level after adjusting for age and BMI (*p* for trend 0.009 and <0.001, respectively). In the same models, the level of coffee consumption was inversely associated with only high FPG among men (*p* for trend 0.007).

The population attributable fraction in table 3 is defined as the proportional reduction in average risk of metabolic syndrome and its components that would be achieved by eliminating the exposure to each level of coffee consumption from the population while distributions of other risk factors in the population remain unchanged. The -7.8% of metabolic syndrome in women population could be attributed to drink ≥3 cups of coffee per day. The proportion of high TG and low HDL-C components in women population that could be attributed to the coffee consumption of ≥3 cups per day were estimated to be -4.3% and -4.0%, respectively. Rather, the population-attributable risk proportions associated with coffee consumption of ≥3 cups per day were -5.8% in high BP component and -5.6% in high FPG component.

In the multivariable logistic regression analysis, compared with women who did not consume coffee, the OR for MetS was 0.57 (95% CI 0.38–0.86) for women who consumed ≥3 cups per day (*p* for trend 0.002; Table 4). In the subgroup analysis of women not receiving medical treatments for hypertension, diabetes, or dyslipidemia, a significantly lower OR for MetS (0.53 [95% CI 0.31–0.93]) was observed in women who consumed ≥3 cups of coffee per day than in women who did not consume coffee. Further, the inverse dose-response association between coffee consumption and MetS remained significant among the women not receiving medical treatments (*p* for trend 0.008). In the same models, there were no significant associations between coffee consumption and MetS in men.

DISCUSSION

In this cross-sectional study, which aimed to evaluate the association between coffee consumption and the prevalence of MetS and its components in Korean adults, women who consumed ≥3 cups of coffee daily had a lower prevalence of MetS than women who did not consume coffee. An inverse dose-response relationship existed between coffee consumption and MetS in women but not in men. In addition, this relationship remained

significant among the women not receiving medical treatment for hypertension, diabetes, or dyslipidemia.

Epidemiological studies examining the association between coffee consumption and MetS have reported controversial findings. Some studies have suggested a protective effect of coffee intake on MetS risk. In a cross-sectional, population-based survey conducted in Poland, a greater consumer of coffee (≥3 cups/day) had lower odds for MetS (OR 0.75, 95% CI 0.66–0.86) than those drinking <1 cup/day.[20] In two population-based, cross-sectional studies conducted in Japan, coffee consumption was significantly associated with a lower prevalence of MetS. Similar to the present study, coffee consumption was inversely correlated with MetS (*p* for trend 0.03) as defined by the AHA/NHLBI criteria in a previous study.[21] In a study of Japanese civil servants, moderate coffee consumption (≥4 cups/day) among men was significantly associated with a lower prevalence of MetS (OR 0.61, 95% CI 0.39–0.95), as compared with non-drinkers.[22] In addition, a similar result was observed in a cohort study conducted in Denmark, which reported that high coffee intake was associated with lower risk of MetS.[13]

However, these findings are in contrast to those of other previous studies. In a 9-year prospective cohort study of 9,514 middle-aged adults in the United States, no relationship was observed between coffee consumption and incident MetS.[5] In two population-based, prospective studies conducted in the same cohort from the Netherlands, there were no significant associations between long-term coffee consumption and MetS or its components.[23,24] In a cross-sectional study of Korean adults aged 19–65 years, a high coffee consumption was associated with a higher risk of MetS, particularly for drinkers of an instant coffee mix containing sugar and powder creamer, who were more likely to have MetS than non-drinkers.[25] Some of this discrepancy could be explained by the different types of coffee, diverse categories for the level of coffee consumption, different diagnostic criteria to define MetS, and varying ages of subjects in the different studies.

The mechanism to explain the relationship between coffee consumption and MetS remains unclear. Coffee contains several biologically active substances that may have either beneficial or harmful effects on human health. The beneficial effect of coffee consumption has gained considerable interest in recent years. Because caffeine is the best-characterized pharmacologically active substance in coffee, it might explain the healthful effects of coffee consumption on MetS, with the following proposed mechanisms: antagonism of adenosine receptors, sympathetic over-activation, and a sympathomimetic agent that is capable of increasing energy expenditure and promoting the loss of body

fat.[26,27] In addition, some studies have suggested that the healthy effects of coffee consumption on chronic diseases may depend on the antioxidant compounds contained in coffee,[9] such as chlorogenic acid, melanoidins, furans, pyrroles, and maltol, which reduce the risk for endothelial dysfunction and the expression of inflammatory molecules.[28] The beneficial actions of polyphenols contained in coffee could be due to their ability to ameliorate endothelial function and to suppress vascular endothelial cell expression of pro-inflammatory cytokines, with the consequent up-regulation of adhesion molecules and monocyte adhesion.[29,30] Coffee also contains several micronutrients, such as magnesium, potassium, niacin, trigonelline, and quinides, that may improve insulin sensitivity, decrease inflammatory marker levels, and reduce diabetes risk.[31-33]

In the present study, high TG and low HDL-C levels were significantly and inversely correlated with coffee consumption among women. Similarly, studies performed in Japan showed an inverse correlation between coffee consumption and serum TG level.[15,21,22] Other clinical trials conducted in the United States reported that increased HDL-C concentrations were observed after coffee consumption.[34,35] However, the results of many other studies contrasted the present findings. Driessen et al. reported no association between coffee consumption and TG or HDL-C levels.[23] In the study by Hino et al., low HDL-C was the only component of MetS that was not correlated with coffee consumption.[15] In a relatively healthy Dutch study population, it appeared that coffee consumption was inversely associated with HDL-C levels in women.[24] The cholesterol-raising factors are diterpenes cafestol and kahweol, which are removed from coffee by paper filters.[36] A meta-analysis of 12 studies conducted in Western countries reported that the intake of coffee, especially unfiltered coffee, was significantly associated with increased TC, low-density lipoprotein cholesterol (LDL-C), and TG, and the changes were related to the level of consumption.[37] A previous meta-analysis of 14 published trials showed that the consumption of unfiltered, but not filtered, coffee dose-dependently increased serum levels of TC and LDL-C.[38] In addition, several studies showed that instant coffee, but not brewed coffee, had a role in changing serum lipid levels. Burr et al. demonstrated a significant increase in serum TC and apolipoprotein B concentrations after the ingestion of instant coffee.[39] In a study of middle-aged Japanese men, instant coffee consumption was strongly associated with elevated levels of serum LDL-C and lower levels of serum TG.[40] The coffee-brewing method and use of coffee additives could modify the cholesterol-increasing effect of coffee. Unfortunately, no distinction was made between the types of coffee in this study, such as boiled, filtered, or instant coffee. One of the

findings in this study is that only high TG and low HDL-C, but not other components of MetS, were significantly and inversely correlated with coffee consumption among women. As presented in table 3, the relationship between coffee consumption and MetS is not explained by the influence of only one or two components of MetS. These findings suggest that it is possible that some synergic effects between MetS components exist.

In this study, coffee consumption was significantly associated with a lower risk of MetS in women, but not in men. Little is known about the effect of sex on the relationship between coffee consumption and MetS. There are differences in hormonal system and metabolic function between men and women. Several studies have noted the sex-specific health effect of coffee, suggesting the difference in response to biochemical materials of coffee and the possibility of more specific interaction in women.[41,42] Gender differences in coffee effect may be influenced by the biological action of sex hormones and sex hormone-binding globulin.[43] In the present study, men were more likely to be smokers and high-risk alcohol drinkers than women (data not shown), and coffee consumption could be associated with these unhealthy lifestyle habits. In particular, smoking was strongly associated with coffee consumption. These differences in lifestyle factors between men and women might partially explain the observed sex difference in the association between coffee consumption and MetS. Furthermore, the beneficial effect of coffee consumption on MetS might be attenuated by the deleterious effects of unhealthy behaviors. Further studies are needed to investigate the sex differences and its mechanisms in the association between coffee consumption and MetS.

The present study has several limitations. First, it is impossible to establish a cause-effect relationship between the level of coffee consumption and MetS risk because of the cross-sectional study design. For example, it is possible that subjects who are taking a medication such as antihypertensives, hypoglycemics, or antidyslipidemic agents, or those with abnormal health examination results refrained from consuming coffee, considering that coffee has a rather harmful effect on health. Therefore, prospective studies are needed to confirm the causal relationships between coffee consumption and MetS. Second, only the frequency of coffee intake was evaluated in this survey. Using the standard questionnaires, it was difficult to assess the type of coffee consumed such as boiled, filtered, or instant coffee; brew strength; and amount of caffeine. In addition, we did not use information on additives such as milk, sugar, and cream because of the lack of such information in the secondary data. Despite these limitations, our study has an advantage in reporting the leading effort to demonstrate a sex-specific relationship between

the level of coffee consumption and MetS risk in a relatively large number of Korean subjects. The survey was recently performed in a nationwide, population-based, representative sample of Koreans, and all analyses in the present study were completely based on sample weights and adjusted for the complex sample design of the survey. Thus, these results can be generalized to the Korean adult population.

In conclusion, the present study provides evidence that coffee consumption is significantly associated with a lower risk of MetS among Korean women. There was also a dose-response inverse relationship between coffee intake and prevalence of MetS. The results of this study suggest a beneficial effect of coffee consumption against the risk for MetS, in addition to the previously reported beneficial effects on diabetes, Parkinson's disease, and liver disease. However, debate continues whether coffee consumption protects against the incidence of MetS and whether habitual heavy coffee intake is somewhat beneficial or detrimental for metabolic risk. Further prospective studies are warranted to evaluate the effects of coffee consumption on MetS and determine the causal relationships.

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Conflict of Interest and Funding Disclosure

The authors declare no conflict of interest.

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Table 1. General characteristics of the study population based on the presence of metabolic syndrome (n=8,246)

	Total	Without MetS (n=5,709)	With MetS (n=2,537)	*p*-value
	Mean ±SE	Mean±SE	Mean±SE	
Age (years)	51.2 ±0.3	47.4±0.3	55.0±0.4	<0.001
Equivalent income (× 10^4 won)*	235 ±9.3	249±9.4	222±13.7	<0.001
Waist circumference (cm)	84.2 ±0.2	78.7±0.2	89.8±0.2	<0.001
Body mass index (kg/m^2)	24.5 ±0.05	22.9±0.1	26.2±0.1	<0.001
Systolic blood pressure (mmHg)	122 ±0.4	114±0.4	130±0.6	<0.001
Diastolic blood pressure (mmHg)	77 ±0.3	73±0.3	81±0.4	<0.001
Fasting plasma glucose (mg/dL)	102 ±0.4	94±0.3	111±0.8	<0.001
Total cholesterol (mg/dL)*	195 ±0.6	190±0.6	199±1.0	<0.001
Triglyceride (mg/dL)*	161 ±2.2	108±1.2	214±4.2	<0.001
HDL-cholesterol (mg/dL)	46.5 ±0.2	51.0±0.2	41.9±0.2	<0.001
Total calorie intake (kcal/day)*	2,101 ±17	2,098±16	2,104±28	0.455
Carbohydrate intake (g/day)*	335.9 ±2.5	333.8±2.6	338.1±3.8	0.437
Fat intake (g/day)*	40.6 ±0.6	42.8±0.6	38.5±0.9	<0.001
Protein intake (g/day)*	74.8 ±0.7	76.6±0.8	73.0±1.1	<0.001
	n (%)	% (SE)	% (SE)	
Women	4,916 (54.1)	56.7 (0.7)	47.8 (1.0)	<0.001
Menopause	2,517 (43.6)	33.7 (1.1)	72.0 (1.7)	<0.001
Marital status: Single	1,120 (14.3)	12.0 (0.6)	19.6 (1.0)	<0.001
Education level: < 12 years	3,242 (34.9)	28.3 (1.0)	51.0 (1.5)	<0.001
Antihypertensive drug use	1,746 (17.2)	7.8 (0.4)	39.9 (1.3)	<0.001
Hypoglycemic agents use	614 (6.4)	2.3 (0.2)	16.4 (0.9)	<0.001
Antidyslipidemic drug use	516 (5.0)	1.5 (0.2)	13.6 (0.9)	<0.001
Smoking				<0.001
None	4,978 (55.2)	57.5 (0.8)	49.8 (1.1)	
Ex-smoker	1,686 (20.8)	19.6 (0.7)	23.8 (1.0)	
Current smoker	1,544 (23.9)	23.0 (0.8)	26.3 (1.1)	
High-risk alcohol consumption	808 (12.7)	11.5 (0.5)	15.3 (0.9)	<0.001
Regular walking activity	3,035 (36.8)	36.8 (0.8)	36.7 (1.3)	0.961
Daily tea consumption	1,018 (13.0)	13.5 (0.6)	12.0 (0.8)	0.170
Daily soda consumption	62 (1.0)	0.9 (0.2)	1.0 (0.3)	0.696
Daily coffee consumption	5,757 (72.4)	73.4 (0.7)	69.8 (1.1)	0.003
Categories of coffee consumption				0.027
None	745 (7.8)	7.4 (0.4)	8.9 (0.7)	
<1 cup/day	1,744 (19.8)	19.2 (0.6)	21.2 (1.0)	
1 cup/day	2,038 (23.5)	23.3 (0.7)	23.8 (1.0)	
2 cups/day	2,041 (25.0)	25.2 (0.7)	24.4 (1.1)	
≥3 cups/day	1,678 (23.9)	24.9 (0.8)	21.7 (1.2)	

HDL: high-density lipoprotein; MetS: metabolic syndrome; SE: standard error. *p*-values were determined using the Student's *t*-test or chi-square test. * Values presented are the estimated mean, but log values were used for comparisons.

Table 2. Associations between coffee consumption and metabolic syndrome and its components by sex

	Coffee consumption										(p-value)
	None		<1 cup/day		1 cup/day		2 cups/day		≥3 cups/day		p for trend
Men (n)	228		594		677		837		994		
Metabolic syndrome											
Estimated proportion, % (SE)	30.1	(3.7)	33.1	(2.3)	31.9	(2.0)	34.6	(2.1)	31.9	(1.8)	(0.785)
Crude OR (95% CI)	1		1.15	(0.77–1.71)	1.09	(0.73–1.62)	1.23	(0.83–1.82)	1.09	(0.74–1.60)	0.861
Age and BMI-adjusted OR (95% CI)	1		0.88	(0.56–1.40)	0.73	(0.46–1.16)	0.84	(0.54–1.31)	0.77	(0.50–1.19)	0.337
Abdominal obesity (High WC)											
Estimated proportion, % (SE)	22.5	(3.2)	27.9	(2.4)	28.1	(2.1)	28.4	(1.9)	31.1	(1.8)	(0.277)
Crude OR (95% CI)	1		1.33	(0.85–2.08)	1.35	(0.91–2.01)	1.37	(0.91–2.06)	1.55	(1.06–2.28)	0.036
Age and BMI-adjusted OR (95% CI)	1		0.86	(0.46–1.61)	0.79	(0.45–1.36)	0.66	(0.38–1.14)	0.78	(0.46–1.34)	0.291
High BP											
Estimated proportion, % (SE)	40.0	(4.3)	46.4	(2.5)	44.4	(2.5)	45.6	(2.2)	39.8	(1.9)	(0.140)
Crude OR (95% CI)	1		1.30	(0.88–1.91)	1.20	(0.79–1.80)	1.25	(0.86–1.82)	0.99	(0.68–1.43)	0.164
Age and BMI-adjusted OR (95% CI)	1		1.20	(0.79–1.82)	1.00	(0.65–1.56)	1.12	(0.74–1.68)	0.98	(0.66–1.46)	0.406
High FPG											
Estimated proportion, % (SE)	36.5	(4.1)	38.5	(2.4)	37.2	(2.5)	38.5	(2.0)	29.4	(1.7)	(0.004)
Crude OR (95% CI)	1		1.09	(0.73–1.62)	1.03	(0.67–1.57)	1.09	(0.72–1.64)	0.72	(0.49–1.06)	0.003
Age and BMI-adjusted OR (95% CI)	1		0.99	(0.65–1.51)	0.88	(0.56–1.38)	0.97	(0.63–1.49)	0.68	(0.45–1.02)	0.007
High TG											
Estimated proportion, % (SE)	40.9	(4.1)	40.9	(2.4)	44.8	(2.2)	46.4	(2.1)	42.3	(1.9)	(0.364)
Crude OR (95% CI)	1		1.00	(0.66–1.51)	1.17	(0.80–1.73)	1.25	(0.85–1.86)	1.06	(0.73–1.55)	0.557
Age and BMI-adjusted OR (95% CI)	1		0.86	(0.56–1.33)	0.95	(0.64–1.42)	0.99	(0.66–1.49)	0.85	(0.57–1.26)	0.613
Low HDL-C											
Estimated proportion, % (SE)	31.8	(3.7)	32.1	(2.6)	34.7	(2.3)	34.0	(2.1)	33.9	(1.7)	(0.923)
Crude OR (95% CI)	1		1.01	(0.69–1.48)	1.14	(0.76–1.69)	1.10	(0.74–1.63)	1.10	(0.76–1.59)	0.574
Age and BMI-adjusted OR (95% CI)	1		0.91	(0.62–1.34)	0.97	(0.65–1.46)	0.93	(0.63–1.36)	0.94	(0.65–1.37)	0.923
(2) Women (n)	517		1150		1361		1204		684		
Metabolic syndrome											
Estimated proportion, % (SE)	35.3	(2.7)	29.9	(1.6)	27.9	(1.3)	22.8	(1.4)	15.3	(1.6)	(<0.001)
Crude OR (95% CI)	1		0.78	(0.60–1.01)	0.71	(0.55–0.92)	0.54	(0.41–0.71)	0.33	(0.23–0.47)	<0.001
Age and BMI-adjusted OR (95% CI)	1		0.99	(0.74–1.34)	0.86	(0.63–1.17)	0.80	(0.58–1.12)	0.54	(0.36–0.81)	0.001
Abdominal obesity (High WC)											
Estimated proportion, % (SE)	32.6	(2.5)	26.9	(1.5)	27.2	(1.4)	25.1	(1.6)	22.6	(1.9)	(0.017)
Crude OR (95% CI)	1		0.76	(0.59–0.99)	0.77	(0.60–1.00)	0.69	(0.53–0.90)	0.61	(0.45–0.82)	0.002
Age and BMI-adjusted OR (95% CI)	1		0.83	(0.53–1.30)	0.83	(0.53–1.32)	0.83	(0.53–1.30)	0.80	(0.47–1.36)	0.484
High BP											
Estimated proportion, % (SE)	45.0	(2.8)	36.0	(1.7)	36.3	(1.6)	28.2	(1.6)	23.1	(1.9)	(<0.001)
Crude OR (95% CI)	1		0.69	(0.53–0.89)	0.70	(0.54–0.91)	0.48	(0.37–0.63)	0.37	(0.27–0.50)	<0.001
Age and BMI-adjusted OR (95% CI)	1		0.88	(0.65–1.21)	0.89	(0.65–1.21)	0.82	(0.59–1.14)	0.79	(0.55–1.13)	0.185
High FPG											

Estimated proportion, % (SE)	25.3	(2.3)	28.2	(1.6)	23.6	(1.4)	22.3	(1.4)	16.1	(1.7)	(<0.001)
Crude OR (95% CI)	1		1.16	(0.88–1.52)	0.91	(0.69–1.21)	0.84	(0.63–1.13)	0.57	(0.40–0.81)	<0.001
Age and BMI-adjusted OR (95% CI)	1		1.45	(1.09–1.95)	1.10	(0.82–1.48)	1.22	(0.90–1.67)	0.93	(0.64–1.36)	0.179
High TG											
Estimated proportion, % (SE)	33.4	(2.7)	28.5	(1.6)	27.7	(1.5)	21.2	(1.4)	19.4	(1.8)	(<0.001)
Crude OR (95% CI)	1		0.79	(0.60–1.05)	0.76	(0.58–1.01)	0.54	(0.41–0.70)	0.48	(0.34–0.67)	<0.001
Age and BMI-adjusted OR (95% CI)	1		0.92	(0.69–1.24)	0.88	(0.65–1.20)	0.71	(0.53–0.96)	0.74	(0.52–1.06)	0.009
Low HDL-C											
Estimated proportion, % (SE)	57.0	(2.5)	52.5	(1.8)	52.5	(1.6)	50.0	(1.7)	38.9	(2.3)	(<0.001)
Crude OR (95% CI)	1		0.83	(0.65–1.07)	0.83	(0.66–1.06)	0.75	(0.59–0.96)	0.48	(0.37–0.63)	<0.001
Age and BMI-adjusted OR (95% CI)	1		0.88	(0.68–1.13)	0.88	(0.70–1.11)	0.83	(0.65–1.06)	0.56	(0.43–0.73)	<0.001

BMI: body mass index; BP: blood pressure; CI: confidence interval; FPG: fasting plasma glucose; HDL-C: high-density lipoprotein cholesterol; OR: odds ratio; SE: standard error; TG: triglyceride; WC: waist circumference.

Table 3. Population-attributable risk proportions associated with risks for metabolic syndrome and its components by sex

	Population-attributable risk, %			
	>0 cup/day	≥1 cup/day	≥2 cups/day	≥3 cups/day
Men				
Metabolic syndrome	8.0	1.2	1.5	-0.9
Abdominal obesity (High WC)	21.6	8.0	5.6	3.8
High blood pressure	7.4	-3.7	-3.2	-3.9
High fasting plasma glucose	-4.0	-7.4	-6.8	-7.7
High triglyceride	6.0	6.0	1.8	-1.2
Low HDL-cholesterol	5.4	5.1	1.2	0.6
Women				
Metabolic syndrome	-37.4	-22.6	-16.0	-7.8
Abdominal obesity (High WC)	-24.0	-8.4	-5.7	-2.7
High blood pressure	-36.3	-17.7	-14.3	-5.8
High fasting plasma glucose	-8.2	-17.2	-9.9	-5.6
High triglyceride	-31.1	-17.7	-13.4	-4.3
Low HDL-cholesterol	-12.6	-7.0	-6.0	-4.0

HDL: high-density lipoprotein; WC: waist circumference.

Table 4. Multivariable logistic regression analyses of metabolic syndrome associated with the level of coffee consumption, including subgroup analysis for those not receiving medical treatments

	All study population				Excluding those receiving medical treatments*			
	Men (n=3,330)		Women (n=4,916)		Men (n=2,452)		Women (n=3,684)	
Coffee consumption categories	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)
None	1		1		1		1	
<1 cup/day	0.88	(0.55–1.42)	0.99	(0.73–1.35)	0.96	(0.51–1.80)	0.93	(0.59–1.47)
1 cup/day	0.71	(0.44–1.16)	0.89	(0.65–1.21)	0.69	(0.37–1.31)	0.74	(0.45–1.23)
2 cups/day	0.85	(0.54–1.34)	0.80	(0.57–1.13)	0.86	(0.46–1.60)	0.73	(0.44–1.20)
≥3 cups/day	0.69	(0.43–1.11)	0.57	(0.38–0.86)	0.83	(0.45–1.52)	0.53	(0.31–0.93)
p for trend		0.158		0.002		0.641		0.008

CI: confidence interval; OR: odds ratio.

*Medical treatments for hypertension, diabetes, and/or dyslipidemia.

Adjusted for the continuous variables of age, body mass index, equivalent income (log-transformed value), fat intake (log-transformed value), and protein intake (log-transformed value) and for the categorical variables of marital status, education level, menopausal status (for women), smoking, and high-risk alcohol consumption.