Endocrinology & Metabolic Syndrome

Song et al., Endocrinol Metab Syndr 2016, 5:2
DOI:10.4172/2161-1017.1000233

Research Article Open Access

Sex Differences in the Risk of Metabolic Syndrome and its Diagnostic Components in Korean Adults

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Rec date: Apr 04, 2016; **Acc date:** Apr 26, 2016; **Pub date:** May 6, 2016

Abstract

Objective: We examined sex differences in the risk of metabolic syndrome (MetS) and its diagnostic components among Korean adults.

Methods: A total of 17,826 adults (7,061 men, 10,765 women) aged 19+ years with no diagnosed chronic diseases, such as diabetes, hypertension, or dyslipidemia were selected from the 2008-2012 Korea National Health and Nutrition Examination Survey data. MetS was classified by the National Cholesterol Education Program Adult Treatment Panel III criteria with the Asia-Pacific specific cut-off for excessive waist circumference. All statistical analyses accounted for the complex sampling design effect and used appropriate sample weights.

Results: The overall prevalence of MetS was slightly higher in men (19.0%) than in women (14.8%). The prevalent diagnostic components were elevated triglycerides (33.2%) in men whereas low HDL-cholesterol (44.9%) and excessive waist circumference (31.3%) in women. The prevalence of MetS increased with age only in women. Women < 60 years had a lower prevalence of MetS than men in the same age category but the prevalence in women surpassed that in men after 60 years. There were differences in common combinations of MetS diagnostic components between men and women.

Conclusion: The MetS risk differed by sex in Korean adults and was markedly high in older women. Our findings warrant specific preventive strategies and clinical managements for MetS according to sex, especially for middle-aged and elderly women.

Keywords: Metabolic syndrome; Metabolic abnormalities; Elevated triglycerides; Low HDL-cholesterol; Excessive waist circumference; Sex; Korean adults

Introduction

Metabolic syndrome (MetS) is defined as a constellation of several metabolic abnormalities, such as excessive waist circumference (WC), elevated triglycerides (TG), low high density lipoprotein cholesterol (HDLC), elevated fasting blood glucose (FBG), and elevated blood pressure (BP) [1]. This syndrome is known to be associated with increased risks for cardiovascular disease [2] and type 2 diabetes [3]. A high prevalence of MetS is observed throughout the world [4], presenting a major problem for global public health.

Sex differences in the risk of MetS and its diagnostic components have been shown in Western populations [5-9]. The overall prevalence of MetS did not significantly differ by sex but its diagnostic components showed different prevalence between men and women: excessive WC and low HDLC were more prevalent in women than in men but elevated TG, FBG, and BP were more prevalent in men than in women among US [5], Canadian [7], and French [8] adults. Several studies reported that the impact of age on increasing MetS prevalence was greater in women than in men [9-11], which were related to the effects of sex hormones on metabolic risk factors, such as central fat accumulation or altered lipid profiles after a menopause [12,13]. Furthermore, MetS have different progression of health consequences by sex. The incidence of type 2 diabetes in the presence of MetS was more strongly related to European women than European men [14] and a sex difference in the association of MetS with mortality risk was observed in US adults [15].

In the Korean adult population, MetS has become an urgent public health problem that needs to be managed at the national level [16]. As Korean adults have different genetic background and lifestyle characteristics from those of Western adults, the effect of sex on the MetS risk needs to be investigated for the Korean adult population. Previous studies conducted in Korea have also shown that the increased rate of MetS prevalence paralleled with age prominently in women compared to men [16-19]. Regarding MetS components, elevated TG and BP were prevalent in Korean men while low HDLC in Korean women [16,17,19]. However, these findings were limited to specific region [17,18] or the former dataset [16,19]. In addition, MetS is a pre-morbid condition and thus the exclusion of individuals with previous diagnosed diabetes or cardiovascular disease is recommended to estimate the risk of MetS [20].

Understanding differential risk of MetS and its diagnostic components by sex in Korean adults is critical to investigate their pathogenesis and prevent further progression of MetS to chronic diseases as considering the fact that cardiovascular disease is one of the major causes of morbidity and mortality in this population [21].

Therefore, the aim of this study was to examine sex differences in the risk of MetS and its diagnostic components among Korean adults who had no previous diagnoses or treatment for diabetes, hypertension, or dyslipidemia based on the most recent nationally representative sample data. Specific objectives were to 1) examine sex differences in the overall prevalence of MetS and its components, 2) determine the age effect on the prevalence of Mets and its components by sex, and 3) identify different combinations of MetS components that make up MetS by sex.

Methods

Data and subjects

This study was based on the data from the 2008-2012 Korea National Health and Nutrition Examination Survey (KNHANES), which is a nationally representative cross-sectional survey conducted by the Korea Centers for Disease Control and Prevention. The KNHANES annually collects data to assess the health and nutritional status of the Korean population. KNHANES is based on a stratified, multistage probability sampling design and consists of three survey sections: health interview, health examination, and nutrition survey. The details of the survey design and procedures have been described elsewhere [22,23].

Among eligible 34,670 subjects aged 19 years or older, we excluded individuals who had incomplete anthropometric or biochemical data (n = 5,088), had prior diagnoses or treatments for diabetes, hypertension, or dyslipidemia (n = 8,650), or were pregnant women (n = 106). Individuals who had no data on sociodemographic and dietary variables (n = 3,000) were also excluded. A total of 17,826 Korean adults (7,061 men and 10,765 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 all individual subjects included in this study.

Data collection

In this study, the data collected from the health interview and the health examination is used. Information about age, lifestyle, medical history, and pregnancy was obtained through the health interview by trained interviewers. Information on anthropometric and biochemical variables was obtained through the health examination by trained examiners.

Overweight/obesity was defined as BMI ≥ 25.0 kg/m^2. WC was measured to the nearest 0.1 cm using a measuring tape in a standing position at the umbilical level (SECA 200, SECA Deutschland, Hamburg, Germany). Systolic and diastolic BP were measured three times to the nearest 2 mmHg using a mercury sphygmomanometer (Baumanometer, WA Baum Co., New York, USA) in a sitting position after at least 5 minutes of rest, and the average of the last two values was used. Venous blood samples were collected from each subject after they fasted for at least 8 hours and analyzed in a certified clinical laboratory. FBG, TG, and HDLC were measured enzymatically using a Hitachi automatic analyzer 7600 (Hitachi, Tokyo, Japan).

Definition of MetS and its Diagnostic Components

MetS was defined based on the criteria of National Cholesterol Education Program Adult Treatment Panel (NCEP ATP) III [1] with the cut-off value of excessive WC for the Asian population adopted from the International Diabetes Federation (IDF) criteria [24]. An individual was diagnosed as having MetS if he or she had three or more of the following five diagnostic components: 1) excessive WC, as defined by WC ≥ 90 cm in men and ≥ 80 cm in women, 2) elevated TG, as defined by TG ≥ 150 mg/dL, 3) low HDLC, as defined by HDLC < 40 mg/dL in men and < 50 mg/dL in women, 4) elevated FBG, as defined by FBG ≥ 100 mg/dL, and 5) elevated BP, as defined by systolic BP ≥ 130 mmHg or diastolic BP ≥ 85 mmHg.

Statistical analyses

All statistical analyses were conducted using the Statistical Analysis Systems (SAS) statistical software package, version 9.3 (SAS Institute Inc., Cary, NC, USA). All analyses accounted for the complex sampling design effect and used appropriate sampling weights of the national survey to represent the Korean adult population. Data were presented as percentage (%) and standard error (SE) for the prevalence of MetS and its diagnostic components by sex.

To adjust difference in the age structure of each year survey, the age-standardized prevalence of MetS and its components was calculated using the sex- and age-specific structures of estimated population based on the 2005 Korea Census [25]. The age-specific prevalence of MetS and its components was estimated according to six age groups in 10-year increments by sex (e.g.: 19-29y, 30-39y, 40-49y, 50-59y, 60-69y, and ≥ 70y).

To determine the significant differences in the prevalence of MetS and its component by sex and age groups, the multivariate adjusted logistic regression analysis was performed after adjustment for living area, education, household income, obesity, current smoking, current alcohol drinking, vigorous physical activity, and total energy intake. P-values less than 0.05 were considered statistically significant.

Results

Table 1 shows the characteristics of the study subjects by sex. The current study included 7,061 men and 10,765 women with mean ages of 46.1 ± 0.3 and 44.2 ± 0.2 years, respectively ($p<0.001$). The distribution of age groups significantly differed by sex ($p < 0.001$).

The percentages of subjects in age groups from 30-39 to 50-59 were higher in women compared to men. On the other hand, the proportion of subjects aged 60 years or older was higher in men than in women.

Men were more likely to live in rural area, have higher education level, be overweight/obese, be current smokers, currently drink alcohol, engage in vigorous physical activity, and have higher intake of total energy than women. However, household income did not differ by sex.

Characteristics	Total (n=17,826)		Men (n=7,061)		Women (n=10,765)		p-value
	%	(SE)	%	(SE)	%	(SE)	
Age group							
19-29y	17.0	(0.5)	17.2	(0.7)	16.9	(0.5)	<0.001
30-39y	24.7	(0.5)	22.7	(0.7)	26.0	(0.6)	
40-49y	21.9	(0.4)	20.7	(0.6)	22.7	(0.5)	
50-59y	17.0	(0.4)	16.5	(0.5)	17.3	(0.4)	
60-69y	11.4	(0.3)	13.1	(0.5)	10.3	(0.4)	
≥ 70y	8.0	(0.3)	9.9	(0.5)	6.7	(0.3)	
Living area							
City	69.4	(0.9)	67.5	(1.1)	70.6	(0.9)	<0.001
Rural	30.6	(0.9)	32.5	(1.1)	29.4	(0.9)	
Education							
Elementary	18.8	(0.5)	15.5	(0.6)	21.0	(0.6)	<0.001
Junior high	10.1	(0.3)	10.8	(0.4)	9.6	(0.3)	
Senior high	38.8	(0.5)	39.3	(0.7)	38.5	(0.6)	
College or more	32.4	(0.6)	34.5	(0.8)	30.9	(0.6)	
Household income							
Lowest	15.7	(0.5)	15.6	(0.6)	15.7	(0.5)	0.775
Medium-low	26.3	(0.6)	26.5	(0.7)	26.2	(0.6)	
Medium-high	29.5	(0.5)	29.8	(0.7)	29.4	(0.6)	
Highest	28.5	(0.7)	28.1	(0.8)	28.7	(0.7)	
Obesity							
Underweight (BMI<18.5kg/m^2)	5.9	(0.2)	3.5	(0.3)	7.9	(0.3)	<0.001
Healthy weight (BMI 18.5-25.0kg/m^2)	66.9	(0.5)	63.5	(0.7)	69.9	(0.6)	
Overweight/Obesity (BMI≥25.0kg/m^2)	27.2	(0.4)	33.0	(0.7)	22.2	(0.5)	
Current smoking							
Yes	25.3	(0.4)	46.5	(0.7)	6.6	(0.3)	<0.001
No	74.7	(0.4)	53.5	(0.7)	93.4	(0.3)	
Current alcohol drinking							
Yes	59.9	(0.5)	76.1	(0.6)	45.7	(0.6)	<0.001
No	40.1	(0.5)	23.9	(0.6)	54.3	(0.6)	
Vigorous physical activity							
Yes	16.5	(0.4)	19.5	(0.6)	13.8	(0.4)	<0.001
No	83.5	(0.4)	80.5	(0.6)	86.2	(0.4)	
	Mean	**(SE)**	**Mean**	**(SE)**	**Mean**	**(SE)**	

Total energy intake (kcal)	2061	(10.6)	2432	(16.4)	1701	(8.8)	<0.001

Table 1: Characteristics of the study subjects from the 2008-2012 Korea National Health and Nutrition Examination Survey[a,b]. [a]All analyses accounted for the complex sampling design effect and used appropriate sampling weights of the national survey. [b]The chi-square test was used for categorical variables and the t-test was used for continuous variable to test the difference in the distribution of these variables between men and women.

Age-standardized prevalences of MetS and its diagnostic components by sex are presented in Table 2. The prevalence of MetS was 16.7% in total subjects and the overall prevalence was slightly higher in men (19.0%) than in women (14.8%). The distribution of number of MetS components significantly differed by sex ($p < 0.001$). Men and women differed with the most prevalent MetS components: elevated TG (33.2%) and low HDLC (28.1%) in men vs. low HDLC (44.9%) and excessive WC (31.3%) in women.

	Total (n=17,826)		**Men (n=7,061)**		**Women (n=10,765)**		**p-value[c]**
	%	**(SE)**	**%**	**(SE)**	**%**	**(SE)**	
No. of MetS components							
0	34.8	(0.5)	34.0	(0.7)	35.6	(0.6)	<0.001
1	29.4	(0.4)	26.6	(0.6)	31.8	(0.6)	
2	19.1	(0.3)	20.4	(0.6)	17.9	(0.4)	
3	11.0	(0.3)	12.4	(0.5)	9.9	(0.3)	
4	4.7	(0.2)	5.5	(0.3)	3.9	(0.2)	
5	1.0	(0.1)	1.1	(0.2)	1.0	(0.1)	
MetS and its components							
Excessive WC	26.6	(0.5)	21.2	(0.6)	31.3	(0.6)	<0.001
Elevated TG	23.5	(0.4)	33.2	(0.7)	14.9	(0.4)	<0.001
Low HDLC	37.1	(0.5)	28.1	(0.7)	44.9	(0.6)	<0.001
Elevated FBG	17.4	(0.4)	21.9	(0.6)	13.4	(0.4)	<0.001
Elevated BP	20.0	(0.4)	27.6	(0.7)	13.3	(0.4)	<0.001
MetS	16.7	(0.4)	19.0	(0.6)	14.8	(0.4)	<0.001

Table 2: Age-standardized prevalence of metabolic syndrome and its diagnostic components by sex among Korean adults from the 2008-2012 Korea National Health and Nutrition Examination Survey[a,b]. [a]All analyses accounted for the complex sampling design effect and used appropriate sampling weights of the national survey. [b]MetS and its diagnostic components were defined based on the criteria of National Cholesterol Education Program Adult Treatment Panel III with the cut-off value of excessive WC for the Asian population adopted from the International Diabetes Federation criteria. An individual was diagnosed as having MetS if he or she had three or more of the following five components: 1) excessive WC, as defined by WC ≥ 90 cm in men and ≥ 80 cm in women, 2) elevated TG, as defined by TG ≥ 150 mg/dL, 3) low HDLC, as defined by HDLC < 40 mg/dL in men and < 50 mg/dL in women, 4) elevated FBG, as defined by FBG ≥ 100 mg/dL, and 5) elevated BP, as defined by systolic BP ≥ 130 mmHg or diastolic BP ≥ 85 mmHg. [c]The chi-square was used to test differences in prevalence of MetS and its components between men and women. BP: Blood Pressure; HDLC: High-Density Lipoprotein Cholesterol; FBG: Fasting Blood Glucose; MetS: Metabolic Syndrome; TG: Triglycerides; WC: Waist Circumference.

Age-specific prevalences of MetS and its diagnostic components by sex are presented in Figure 1. The overall prevalence of MetS increased with age only in women. Men < 60 years had a higher prevalence of MetS than women in the same age category. However, the sex difference was reversed in adults ≥ 60 years of age. The prevalences of excessive WC and low HDLC were significantly higher in women than in men across all age groups. Elevated TG was more prevalent in men aged < 70 years than in women, while in subjects aged 70 years and older, elevated TG were more prevalent in women than in men. The prevalence of elevated FBG was significantly higher in men aged 30–69 years than in women but in subjects aged 70 years and older, there was no difference in the prevalence of FBG between men and women. The prevalence of elevated BP increased with age in men and women and was higher in men aged < 60 years than in women.

Citation: SuJin Song, Hee Young Paik, YoonJu Song, Won O Song (2016) Sex Differences in the Risk of Metabolic Syndrome and its Diagnostic Components in Korean Adults. Endocrinol Metab Syndr 5: 233. doi:10.4172/2161-1017.1000233

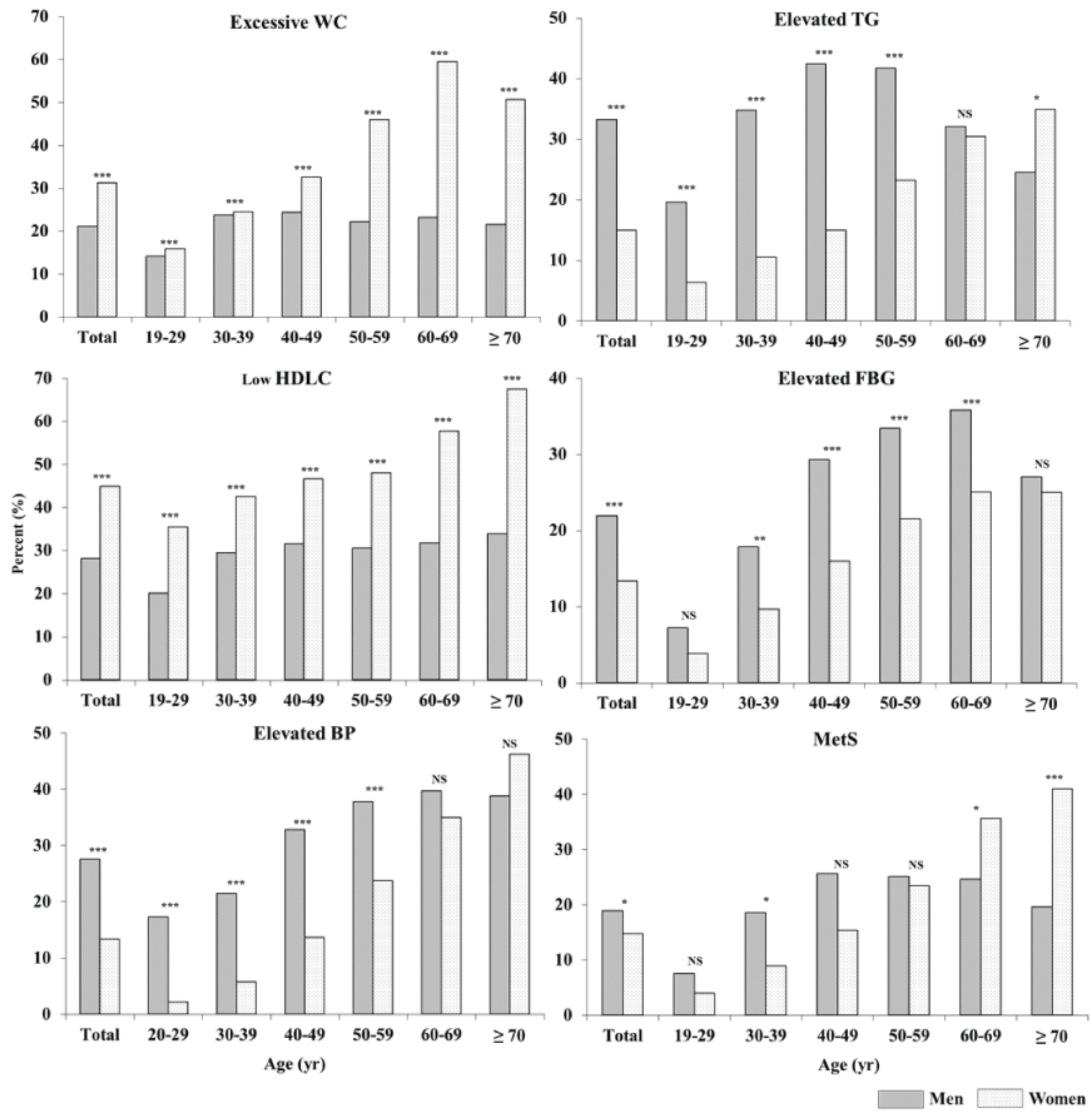

Figure 1: Age-specific prevalence of metabolic syndrome and its diagnostic components by sex among Korean adults from the 2008-2012 Korea National Health and Nutrition Examination Survey[a,b,c]. [a]All analyses accounted for the complex sampling design effect and used appropriate sampling weights of the national survey. [b]MetS and its diagnostic components were defined based on the criteria of National Cholesterol Education Program Adult Treatment Panel III with the cut-off value of excessive WC for the Asian population adopted from the International Diabetes Federation criteria. An individual was diagnosed as having MetS if he or she had three or more of the following five components: 1) excessive WC, as defined by WC ≥ 90 cm in men and ≥ 80 cm in women, 2) elevated TG, as defined by TG ≥ 150 mg/dL, 3) low HDLC, as defined by HDLC < 40 mg/dL in men and < 50 mg/dL in women, 4) elevated FBG, as defined by FBG ≥ 100 mg/dL, and 5) elevated BP, as defined by systolic BP ≥ 130 mmHg or diastolic BP ≥ 85 mmHg. [c]The logistic regression was used to obtain the p-values after adjustment for living area, education, household income, obesity, current smoking, current alcohol drinking, vigorous physical activity, and total energy intake ($^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$). BP: Blood Pressure; HDLC: High-Density Lipoprotein Cholesterol; FBG: Fasting Blood Glucose; MetS: Metabolic Syndrome; NS: Not Significant; TG: Triglycerides; WC: Waist Circumference.

Table 3 shows sex differences in combinations of MetS diagnostic components among subjects with MetS. Distinct combinations of MetS components were observed by sex. In women with MetS, excessive WC + elevated TG + low HDLC was the most common combination (23.6%), followed by excessive WC + low HDLC + elevated FBG (11.8%) and excessive WC + low HDLC + elevated BP (10.7%). In men with MetS, excessive WC + elevated TG + low HDLC (12.5%), elevated TG + low HDLC + elevated BP (10.1%), and elevated TG + low HDLC + elevated FBG (8.8%) were the most prevalent combinations.

		Combinations of MetS components					Men (n=1,408)	Women (n=1,754)
		Excessive WC	Elevated TG	Low HDLC	Elevated FBG	Elevated BP	% (SE)	% (SE)
No. of MetS components	3	x	x	x			12.5 (1.1)	23.6 (1.3)
		x	x		x		5.0 (0.7)	2.4 (0.5)
		x	x			x	8.0 (0.9)	2.2 (0.5)
		x		x	x		2.8 (0.5)	11.8 (1.0)
		x		x		x	2.3 (0.4)	10.7 (0.9)
		x			x	x	5.2 (0.7)	4.8 (0.7)
			x	x	x		8.8 (0.9)	3.9 (0.6)
			x	x		x	10.1 (1.0)	4.2 (0.5)
			x		x	x	8.6 (1.0)	0.9 (0.3)
				x	x	x	2.0 (0.4)	2.5 (0.4)
	4	x	x	x	x		6.7 (0.8)	8.9 (0.8)
		x	x	x		x	6.4 (0.8)	8.8 (0.8)
		x	x		x	x	7.0 (0.8)	1.8 (0.4)
		x		x	x	x	2.2 (0.4)	5.6 (0.7)
			x	x	x	x	6.6 (0.7)	1.5 (0.3)
	5	x	x	x	x	x	5.8 (0.8)	6.6 (0.7)
Prevalence of each MetS component								
Men	% (SE)	63.9(1.5)	85.5(1.1)	66.2(1.5)	60.7(1.7)	64.3(1.5)		
Women	% (SE)	87.1(1.1)	64.6(1.4)	87.8(1.0)	50.6(1.4)	49.5(1.6)		

BP: blood pressure; HDLC: high-density lipoprotein cholesterol; FBG, fasting blood glucose; MetS, metabolic syndrome; TG, triglycerides; WC, waist circumference.

[a]All analyses accounted for the complex sampling design effect and used appropriate sampling weights of the national survey.

[b]MetS and its diagnostic components were defined based on the criteria of National Cholesterol Education Program Adult Treatment Panel III with the cut-off value of excessive WC for the Asian population adopted from the International Diabetes Federation criteria. An individual was diagnosed as having MetS if he or she had three or more of the following five components: 1) excessive WC, as defined by WC ≥90 cm in men and ≥80 cm in women, 2) elevated TG, as defined by TG ≥ 150 mg/dL, 3) low HDLC, as defined by HDLC < 40 mg/dL in men and < 50 mg/dL in women, 4) elevated FBG, as defined by FBG ≥ 100 mg/dL, and 5) elevated BP, as defined by systolic BP ≥ 130 mmHg or diastolic BP ≥ 85 mmHg.

Table 3: Combinations of diagnostic components of metabolic syndrome among subjects with metabolic syndrome by sex based on the 2008–2012 Korea National Health and Nutrition Examination Survey[a,b].

Discussion

Our study provides the latest information on sex differences in the risk of MetS and its diagnostic components using the nationally representative sample of Korean adults who had not diagnosed or taken medications for diabetes, dyslipidemia, or hypertension. The overall prevalence of MetS was slightly higher in men than in women but the steeper age-related increases in the prevalence of MetS and its components was shown in women compared to men. In addition, the common MetS components differed by sex and thus men and women who had MetS were differentially characterized by the distinct combinations of diagnostic components that made up MetS.

In this study, the most high risk group of MetS was elderly women. Among men, a plateau or decrease in MetS prevalence was observed in the age groups over 50 years. On the other hand, the prevalence continuously increased with age among women. This finding is consistent with previous works in Western [10,11] and Asian populations [16,26,27], which have shown that men from young to middle-aged group tend to have a higher prevalence of MetS than women of the same age group, but women have a higher prevalence than men above the age of 60 years. Menopause may be one of the major contributing factors for the increase in MetS prevalence in middle-aged and elderly women [10,28]. Post-menopause is associated with the emergence of several metabolic risk factors, including increased central fat, increased TG, reduced HDLC, and insulin resistance through the estrogen deficiency [12,13]. In the cross-sectional study of Korean adults [28], postmenopausal women had significantly higher prevalences of all MetS components than premenopausal women and the menopausal status was a key predictor of having MetS. Our study also demonstrated that the prevalence of all MetS components increased with age in women. Based on these findings, preventive programs for women prior to menopause are necessary and therapeutic strategies should be targeted to elderly women.

According to our results, common MetS components differed by sex: excessive WC and low HDLC were more prevalent in women than in men while elevated TG, FBG, and BP were more prevalent in men than in women, which were consistent with findings from previous studies conducted in Asian [16,19,27] and Western [5,7,8] populations although each study used different diagnostic criteria. In addition to different MetS components by sex, men and women who had been diagnosed as having MetS in this study showed different combinations of MetS components, respectively. In US adults from the third NHANES, the most prevalent MetS combination was the clustering of elevated TG, low HDLC, and elevated BP in younger men but elevated TG, low HDLC, and excessive WC in younger women; the presence of all five components was the most common combination in both older men and women [15]. Oh et al. [18] also revealed the sex-specific clustering of MetS components in urban Korean adults. MetS is a heterogeneous cluster of five diagnostic components with sex variation and thus MetS needs to be differently addressed according to various combinations by sex.

These differences in the MetS diagnostic components and/or combinations might lead to different progression of health consequences by sex. According to several studies of meta-analysis, MetS was a stronger predictor for cardiovascular disease morbidity and mortality in women than in men [2,29,30]. A European Prospective Investigation into Cancer and Nutrition-Potsdam Study showed that the incidence of type 2 diabetes in the presence of MetS defined by the NCEP ATP III criteria was more strongly related to women than men [14]. In addition, each MetS component was differentially associated with the progression of health outcomes by sex. In the European study [14], elevated TG was associated with the risk of diabetes only in women while elevated BP was associated with the risk of diabetes only in men and excessive WC and elevated FBG were more strongly associated with the risk of diabetes in women than in men. A US study [15] using the third NHANES data also found that the various MetS combinations were not associated with elevated mortality risk in older men, but regardless of the absolute number of MetS components, having elevated FBG or low HDLC was strongly associated with the risk of mortality in older women. Based on these findings, sex-specific preventive strategies and clinical managements for MetS and chronic diseases should be suggested.

Different MetS features by sex might support the concept of sex-specific criteria for MetS diagnosis as a prerequisite to estimate individuals at higher risk of MetS and predict the risk of chronic diseases accurately. In most current diagnostic criteria, the same diagnostic components are used to define MetS for both men and women [1]. Some of the diagnostic components, such as excessive WC and low HDLC, use sex-specific cut-off values, but no detailed rationale for the values related to the risk of cardiovascular disease. In this study, low HDLC was defined as <40 mg/dL in men and <50 mg/dL in women based on the NCEP ATP III criteria [1]. These cut-off values were associated with insulin resistance or hypertension and adopted from epidemiologic studies conducted in Western populations [31-33]. Most recently, Moon et al. [34] suggested the optimal cut-off values of low HDLC for predicting the risk of cardiovascular disease as 43 mg/dL for Korean men and 48 mg/dL for Korean women. For excessive WC, we used the cut-off values from the Asian-specific IDF criteria (90 cm for men and 80 cm for women) [24]. However, Lee et al. [35] suggested that WC values of 90 cm for men and 85 cm for women were more appropriate to predict metabolic risk factors in Korean adults. To increase the predictability of MetS for the development of cardiovascular disease, it is necessary to review the validity of current MetS criteria and their cut-off values according to sex.

Our study has several limitations. We used one of the current available definitions for MetS diagnosis, so our ability to directly compare the present findings with those from previous studies which used different definitions was limited. However, there is still no universally standardized MetS definition [20]. This study was based on the cross-sectional data, so we could not examine the sex differences in the predictive ability of MetS for the development of chronic diseases, such as type 2 diabetes or cardiovascular disease. Some known confounding variables of MetS, such as pre-diabetes condition, family history, or sex hormones were not collected throughout the whole dataset and thus not considered in the analyses. Especially, the recent study [36] described the beneficial effects of nutraceuticals on the risks of dyslipidemia and cardiovascular disease. However, in the present study, we could not examine the association between nutraceuticals and MetS due to the lack of information on nutraceuticals consumption of the study population. However, we used the most recent data and the large nationally representative sample to describe the current estimation of MetS risk by sex.

Conclusions

In conclusion, our results confirmed the important sex differences in the risk of MetS and its components, including the overall and age-specific prevalence among Korean adults. This information might be helpful to identify a high risk group suffering from MetS and prevent chronic diseases through sex-specific intervention strategies. Especially, for middle-aged and elderly women, preventive and therapeutic guidelines to address the higher prevalence of MetS need to be suggested. Prospective studies to identify sex-specific determinants of MetS and to determine the different effects of MetS and its components on further progression to chronic diseases by sex are also needed.

Funding Source

This study was funded by the Korea Centers for Disease Control and Prevention (grant number: 2014ER630900).

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