Prevalence of Metabolic Syndrome and Its Relationship to White Blood Cell Count in a Population of Thai Men and Women Receiving Routine Health Examinations

Vitool Lohsoonthorn, Bodi Dhanamun, and Michelle A. Williams

Background: Patients with metabolic syndrome (MetS) are at increased risk for developing diabetes mellitus and cardiovascular disease. Limited information is available about the prevalence of MetS among Thai men and women. In this study we sought to estimate the prevalence of MetS among a population of patients receiving annual health exams. We also studied the relationship between MetS and elevated white blood cell (WBC) count.

Methods: This was a cross-sectional study of 1383 patients (375 men and 1008 women) who participated in annual health examinations at the Preventive Medicine Clinic of the King Chulalongkorn Memorial Hospital in Bangkok, Thailand, from July 1999 through February 2000. The presence of MetS was defined using the modified criteria of the National Cholesterol Education Program Adult Treatment Panel III.

Results: Overall, the prevalence of the MetS was 12.8% and was more common among men than women (15.7% *v* 11.7%). Advanced age and elevated WBC counts were the only statistically significant risk factors of MetS in this population. The WBC count was statistically significantly correlated with high-density lipoprotein-cholesterol and triglyceride ($P = .05$). Men with highest WBC count ($\geq 7.50 \times 10^3$ cell/μL) had a 2.98-fold increased in risk of MetS (odds ratio 2.98, 95% confidence interval 1.29 to 6.87), as compared with men in the lowest quartile ($< 5.40 \times 10^3$ cell/μL). Among women, the risk of MetS increased across successive quartiles of WBC counts (1.00, 2.26, 2.88, and 4.30, with the lowest quartile as the referent group).

Conclusions: In this study of Thai men and women receiving routine health examinations, MetS was found to be prevalent. In addition, WBC count (indicative of systemic chronic inflammation) is positively associated with MetS. Am J Hypertens 2006;19:339–345 © 2006 American Journal of Hypertension, Ltd.

Key Words: Metabolic syndrome, prevalence, white blood cell count, Thailand.

Metabolic syndrome (MetS), also referred to as insulin resistance syndrome or syndrome X, is a cluster of cardiovascular disease risk factors which include high blood pressure (BP), elevated triglycerides, low high-density lipoprotein (HDL) concentrations, impaired glucose tolerance, and excess abdominal fat. Rather than a disease MetS is a group of commonly diagnosed metabolic disorders that are frequently clustered in individuals. At least four sets of criteria have been proposed for categorizing individuals with MetS.[1–4] For instance, the European Group for the Study of Insulin Resistance (EGIR) proposed a modified version of the criteria originally specified by the World Health Organization. The EGIR developed criteria for specific use in nondiabetic populations.[2] The National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III)[3] specified MetS criteria that were more amenable to measurements taken in routine clinical practice. Importantly the use of similar although nonoverlapping criteria for MetS has resulted in considerable variation in prevalence estimates of the syndrome across studies.[5] The prevalence of MetS among adults in the United States who participated in the Third National Health and Nutrition Examination Survey

Received August 27, 2005. First decision October 17, 2005. Accepted October 26, 2005.

From the Department of Preventive and Social Medicine (VL, BD), Faculty of Medicine, Chulalongkorn University, Bangkok, Thailand; and Department of Epidemiology (MAW), Multidisciplinary International Research Training Program, University of Washington School of Public Health and Community Medicine, Seattle, Washington.

This study was supported by Rachadapiseksompoj Faculty of Medicine Research Fund Chulalongkorn University, Thailand, and by the National Institutes of Health (grants T37-TW00049 and T37-MD-100449).

Address correspondence and reprint requests to Dr. Vitool Lohsoonthorn, University of Washington, MIRT Program, Department of Epidemiology, Box 357236, 1959 NE Pacific Street (HSB, F-263), Seattle, WA 98195; e-mail: vitool@u.washington.edu

0895-7061/06/$32.00
doi:10.1016/j.amjhyper.2005.10.008

varied from 16% for African American men to 37% for Hispanic women.[6] A comparison of the prevalence of the MetS using two proposed definitions among Americans ≥20 years of age indicated that age-adjusted MetS prevalence estimates were 23.9% using the NCEP ATP III criteria and 25.1% using the World Health Organization criteria.[7]

Despite differences in overall MetS prevalence estimates, published reports consistently indicate that MetS increases with age[6,8,9] and increasing body weight.[10] Recently investigators reported that increased white blood cell (WBC) counts, a biological marker of systemic inflammation, is associated with components of MetS[11,12] Patients with MetS are at increased risk for diabetes and cardiovascular events,[13] resulting in a general decline in the quality of life and an increasingly heavy burden on healthcare systems. It has been estimated that MetS soon will overtake cigarette smoking as the primary risk factor for cardiovascular disease among Americans.[10,14] Little information exists on the prevalence and epidemiological characteristics of the MetS in Thailand. We therefore conducted the present study to estimate the prevalence of MetS among Thai men and women undergoing routine health examinations. We also sought to evaluate the extent to which (if at all) elevated WBC counts were associated with components of MetS and with the risk of MetS, overall.

Methods

Study Population and Data Collection

We conducted a cross-sectional study of 1383 patients (375 men and 1008 women) who first participated in annual health examinations at the Preventive Medicine Clinic of King Chulalongkorn Memorial Hospital in Bangkok, Thailand, from July 1999 through February 2000. Participants were those with no diagnosed diabetes mellitus or hypertension and no current use of lipid- or BP-lowering medication. During routine clinic visits the participants were asked to provide information about their age, marital status, occupation, education, medical history, smoking status, alcohol consumption habits, and participation in regular weekly physical exercise and other leisure activities.

Participants underwent routine physical examinations that included height, weight, resting BP, and an overnight fasting venous blood sample. Standing height was measured without shoes to the nearest 0.5 cm. Weight was determined without shoes and with participants lightly clothed. Weight was measured using an automatic electronic scale (Seca, Inc., Hamburg, Germany) to the nearest 100 g. Blood pressure was determined using an automatic sphygmomanometer (UDEX-IIα, UEDA, Corp., Tokyo, Japan). Participants were instructed to rest in seated position for 5 min before BP measurements were determined.

Laboratory Analyses

Participants provided an overnight fasting venous blood sample. Serum samples were used to determine lipid profiles. Serum triglyceride (TG) concentration was determined by standardized enzymatic procedures using glycerol phosphate oxidase assay. High-density lipoprotein cholesterol (HDL-C) was measured by a chemical precipitation technique using dextran sulfate. Plasma samples were used to determine fasting plasma glucose (FPG) using the hexakinase method. White blood cell (WBC) count was determined on the automated WBC-Differential System SE 9500 (Sysmex Corporation, Kobe, Japan). The coefficient of variation for the WBC assay was 3.6%. All laboratory assays were completed without knowledge of participants' medical history. Lipid, lipoprotein, and FPG concentrations were reported as milligrams per deciliter. The WBC count was reported as cells per microliter.

All participants provided informed consent before the study. The research protocol was reviewed and approved by the Ethical Committee of Faculty of Medicine, Chulalongkorn University, and the Division of Human Subjects Research, University of Washington.

Analytical Variable Specification

Presence of MetS was defined using a modified version of the ATP III criteria.[3] Briefly, four of the five MetS components were defined using the following ATP III categorizations: 1) high BP ≥130/85 mm Hg; 2) hypertriglyceridemia ≥150 mg/dL; 3) low HDL-C <40 mg/dL; 4) hyperglycemia or high fasting glucose ≥110 mg/dL. The fifth component was defined based on body mass index (BMI) rather than on waist circumference measures to identify individuals with central adiposity.[15] We classified participants with a BMI ≥25 kg/m^2 as having high central obesity. Participants with three of any of the five components were classified as having MetS.

Next we classified subjects according to categories of WBC counts. The WBC counts, expressed as cells per microliter, were categorized into approximate quartiles for men and women separately. The resulting four categories for men were as follows: 1) $<5.40 \times 10^3$ cells/μL; 2) 5.40 to 6.29 $\times$ 10^3 cells/μL; 3) 6.30 to 7.49 $\times$ 10^3 cells/μL; and 4) $\geq 7.50 \times 10^3$ cells/μL. The corresponding categories for women were as follows: 1) $<5.38 \times 10^3$ cells/μL; 2) 5.38 to 6.47 $\times$ 10^3 cells/μL; 3) 6.48 to 7.69 $\times$ 10^3 cells/μL; and 4) $\geq 7.70 \times 10^3$ cells/μL.

Statistical Analyses

We first explored frequency distributions of sociodemographic, behavioral characteristics and medical histories. For categorical variables the χ^2 test was used to evaluate differences in distribution of covariates for affected and unaffected patients. The correlation between WBC count and each component of MetS was examined using partial correlation coefficient adjusted for age and all other MetS components. Logistic regression procedures were used to examine the risk of having MetS. Univariate and multivariable logistic regression procedures were used to calculate unadjusted odd ratios (OR) of potential risk factors asso-

Table 1. Prevalence of one or more abnormalities of the metabolic syndrome among Thai men and women receiving health examination

Number of metabolic abnormalities	Men		Women		Total cohort	
	n	(%)	*n*	(%)	*n*	(%)
None	123	(32.8)	422	(41.9)	545	(39.4)
≥1	252	(67.2)	586	(58.1)	838	(60.6)
≥2	140	(37.3)	281	(27.9)	421	(30.4)
≥3*	59	(15.7)	118	(11.7)	177	(12.8)
≥4	16	(4.3)	39	(3.9)	55	(4.0)
5	1	(0.3)	6	(0.6)	7	(0.5)

* According to criteria in the National Cholesterol Education Program Expert Panel Adult Treatment Panel III (see Ref. [3]); individual with three or more metabolic abnormalities was classified as having metabolic syndrome.

ciated with MetS. Confounding factors were evaluated on the basis of their hypothesized relationship with the covariates of interest and with MetS. Confounding was assessed by entering potential covariates into a logistic regression model one at a time, and by comparing the adjusted and unadjusted OR.[16] Final logistic regression models included covariates that altered unadjusted OR by ≥10%. All analyses were completed separately for men and women. Statistical analyses were performed using SPSS software, version 13.0 (SPSS Inc., Chicago, IL). All reported *P* values were two-tailed, and confidence intervals (CI) were calculated at the 95% level.

Results

Overall the prevalence of the MetS was 12.8%, and more common among men than women (Table 1). The prevalence of each component of MetS is summarized in Fig. 1. The three most common metabolic abnormalities in men were high BP, hypertriglyceridemia and low HDL-C. Among women, low HDL-C, high BP, and hypertriglyceridemia were the most common abnormalities. As shown in Table 2, men with MetS in comparison to those without the syndrome were older ($P = .001$), were more likely to have reported being former consumers of alcohol ($P = .296$), and had lower educational attainment ($P = .295$). The latter two covariates, however, did not reach statistical significance. Women with MetS, as compared with their counterparts without the syndrome, were older ($P = .001$), less well educated ($P = .001$), and reported having smoked cigarettes at some point ($P = .035$). Other factors including participation in exercise and leisure activities, as well as laborer occupation were not statistically significantly associated with MetS.

Adjusted mean WBC counts for the different groups with respect to five components of MetS in both genders are listed in Table 3. Generally the participants with MetS-defining abnormalities had higher WBC counts than those without MetS-defining abnormalities. This pattern of association was evident for both men and women. Women with BMI ≥25 kg/m^2, high FPG, high TG, and low HDL-C had WBC counts that were approximately 400 to 600 cells/μL higher than those without metabolic abnormalities (all *P* values $< .05$). Men with high TG and low HDL-C had statistically significant higher WBC count (670 and 550 cells/μL, respectively, [*P* values $< .05$]) than those without metabolic abnormalities.

Table 4 shows partial correlation coefficients for each of the MetS components and WBC count after adjustment for age and all other MetS components. Among men, there was statistically significant positive correlations ($P = .05$) between WBC count and TG. A statistically significant negative correlation was observed between WBC count and HDL-C concentration. Among women, WBC count was positively correlated with BMI and TG ($P = .05$), and was inversely correlated with HDL-C concentrations ($P = .001$). The WBC count was most strongly correlated with BMI ($r = 0.14$) and HDL-C ($r = -0.11$).

We next estimated multivariable logistic regression models to identify independent risk factors for MetS in our study population. The results of these analyses are summarized in Table 5. Advanced age and elevated WBC counts were the only statistically significant risk factors of MetS in this population. Men with highest quartile of WBC count (≥7.50 × 10^3 cells/μL) had a 2.98-fold increased in risk for MetS as compared with men with

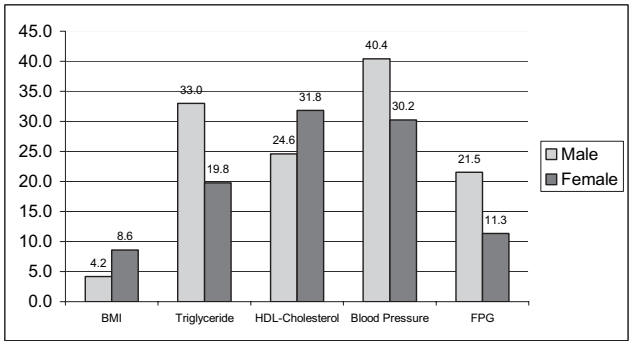

FIG. 1 Prevalence of each component of metabolic syndrome (MetS) among Thai men and women.

Table 2. Characteristics of study population according to metabolic syndrome status among Thai men and women

	Metabolic syndrome, men					Metabolic syndrome, women				
	No (*N* = 316)		Yes (*N* = 59)		*P* value	No (*N* = 890)		Yes (*N* = 118)		*P* value
Characteristic	*n*	%	*n*	%		*n*	%	*n*	%	
Age (y)					.001					<.001
<20	5	1.6	1	1.7		10	1.1	0	0.0	
20–29	55	17.4	2	3.4		134	15.1	2	1.7	
30–39	89	28.2	7	11.9		235	26.4	7	5.9	
40–49	67	21.2	16	27.1		265	29.8	30	25.4	
50–59	54	17.1	13	22.0		168	18.9	44	37.3	
60–69	34	10.8	16	27.1		67	7.5	29	24.6	
≥70	12	3.8	4	6.8		11	1.2	6	5.1	
Education					.295					<.001
≤Primary education	84	26.9	21	36.2		414	47.3	78	69.0	
<Bachelor degree	129	41.4	23	39.7		243	27.8	24	21.2	
≥Bachelor degree	99	31.7	14	24.1		218	24.9	11	9.7	
Labor work					.699					.877
Yes	43	13.6	9	15.5		116	13.1	16	13.6	
No	273	86.4	49	84.5		773	87.0	102	86.4	
Alcohol drinking status					.296					.678
Never drinker	113	35.9	17	28.8		683	76.9	92	78.6	
Ever drinker	202	64.1	42	71.2		205	23.1	25	21.4	
Smoking status					.454					.035
Never smoker	164	51.9	27	46.6		839	94.6	104	89.7	
Ever smoker	152	48.1	31	53.5		48	5.4	12	10.3	
Exercise					.333					.635
Yes	163	51.8	26	44.8		313	35.4	44	37.6	
No	152	48.3	32	55.2		572	64.6	73	62.4	
Leisure-time activities					.718					.379
Yes	210	67.1	41	69.5		557	62.7	69	58.5	
No	103	32.9	18	30.5		332	37.4	49	41.5	

lowest quartile of WBC count (<5.40 × 10^3 cells/μL) (OR = 2.98, 95% CI = 1.29 to 6.87). Among women, the risk of MetS increased across successive quartiles of WBC counts (1.00, 2.26, 2.88, and 4.30, with the lowest quartile as the referent group). Men in the age groups 40 to 59 years and ≥60 years had a 3.51-fold and 5.97-fold increased in risk for MetS as compared with men in the age group <40 respectively, whereas in women the increased risk for MetS among age group 40 to 59 years and ≥60 years were 8.97-fold and 20.18-fold those of individuals <40 years of age.

Discussion

Despite attempts in recent years to reach an agreement on the definition of MetS, it remains difficult to compare prevalence estimates published for different populations. Available studies often differ with respect to study design, sample selection, study period, and definition of MetS.[17] The prevalence of MetS (12.8%) among members of our present study sample (namely, Thai men and women undergoing routine health examinations in Bangkok) is lower than estimates reported for adults in the US (21.8%).[6] Our prevalence estimates in women, however, are similar to those reported for Japanese women (11.7% *v* 11.5%).[15] Hence it is evident that there is a wide variation of MetS prevalence estimates reported for men and women. Estimates varied from 5.2% (Korea) to 42.0% (Iran) in men and from 8.1% (Taiwan) to 39.9% (India) in women.[18–21] Differences in nutrition, levels of physical activity, genetic background, and population structure all influence the prevalence of MetS.

The prevalence of the MetS is age dependent. In the present study, MetS was infrequent among younger subjects (<5% for both men and women in the 20- to 29-year age group), but rose considerably, to 27.1% and 24.6% for men and women, respectively, in the 60- to 69-year age group. Similarly, among American, Korean and Mexican population the prevalence of MetS is highly age dependent.[6,8,9] In the present study the correlations between WBC and some metabolic parameters were statistically significant, but these associations were weak. Among men the WBC count was statistically significantly and positively correlated with triglyceride and was inversely correlated with serum HDL-C concentrations. These findings were similar to those reported in a workplace-based study of middle-age Japanese men.[22]

It is known that MetS associated with an increased risk of

Table 3. Adjusted means of white blood cell count (per 1000 per μL) among Thai men and women according to selected features of metabolic syndrome

Variable	Men			Women		
	n	Means of WBC (95% CI)	*P* value	*n*	Means of WBC (95% CI)	*P* value
Obesity						
BMI ≥25 kg/m^2	14	6.99 (5.98–7.99)	.648	85	7.37 (6.97–7.77)	.002
BMI <25 kg/m^2	356	6.75 (6.55–6.94)		904	6.72 (6.60–6.84)	
High BP						
SBP ≥130 mm Hg or DBP ≥85 mm Hg	151	6.81 (6.49–7.14)	.657	300	6.98 (6.77–7.20)	.028
SBP <130 mm Hg and DBP <85 mm Hg	219	6.72 (6.45–6.98)		689	6.69 (6.55–6.82)	
High fasting plasma glucose						
≥110 mg/dL	81	7.08 (6.65–7.51)	.100	114	7.24 (6.89–7.59)	.007
<110 mg/dL	289	6.67 (6.45–6.89)		875	6.72 (6.60–6.84)	
High triglyceride						
≥150 mg/dl	122	7.20 (6.85–7.56)	.003	197	7.16 (6.88–7.44)	.003
<150 mg/dl	248	6.53 (6.29–6.77)		792	6.68 (6.55–6.81)	
Low HDL cholesterol						
<40 mg/dL (men)/<50 mg/dL (women)	92	7.17 (6.78–7.57)	.019	315	7.04 (6.83–7.24)	.003
≥40 mg/dL (men)/≥50 mg/dL (women)	278	6.62 (6.40–6.84)		674	6.66 (6.52–6.79)	

BMI = body mass index; BP = blood pressure; SBP = systolic blood pressure; DBP = diastolic blood pressure; HDL = high-density lipoprotein; WBC = white blood cells.

Separate models were estimated for men and women. Means of WBC count were adjusted for age, smoking status, drinking status, BMI, high blood pressure, high fasting plasma glucose, high triglyceride, and low HDL-cholesterol.

diabetes and cardiovascular disease–related morbidity and mortality, resulting in an enormous economic burden to society.[23] Men with four or five features of MetS have a 3.70-fold increased risk for coronary heart disease and a 24.50-fold increased risk for diabetes compared with men with none of these abnormalities (both $P = .0001$).[24] On the basis of these and other similar observations, investigators have encouraged patients to focus on improving their levels of physical activity, reducing their weight, increasing consumption of dietary fiber and low-fat dairy products, reducing total fat consumption, limiting alcohol intake, and refraining from cigarette smoking.[10]

Several limitation of our study merit consideration here. First, this study was cross-sectional study in design and thus did not permit the identification of causal relationship between WBC count and MetS. Second, our study population included individuals who received annual health examinations. Some characteristics of the present study population may be substantially different from other populations that do not have access to or make use of available medical services. Therefore the generalizability of our study may be limited and does not reflect the general Thai population. Third, misclassification of MetS status may have occurred in our study because we did not have direct measurements of waist circumference and thus had to use BMI as a measure of central adiposity. In sensitivity analyses, we noted that ex-

Table 4. Partial correlation coefficients (*r*) for each components of metabolic syndrome in relation to white blood cell count

Covariate	Men		Women	
	Partial* correlation (*r*)	*P* value	Partial* correlation (*r*)	*P* value
BMI (kg/m^2)	0.06	.280	0.14	<.001
SBP (mm Hg)	0.02	.655	0.04	.186
DBP (mm Hg)	0.00	.983	0.01	.784
HDL (mg/dL)	−0.12	.024	−0.11	.001
Triglyceride (mg/dL)	0.11	.032	0.09	.007
Fasting plasma glucose (mg/dL)	0.10	.055	0.04	.275

Abbreviations as in Table 3.

* Adjustment for age and all other metabolic syndrome components.

Table 5. Odds ratio (OR) and 95% confidence intervals (CI) for selected risk factors of metabolic syndrome among Thai men and women

	Men		Women	
Risk factor	**OR**	**95% CI**	**OR**	**95% CI**
Age (y)				
<40	1.00	Reference	1.00	Reference
40–59	3.51	1.62–7.61	8.97	4.24–18.98
≥60	5.97	2.53–14.10	20.18	8.91–45.73
WBC count (cells/μL)*				
Quartile 1	1.00	Reference	1.00	Reference
Quartile 2	0.55	0.17–1.76	2.26	1.08–4.73
Quartile 3	1.68	0.68–4.17	2.88	1.42–5.84
Quartile 4	2.98	1.29–6.87	4.30	2.18–8.51
Smoking status				
Never smoker	1.00	Reference	1.00	Reference
Ever smoker	1.00	0.53–1.88	1.99	0.93–4.27
Alcohol drinking status				
Never drinker	1.00	Reference	1.00	Reference
Ever drinker	1.45	0.73–2.88	0.88	0.52–1.50

WBC = white blood cell.
All OR were adjusted for all other covariates in the model. Separate models were estimated for men and women.
* In men, Q1: <5.40, Q2: 5.40–6.29, Q3: 6.30–7.49, Q4: ≥7.50. In women, Q1: <5.38, Q2: 5.38–6.47, Q3: 6.48–7.69, Q4: ≥7.70.

cluding BMI from the criteria for MetS did not alter the association between WBC and the risk of MetS (data not shown). Fourth, we were not able to evaluate MetS thoroughly in relation to precise details concerning type and frequency of food consumption, as well as type, frequency, and duration of physical activity. Larger, prospective cohort studies that use validated data collection instruments and biological markers will overcome these limitations.

In conclusion, we noted that increased WBC counts were associated with clustered components of MetS in Thai men and women receiving routine health care in Bangkok. The prevalence of MetS in this population was high as in those of some developed countries. Our findings emphasize the need for health intervention programs designed to prevent, detect, and treat MetS. Successful implementation of such programs will likely reduce the burden of cardiovascular disease and diabetes in an increasingly sedentary and overweight Thai population.[3]

Acknowledgments

The authors thank the staff of the Preventive Medicine Clinic, King Chulalongkorn Memorial Hospital in Bangkok, Thailand, for their assistance in data collection, and Bizu Gelaye for skillful technical assistance.

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