Original Article

Body mass index (BMI) as a major factor in the incidence of the metabolic syndrome and its constituents in unaffected Taiwanese from 1998 to 2002

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A large health screening program in Taiwan with members who have periodic checks provides an opportunity to track individuals who are healthy at baseline for the emergence of the metabolic syndrome (MS) and its component disorders. The syndrome comprised abdominal obesity assessed by waist circumference, high fasting serum glucose (FSG), high triglyceride (TG), low high density lipoprotein-cholesterol (HDL-C) and high blood pressure. A cohort of 9,785 adults (4,707 men and 5,078 women), aged 19 to 84 years, who were free from the MS at baseline were followed for 4 years from 1998 to 2002. Using Asian criteria for abdominal obesity and reducing the threshold for FSG from ≥110 mg/dL to ≥100 mg/dL, the incidence of MS during the 4-year follow up in the MJ Health Screening Center Study in Taiwan was 12.7% (17.5% for men and 8.3% for women). The incidence of the MS in men exceeded that for women up until 50-59 years and then this gender was reversed in the older age groups pointing to pre-menopausal protection in women. The most evident manifestations of the incident of metabolic abnormalities were high FSG, high blood pressure and high TG, particularly in post-menopausal women. Baseline body mass index and age were the most significant predictors of MS for both men and women, with cigarette smoking significantly predictive in men. Incident information should inform preventive and intervention strategies in Taiwanese, both Chinese and Indigenous, more effectively than MS and its component disorder prevalences.

Key Words: BMI, incidence, metabolic syndrome, metabolic abnormalities, Taiwan

INTRODUCTION

The metabolic syndrome (MS) is characterized by a constellation of pre-diabetes and cardiovascular metabolic risk factors that have become a global health burden.[1, 2] The concept of the MS is that somehow these variables are connected by a common underlying pathophysiology or causality. They collectively constitute a remediable syndrome which might present an opportunity to prevent the growing burden of diabetes and its complications. The use of 'syndrome' terminology, however, usually belies incomplete understanding of an emerging poorly defined medical problem. This is even more the case when marked cross-cultural differences in occurrence of the syndrome in question are in evidence.

By comparison with more westernized societies, transitional economies are experiencing a surge in the prevalence of the so-called metabolic syndrome and have prospects that its diabetic sequelae may overwhelm their health care systems. From a low base, against overall improvements in the vital statistics of neonatal and childhood mortality and of life expectancy,[3] Taiwan is experiencing this phenomenon. The major Taiwanese birthweight and schoolchildren study points to the importance of maternal nutrition during pregnancy as key considerations in the evolution of cardiovascular risk and diabetes.[4] Some studies reported the prevalence of the MS in the Taiwan area.[5-7] However, limited information is available about the incidence of the MS in Taiwanese adults.

Chung had reported that the prevalence of the MS was 9.5% (10.6% in men and 8.1% in women) in a large health check-up population in Taiwan and was significantly affected by age and gender.[5] We have undertaken a prospective assessment of the incidence of metabolic disorders and of the MS in the same cohort of 9,785 adults, aged 19 to 84 years, who were free from the MS at baseline.

MATERIALS AND METHODS

Study Population

The MJ Health Screening Center is a membership-oriented private institute with four health check-up clinics

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(in Taipei, Taoyuan, Taichung, and Kaohsiung) around Taiwan island, which provides periodic health examination for its members. It has averaged about eighty thousand member health examinations every year since 1996. Each member completes a self-administered questionnaire, has anthropometric and blood pressure measurements, and laboratory investigations. The questionnaire includes sociodemographic characteristics, behaviors such as physical activity, food and beverage (especially alcohol) consumption, cigarette smoking, as well as a personal and family health history. The Institutional Review (Ethics) Committee at the MJ Health Screening Center approved the protocol for this research on human subjects.

During the period 1998-2002, 14,852 members attended at least twice at the MJ Health Screening Center for health assessment at their own volition. We excluded individuals who were younger than 19 years (n=214), were older than 84 years (n=6), who had the MS at baseline (n=4,095), or who had missing values for any one of the 5 components of the MS, as well as those who had missing values for any variable used in the analyses (n=752). Finally, a total of 9,785 subjects (4,707 men and 5,078 women), aged 19 to 84 years, who were free of the MS were eligible for the study.

Anthropometric measurements and blood pressure measures

Using an auto-anthropometer, Nakamura KN-5000A (Nakamura, Tokyo, Japan) body weight and height were measured. Body weight was measured to the nearest 0.1 kg with subjects barefoot and wearing light indoor clothing. Body height was recorded to the nearest 0.1 cm. Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters. Waist circumference (WC) was measured at the narrowest abdominal circumference using a tape measure. The resting blood pressure was measured twice on the right arm using a computerized auto-mercury-sphygmomanometer (CH-5000, Citizen, Tokyo, Japan) with the participant seated and after 5 minutes of rest. The mean of the two measurements was used in the analysis. Hypertension was defined as systolic blood pressure (SBP) ≥ 140 mmHg and/or diastolic blood pressure (DBP) ≥ 90 mmHg or where there was current use of anti-hypertensive medication.[8]

Biochemical parameters

Participants were advised to fast for at least 12 hours before examination. Fasting serum glucose (FSG), triglyceride (TG), and high density lipoprotein-cholesterol (HDL-C) were measured enzymatically on the Hitachi 7150 autoanalyzer (Hitachi, Tokyo, Japan).[9] Diabetes mellitus (DM) was defined as FSG level ≥ 126mg/dL (7.0 mmol/L) or use of anti-diabetic medications.[10]

Major lifestyle variables

Additional covariate information included age, education (primary school or under, junior high school, senior high school, junior college or university and above), smoking status (0, <10 or ≥10 cigarettes/day), alcohol consumption (0, ≤30 or >30g ethanol/day), and occupational physical exertion (sedentary, moderate or vigorous), recorded by self-administered questionnaire.

Metabolic syndrome

The definition of the MS was in accordance with the modified United States National Cholesterol Education Program/Adult Treatment Panel III (ATP-III) definition.[1] An incident event was identified if participants developed 3 or more of the following: high FSG [11] (FSG level ≥100 mg/dL [5.6 mmol/L] or use of anti-diabetic medications), high blood pressure (SBP ≥130 mmHg, DBP ≥85 mmHg or with current use of anti-hypertensive medication), abdominal obesity (WC ≥80 cm for women and ≥90 cm for men,[6, 12] adopting the Asian WC cut-off point), high TG (TG level ≥150 mg/dL [1.70 mmol/L] or with current use of lipid-lowering medication), low HDL-C (HDL-C level ≤40 mg/dL [1.29 mmol/L] in women, ≤50 mg/dL [1.03 mmol/L] in men or with current use of lipid-lowering medication).

Statistical Analysis

Differences in baseline sociodemographic, clinical and biochemical characteristics between whose with or without the MS were tested for statistical significance with Student's t tests, Wilcoxon rank sum tests, or chi-sqaure tests stratified by gender.

The follow-up time was calculated from the date of the baseline examination to the date of the MS identification or end of the year 2002 examination, or until censored. To take account of the possible effect modifications, we stratified data according to gender and age groups. The distribution for development of the metabolic abnormalities and the MS after a four-year follow-up was stratified by gender and age groups. The four-year incidence rates of the MS and the components of the MS were also studied.

BMI has been used for assessing the amount of body fat, but is a compound measurement in its own right with assumptions about how it relates to degree of body fatness, like the degree of sedentariness at the time of measurement and the kind of muscle–building activity regularly undertaken by an individual. It is different to WC which, although an index of body fatness, is particularly related to central (intra-abdominal) fat distribution. We classified BMI into underweight (BMI <18 kg/m^2), optimal BMI (18-22.9 kg/m^2), overweight (23-24.9 kg/m^2) and obese (BMI ≥25 kg/m^2) according to the 2000 World Health Organization Asian Pacific Guideline.[13] The distribution of the MS for different BMIs and WCs was examined.

Finally, we calculated the MS incidence in relation to a number of sociodemographic characteristics and lifestyle variables using Cox proportional hazards models to estimate the hazard ratios (HRs) and 95% confidence intervals (CIs) of incident MS by gender. All analyses were performed with the use of SAS software (SAS Institute, Cary, NC). Reported probability values are 2-sided. *P* values <0.05 were considered to be statistically significant.

RESULTS

The baseline characteristics of the 9,785 eligible subjects who were free of the MS are shown in Table 1. During

Table 1. Baseline characteristics of the participants in the MJ Health Screening Center Study in Taiwan

Characteristics	Men			Women		
	Metabolic Syndrome ‡			Metabolic Syndrome ‡		
	No N=3,883	Yes N=824	*p* values §	No N=4,657	Yes N=421	*p* values §
Age（yrs）	41.1±11.7	44.9±11.8	****	39.3±10.4	50.9±11.0	****
Education (%)						
Primary school and under	76.3	23.7	***	76.8	23.2	****
Junior high school	79.3	20.7		88.5	11.5	
Senior high school	82.4	17.6		94.8	5.2	
Junior college	85.0	15.0		95.3	4.7	
University and above	83.1	16.9		96.2	3.8	
Smoking status (%)						
Nonsmoker	84.0	16.0	****	91.4	8.6	**
<10 cigarettes /day	84.1	15.9		97.1	2.9	
≥10 cigarettes /day	78.6	21.4		97.4	2.6	
Alcohol consumption (%)						
Never	83.7	16.3	*	91.7	8.3	0.39
≤30g/day	81.3	18.7		91.1	8.9	
>30g/day	78.5	21.5		96.4	3.6	
Occupational Physical Exertion (%)						
Light (sedentary)	81.9	18.1	0.49	92.6	7.4	**
Middle (moderate)	82.9	17.1		90.4	9.6	
Heavy (vigorous)	83.6	16.4		88.4	11.6	
BMI † (kg/m^2)	22.6±2.5	24.8±2.5	****	21.2±2.6	24.4±2.9	****
WC † (cm)	78.8±7.1	84.9±6.6	****	69.5±6.3	77.2±7.3	****
SBP † (mmHg)	115±14.5	121±16.7	****	109±14.9	124±20.3	****
DBP † (mmHg)	72.6±9.7	76.2±10.1	****	69.4±9.7	75.0±11.0	****
TG † (mg/dL)	105±50.3	144±64.2	****	82.2±35.5	118±44.8	****
HDL-C † (mg/dL)	46.6±11.3	41.2±11.3	****	55.6±13.0	48.5±12.0	****
FSG † (mg/dL)	95.8±11.5	100±19.2	****	92.3±9.4	97.7±10.8	****
Diabetes (%)	1.4	3.8	****	0.6	2.6	****
Hypertension (%)	9.5	17.7	****	5.5	25.6	****

† BMI, body mass index; WC, waist circumference; SBP, systolic blood pressure; DBP, Diastolic blood pressure; TG, triglycerides; HDL-C, high-density-lipoprotein cholesterol; FSG, fasting serum glucose. The conversion factors are as follow: triglycerides, mg/dL=0.01129 mmol/L; high-density-lipoprotein cholesterol, mg/dL=0.02586 mmol/L; fasting glucose, mg/dL=0.05551 mmol/L

‡ Metabolic Syndrome, by modified NCEP definition, adopting Asian WC cuff-off point.

§ * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, **** $p < 0.0001$.

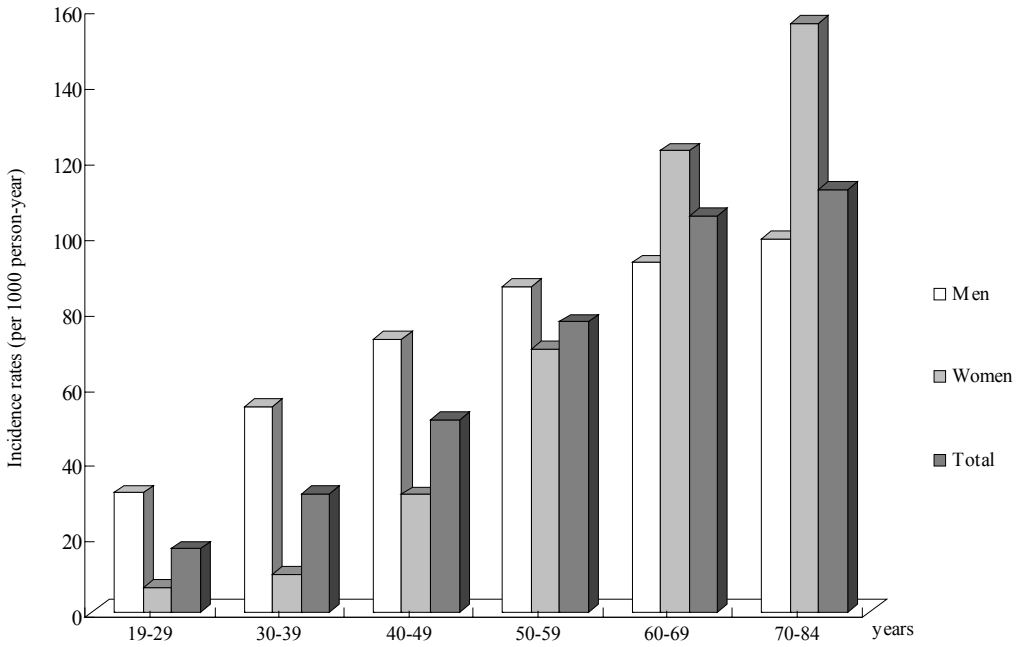

Figure 1. Age-gender specific 4-year incidence rates of the metabolic syndrome in the MJ Health Screening Center Study in Taiwan

the 4 years of follow-up, 1,245 incident cases (824 men and 421 women) of the MS were identified. Those with the MS were significantly different from those without the metabolic syndrome in age, education level and

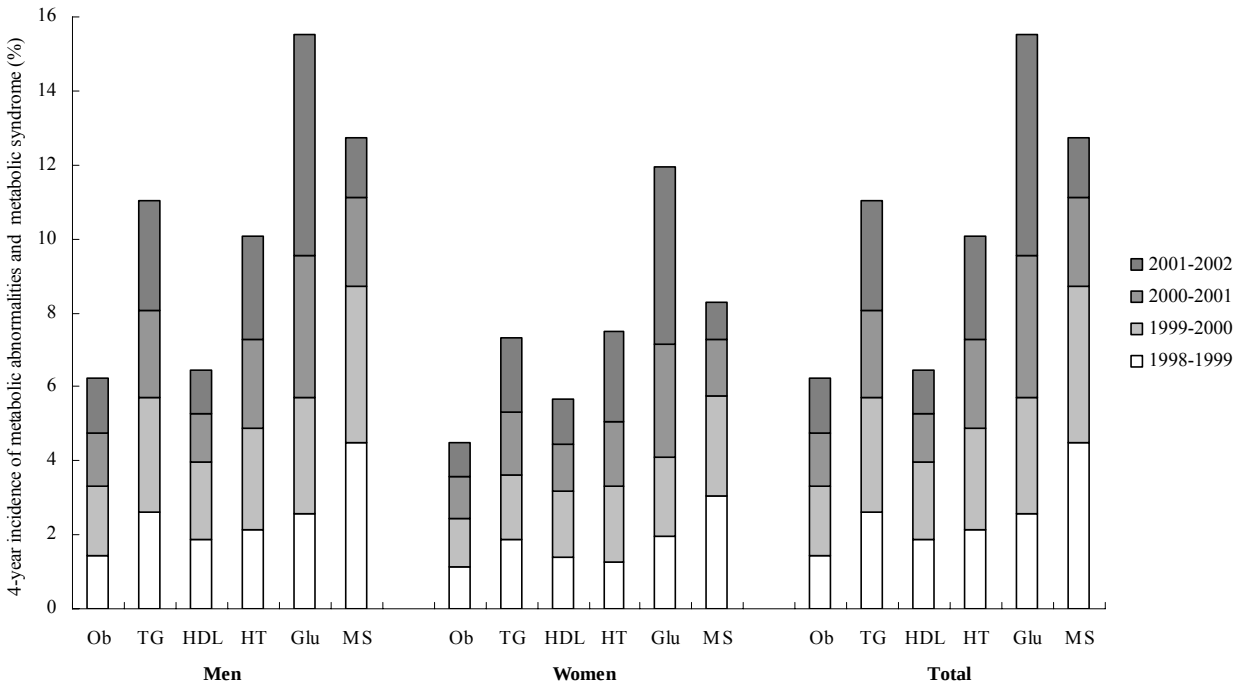

Figure 2. 4-year incidence of the metabolic abnormalities and metabolic syndrome in the MJ Health Screening Center Study in Taiwan, by gender (Glu = high FSG; HT = high blood pressure; Ob = abdominal obesity; TG = high TG; HDL = low HDL-C)

smoking status for both men and women. Men who had the MS were 3 years older, and women who had it, 11 years older. Compared with subjects without the MS, those who had the MS were older and were more likely to be male, to have less years of education, to have greater WC and BMI, higher SBP, DBP, TG, HDL-C, FSG, and lower HDL-C, and likely to have diabetes and hypertension. Men who had the MS had slightly but significantly higher alcohol consumption (p=0.01) and were likely to be smokers (p<0.0001), but not in women. Relatively more women had occupations which were sedentary than did men without having the MS (p=0.003).

We have then traced those without the MS over the 4 years from 1998 to 2002 and found the incidence rate for the MS to be 64.2 (95%CI: 60.0-68.4) and 29.6 (95%CI: 26.8-32.4) per 1000 person-years for men and women, respectively. The incidence rates of the MS were 31.6, 54.3, 72.4, 86.3, 92.6 and 99.1 per 1000 person-years in the 19-29, 30-39, 40-49, 50-59, 60-69 and 70-84 age groups in men, respectively, and were 6.3, 10.0, 31.0, 69.7, 122.2 and 156.1 per 1000 person-years in women. Up until the age of 50-59 years, women had lower incidence rates for the MS than men, but this phenomenon disappeared and reversed rapidly with increasing age (Figure 1). The overall incidences of metabolic abnormalities were, in descending order, high FSG (15.5%), high TG (11.0%), high blood pressure (10.0%), low HDL-C (6.4%), abdominal obesity (6.2%), and for the metabolic syndrome itself 12.7% (Figure 2). The incidences rate of high TG, high blood pressure, low HDL-C and abdominal obesity were similar every year, but it was gradually increasing for high FSG and reducing for the MS year by year. In general, Figure 3 shows the age-specific incidences of metabolic abnormalities and the MS for both genders and the trends with time from 1998 to 2002, when participants also get 4 years older. The most striking incidence in metabolic abnormality, for men and women, is in high FSG followed by high TG and high blood pressure which appears to exceed the age effect shown in figures 3, especially for men. This is also evident for the integrated assessment provided by the MS itself (Figure 1). Nevertheless, the incidences of high FSG, high blood pressure, abdominal obesity, high TG, low HDL-C and MS sharply increased with advancing age in women, and modestly in men (Figure 3). Until the age of 50-59 years, women had lower incidences of abdominal obesity, high TG and high FSG than men did. The age-specific incidence of high blood pressure and high FSG were highest amongst metabolic abnormalities for both genders.

Figure 4 shows the incidence of number of metabolic abnormalities during the 4-year follow up in the MJ Health Screening Center Study in Taiwan among men and women. The incidences of zero metabolic abnormalities were 63.1%, 56.0%, 51.3%, 48.7%, 52.7% and 49.5% in the 19-29, 30-39, 40-49, 50-59, 60-69 and 70-84 age groups for men, respectively, and were 82.9%, 79.3%, 67.6%, 53.5%, 42.2% and 38.2% for women. The incidences of four metabolic abnormalities were only 0.53%, 0.05%, 0.16% and 0.26% in 19-29, 30-39, 40-49 and 60-69 age groups for men, respectively, and were only 0.08% in 40-49 age group for women, respectively. Almost none developed the full five metabolic abnormalities during the 4-year follow up.

We also ascertained the frequency of contributors to the MS (Figure 5). The subjects who were free of the MS at baseline had the possibility of zero, one or two metabolic abnormalities themselves. The cluster of abdominal obesity and another two metabolic abnormalities was the most common pattern for men (34.1%) and women (41.3%). More than 17% of participants developed a syndrome with a high FSG, high TG and low HDL-C (18.4%

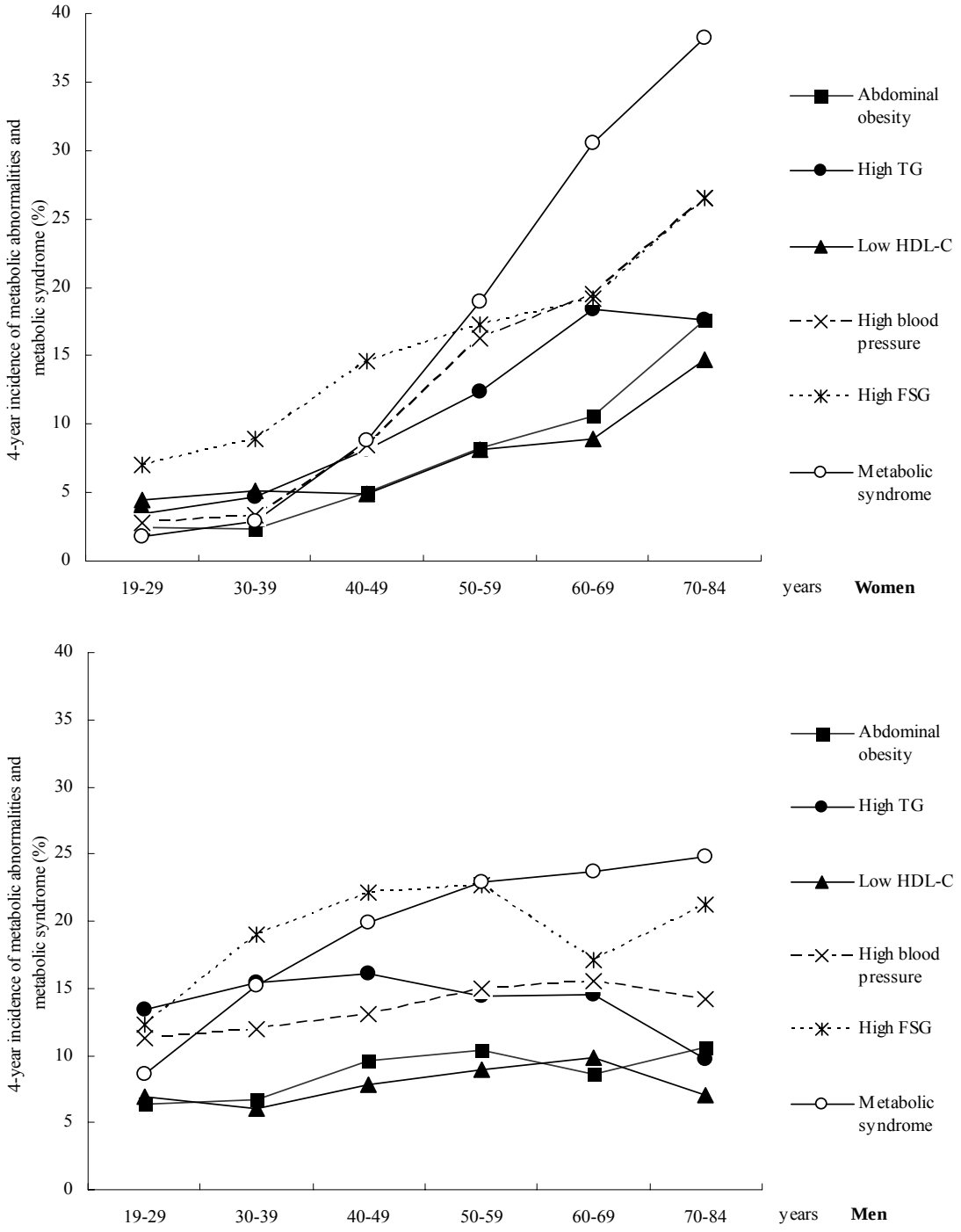

Figure 3. Age related 4-year incidence of the metabolic abnormalities and metabolic syndrome in men and in women in the MJ Health Screening Center Study in Taiwan

for men and 14.7% for women), and approximately 11% of participants developed a syndrome with abdominal obesity and three other metabolic abnormalities (10.8% for men and 14.0% for women), and a syndrome with high TG, low HDL-C and high blood pressure (11.8% for men and 9.9% for women), respectively. Barely 0.7% of participants developed a syndrome of five of metabolic abnormalities (0.9% for men and 0.2% for women).

Waist circumference, one of the components of the MS, is used to represent abdominal obesity, so the MS itself incorporates the obese concept. However, WC and BMI have quite different conceptual derivations: BMI minimizes the numerical contribution by body fat to weight in the numerator through the division of weight by height squared (which in sedentary subjects has little to do with body fat) in the denominator. We therefore took account of the relationships between WC and BMI (r=0.78 in men and r=0.74 in women, $p<0.0001$, data not shown). Figure 6 shows the incidence of the MS in eight categories of different combinations of BMI: below 18, 18-22.9, 23-24.9 or at and above 25 kg/m^2 and presence of absence of defined abdominal obesity in men and in women. The incidences of the MS with abdominal obesity were 10%, 31.8% and 48.1% in the so-called optimal BMI range (18-22.9 kg/m^2), overweight (23-24.9 kg/m^2) and obese (BMI ≥25 kg/m^2) groups in men, and were 18.1%, 20.3% and

36.4% in women, respectively. No men or women who were underweight (BMI <18 kg/m^2) with abdominal obesity had evidence of the MS. However, the incidences of the MS without abdominal obesity were 2.4%, 8.3%, 19.1% and 31.3% in underweight, so-called optimal BMI, overweight and obese groups of men, and were 0.2%, 3.9%, 13.3% and 25.4% in the same groups of women.

We examined the incident MS in relation to a number of sociodemographic characteristics and lifestyle variables by sex and age group (Table 2). In Model I, a univariable Cox proportion hazards regression model, significant positive relations were found between the MS and age, smoking status, alcohol consumption, and BMI in men, and were found between the MS and age, occupa-

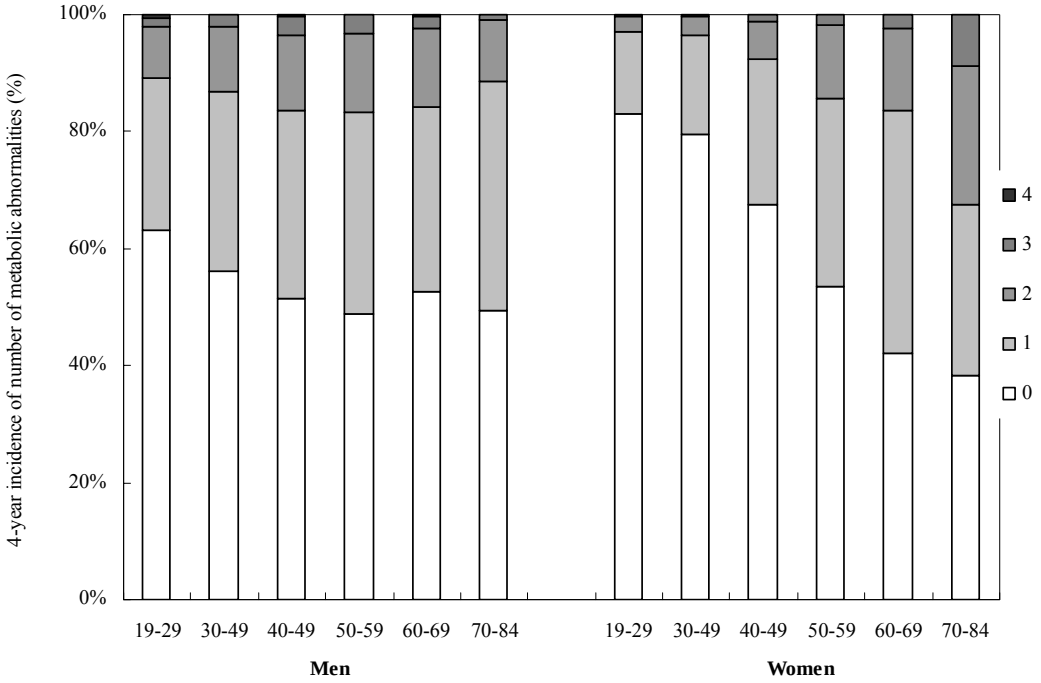

Figure 4. The cumulative incidence of number of metabolic abnormalities in each age strata during the 4-year follow up in the MJ Health Screening Center Study in Taiwan, by gender

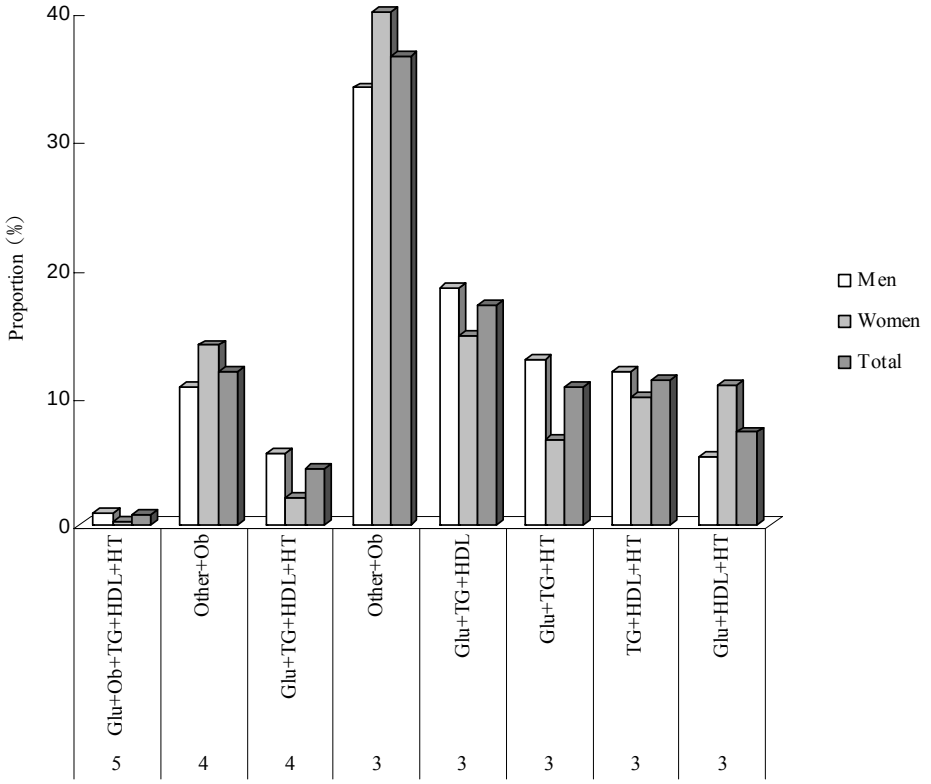

Figure 5. The proportion of the metabolic syndrome during the 4-year follow up in the MJ Health Screening Center Study in Taiwan, by gender (Glu = high FSG; HT = high blood pressure; Ob = abdominal obesity; TG = high TG; HDL = low HDL-C)

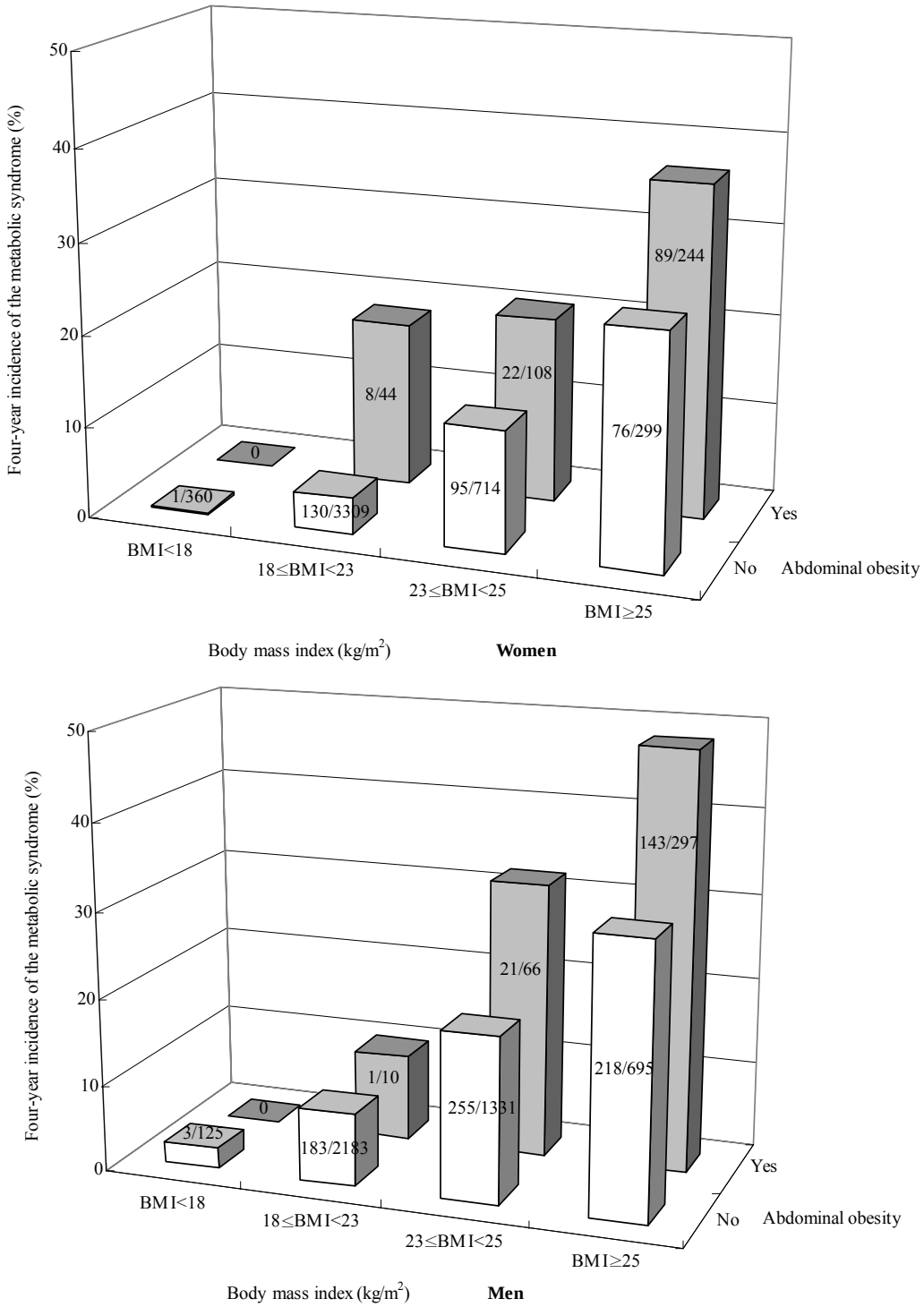

Figure 6. 4-year incidence of the metabolic syndrome in eight categories of different combinations of BMI above 18, 18-22.9, 23-24.9 or below 25 kg/m^2 and abdominal obesity in men and in women in the MJ Health Screening Center Study in Taiwan.

tional physical exertion, and BMI in women, respectively. For smoking status, alcohol consumption, and occupational physical exertion, the positive associations were attenuated simultaneously after adjustment for major lifestyle factors (Model II). To determine the influence of BMI category on the association of major lifestyle factors and the MS, we additionally adjusted for BMI category in the Model III. There was no significant attenuation of the positive associations of the MS and age (HR=1.02, 95%CI: 1.01-1.02 for men; HR=1.06, 95%CI: 1.05-1.07 for women). The risk was raised by 34% (HR=1.34, 95%CI: 1.14-1.57) for participants smoking 10 or more cigarettes per day compared with nonsmoker, but this was not seen in women. The multivariable HRs across underweight, optimal BMI, overweight and obese groups were 0.30 (95%CI: 0.09-0.95), 1.0, 2.45 (95%CI: 2.03-2.96), and 5.00 (95%CI: 4.18-5.98) in men (p for trend < 0.0001), and were 0.09 (95%CI: 0.01-0.67), 1.0, 2.34 (95%CI: 1.81-3.02), and 5.48 (95%CI: 4.32-6.95) in women (p for trend < 0.0001), respectively. They were not statistically significant between the metabolic syndrome and education level, alcohol consumption, and occupational physical exertion in this BMI-adjusted multivariable Model.

Table 2. Hazard Ratios (95% CIs) for the metabolic syndrome† during the 4-year follow up in the MJ Health Screening Center Study in Taiwan, by age and gender

	Men			women		
	N= 4707			N=5078		
	Model I‡	Model II§	Model III¶	Model I‡	Model II§	Model III¶
Age（yrs）	1.02 (1.01, 1.03)	1.02 (1.01, 1.02)	1.02 (1.01, 1.02)	1.08 (1.07, 1.09)	1.06 (1.05, 1.07)	1.06 (1.05, 1.07)
Education						
Primary school and under	1.47 (1.17, 1.84)	1.13 (0.88, 1.47)	1.14 (0.88, 1.47)	4.85 (3.74, 6.27)	1.68 (1.22, 2.31)	1.30 (0.95, 1.77)
Junior high school	1.25 (0.95, 1.66)	1.17 (0.88, 1.56)	1.18 (0.89, 1.57)	2.21 (1.53, 3.19)	1.20 (0.82, 1.77)	1.05 (0.72, 1.53)
Senior high school	1	1	1	1	1	1
Junior college	0.82 (0.67, 1.00)	0.93 (0.75, 1.13)	0.94 (0.77, 1.15)	0.85 (0.60, 1.19)	0.98 (0.69, 1.38)	1.17 (0.82, 1.65)
University and above	0.90 (0.75, 1.09)	0.99 (0.81, 1.20)	0.96 (0.79, 1.17)	0.69 (0.47, 1.00)	0.75 (0.51, 1.09)	0.85 (0.58, 1.24)
p for trend	<0.0001	0.21	0.14	<0.0001	<0.0001	0.06
Smoking status						
Nonsmoker	1	1	1	1	1	1
<10 cigarettes /day	1.02 (0.84, 1.25)	1.02 (0.83, 1.25)	1.02 (0.84, 1.25)	0.34 (0.15, 0.77)	0.51 (0.22, 1.15)	0.53 (0.23, 1.20)
≥10 cigarettes /day	1.42 (1.22, 1.66)	1.35 (1.15, 1.59)	1.34 (1.14, 1.57)	0.29 (0.07, 1.18)	0.45 (0.11, 1.86)	0.59 (0.14, 2.39)
p for trend	<0.0001	0.0005	0.0005	0.003	0.04	0.12
Alcohol consumption						
Never	1	1	1	1	1	1
≤30g/day	1.19 (1.02, 1.38)	1.09 (0.93, 1.27)	0.96 (0.82, 1.13)	1.14 (0.84, 1.54)	1.13 (0.83, 1.53)	0.97 (0.72, 1.32)
>30g/day	1.45 (1.16, 1.81)	1.24 (0.98, 1.57)	1.02 (0.80, 1.29)	0.42 (0.10, 1.71)	0.48 (0.11, 1.96)	0.50 (0.12, 2.02)
p for trend	0.0003	0.07	0.89	0.96	0.93	0.56
Occupational Physical Exertion						
Light	1	1	1	1	1	1
Middle	0.97(0.82, 1.14)	0.97 (0.82, 1.15)	1.00 (0.84, 1.19)	1.36 (1.10, 1.67)	1.06 (0.85, 1.31)	1.04 (0.84, 1.30)
Heavy	0.93 (0.77, 1.13)	0.79 (0.64, 0.98)	0.84 (0.68, 1.04)	1.60 (1.13, 2.28)	0.85 (0.59, 1.23)	0.81 (0.56, 1.17)
p for trend	0.50	0.06	0.19	0.0003	0.76	0.55
BMI category(kg/m^2)						
BMI<18 kg/m^2	0.27 (0.08, 0.86)		0.30 (0.09, 0.95)	0.06 (0.01, 0.49)		0.09 (0.01, 0.67)
18 kg/m^2≦BMI<23 kg/m^2	1		1	1		1
23 kg/m^2≦BMI<25 kg/m^2	2.55 (2.11, 3.07)		2.45 (2.03, 2.96)	3.67 (2.87, 4.70)		2.34 (1.81, 3.02)
BMI≧25 kg/m^2	5.04 (4.21, 6.01)		5.00 (4.18, 5.98)	8.78 (7.00, 11.02)		5.48 (4.32, 6.95)
p for trend	<0.0001		<0.0001	<0.0001		<0.0001

† Metabolic Syndrome, by modified NCEP definition, adopting Asian WC cuff-off point.
‡ Model I: univariable Cox proportion hazards regression model.
§ Model II: adjusted for age, education, smoking status, alcohol consumption, occupational physical exertion.
¶ Model III: adjusted for Model II and BMI category.

Table 3. Prevalence or incidence of the metabolic syndrome and metabolic abnormalities in different population by different definition

	MJ		MJ		TwSHHH		Kinmen		NHANES III		DESIR	
	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women
Population	Taiwan		Taiwan		Taiwan		Taiwan		US		France	
Year	2000-2001		1998-2002		2002		1991-1995		1988-1994		1994-1996	
Study	cross-sectional study		cohort study		cross-sectional study		cross-sectional study		cross-sectional study		cohort study	
Subjects (N)	11,731	12,598	4,707	5,078	2,815	3,121	3,604	4,716	4,265	4,549	2,109	2,184
Age (yrs)	≥20		19-84		20-79		30-92		≥20		30-64	
High blood pressure (%)												
≥130/85 mmHg	35.4	24.3	12.9	7.4	36.6	23.9	61.0	43.7	38.2	29.3	24.3	16.9
Low HDL-C (%)												
≤50/40 mg/dl (Men/Women)	26.1	26.1	7.3	5.6	22.5	25.1	20.9	37.6	35.2	39.3	13.4	14.6
High FSG (%)												
≥110 mg/dl	12.5	8.4	6.1	3.3	11.5	9.8	23.2	19.6	15.6	10.0	7.9	3.6
≥100 mg/dl			19.4	11.9	20.0	17.5						
High TG (%)												
≥150 mg/dl	30.2	14.1	15.0	7.3	35.2	20.7	13.7	10.4	35.1	24.7	14.0	11.1
Abdominal obesity (%)												
≥102/88 cm (Men/Women)	1.8	4.1	0.7	1.0			3.7	28.5	29.8	46.3	4.4	7.4
≥90/80 cm (Men/Women)	16.5	13.0	8.1	4.4	29.5	30.8	25.7	51.2				
Metabolic syndrome (%)												
ATP III 2001† (%)	10.6	8.1	9.2	4.9			11.2	18.6	24.0	23.4	10.5	8.0
	9.5		7.0				15.4		23.7			
DOH 2004‡ (%)	15.5	10.5	12.5	6.0	18.3	13.6	23.7	17.7				
	12.9		9.2		15.7		21.1					
DOH 2006§(%)			17.5	8.2	20.4	15.3						
			12.7									
Reference	5				7		6		14		15	

† ATP III 2001 required meeting at least three of the risk factors: (1) FSG level ≥110 mg/dl; (2) SBP ≥130 mmHg or DBP ≥85 mmHg; (3) WC ≥88 cm for women and ≥102 cm for men (4)TG level ≥150 mg/dl; (5) HDL-C level ≤40 mg/dl for women and ≤50 mg/dl for men.

‡ DOH 2004 required meeting at least three of the risk factors: (1) FSG level ≥110 mg/dl; (2) SBP ≥130 mmHg or DBP ≥85 mmHg; (3) WC ≥80 cm for women and ≥90 cm for men (4)TG level ≥150 mg/dl; (5) HDL-C level ≤40 mg/dl for women and ≤50 mg/dl for men.

§ DOH 2006 required meeting at least three of the risk factors: (1) FSG level ≥100 mg/dl; (2) SBP ≥130 mmHg or DBP ≥85 mmHg; (3) WC ≥80 cm for women and ≥90 cm for men (4)TG level ≥150 mg/dl; (5) HDL-C level ≤40 mg/dl for women and ≤50 mg/dl for men.

DISCUSSION

Using Asian criteria for abdominal obesity [6] and reducing the threshold for FSG from ≥110 mg/dL to ≥100 mg/dL,[11] the overall incidence of metabolic syndrome during the 4-year follow up in the MJ Health Screening Center Study in Taiwan was 12.7% (17.5% for men and 8.2% for women). Using the same definition of the MS, the prevalence in the Taiwanese Survey on Prevalence of Hyperglycemia, Hyperlipidemia and Hypertension (TwSHHH) [7] in 2002 was higher in men than in women aged 20-79 years (20.4% vs. 15.3%). Regardless of the MS definition, similar phenomena were found in that the incidence of the MS increased with advancing age and in both genders as did prevalence. Younger women had lower incidence rates of the MS than younger men, but developed higher rates than men after the age of 50-59 years in our study. Similarly, the prevalences of the MS in Kinmen,[6] the MJ Health Screening Center Study (2000-2001),[5] the TwSHHH survey (2002),[7] the NHANES III survey (1988-1994)[14] and the DESIR cohort study (1994-1996)[15] in France increased with age. Only in Kinmen, where the gender cross-over phenomenon occurred in the 40-49 years age group and in the MJ Health Screening Center Study and TwSHHH survey where this occurred in the 50-59 years age group, as it did in our study of incidence, have these gender-age divergences been documented. This phenomenon is presumably the result of the development of estrogen hormone deficiency in post-menopausal women around the age of 50 years. The incidence of metabolic abnormalities sharply increases in post-menopausal women, but modestly in men at the same age.[16, 17] Apparently, estrogen hormone protective effects operate in premenopausal women allowing a lower incidence of the MS than men. Since we now know that some of the features of the MS can be prevented or alleviated with soy or its traditional products in women[18, 19] which provide a source of phyto-estrogens, these findings on peri-menopausal MS incidence in Taiwan, with a relatively high consumption of soy (tofu) are of particular interest.

The frequency of metabolic abnormalities varies among ethnicities and countries. In the present study, high FSG was the most incident of metabolic abnormalities in both genders .In comparison with other studies, this may be partly a feature of a downward revision in threshold for FSG from ≥110 mg/dL to ≥100 mg/dL.[11] This would mean an increase in incidence from 6.1% to 19.4% in men and from 3.3% to 11.9% in women (Table 3). This result would have meant a smaller increase in the incidence of the MS from 12.5% to 17.5% in men and from 6.0% to 8.2% in women. The TwSHHH survey analysis used different criteria for FSG which resulted in higher prevalences of high FSG rising from 11.5% to 20.0% in men and from 9.8% to 17.5% in women, and slightly higher prevalences of the MS, increasing from 18.3% to 20.4% in men and from 13.6% to 15.3% in women aged 20-79 years.[7] Although the reduced threshold for FSG, one of the components of the MS, results in a higher prevalence or incidence of high FSG, the prevalence or incidence of the MS only increases by 2-5 percentage points on this basis (Table 3), as compared to the real biological change which remains substantial.

Notably, incidences of high blood pressure (7.4% in women and 12.9% in men) and high TG (7.3% in women and 15.0% in men) were common found among the 4,707 men and 5,078 women aged 19 to 84 years during the 4 years follow up. By contrast, 2,109 men and 2,184 women from the DESIR cohort study in central-western France, aged 30 to 64 years, had high blood pressure incidence of 24.3% and high TG of 14.0% in men, and high blood pressure of 16.9% and low HDL-C of 14.6% in women three years later.[15] In men, high blood pressure and high TG were common in the present MJ Health Screening Center Study[5] and the TwSHHH survey,[7] while high blood pressure and low HDL-C were common in the NHANES III survey,[14] and high blood pressure and abdominal obesity were common in Kinmen.[6] In women, low HDL-C and high blood pressure were common in MJ Health Screening Center Study,[5] while abdominal obesity and low HDL-C were common in the TwSHHH survey[7] and the NHANES III survey,[14] and abdominal obesity and high blood pressure were common in Kinmen.[6] Thus, it appears that high blood pressure and high TG are responsible for the high frequency of the MS in men in many populations irrespective of a reduced threshold for FSG. Thus, optimal control of blood pressure and lipids are and would be emphasized in the prevention coronary heart disease events when adopting a metabolic syndrome-derived strategy.[20]

In the present analysis of incidence, BMI for men and women, and cigarette smoking in men, emerge as of likely major pathogenetic significance for incidence of the MS, including its body fat distribution, blood pressure and lipoprotein components, and for its presumed relevance to the ultimate development of diabetes and cardiovascular disease. It has been of considerable interest how abdominal fatness (measured as WC) and its simplicity in assessment as a body circumference might make the MS pathogenesis intelligible and clinical documentation straightforward. WC is likely to continue to be a useful public health and clinical nutrition tool, but the present study draws attention to the intrinsic value of BMI in body compositional and chronic metabolic disease appraisal. This is because of the present finding that BMI predicts the MS incidence, in part, independent of abdominal obesity. The reasons for this are unclear, but point to the broader relevance of body composition, including assessment of lean mass in metabolic health. In prevalence studies, abdominal obesity is the most frequently observed component of the MS in women in Taiwan [6, 7] and in the US,[14] but the incidence of abdominal obesity in our study is not high (4.5% in women and 8.1% in men). When we examined the components of the MS, we found that 36.5% of the cluster of abdominal obesity and another two metabolic abnormalities was most common (34.1% for men and 41.3% for women). This may be a result of using Asian criteria for abdominal obesity, and of a somewhat high prevalence of obesity in Taiwan.[7]

BMI showed a dose-response association with increased risk of the incident MS, and the hazard ratio for BMI above 25 kg/m^2 versus BMI range 18-22.9 kg/m^2 was 5.00 (95%CI: 4.18-5.98) in men and 5.48 (95%CI: 4.32-6.95) in women after adjustment for sociodemographic characteristics and lifestyle variables. Our study

did find significantly high relationships between WC and BMI, which corresponds with the findings in the 1993-1996 Nutrition and Health Survey in Taiwan (NAHSIT).[21] Although 3-8% of normal weight adults without abdomen obesity have the MS (8.3% in men and 3.9% in women), normal weight adults with abdominal obesity have about a 6-fold higher incidence of the MS in women, and but is not seen in men. Overweight or obese adults with abdominal obesity reach a 6- to 12-fold higher incidence compared with normal weight adults without abdominal obesity for women, and 5-6 fold higher for men. Simultaneously overweight or obese people with abdomen obesity have additional risk for the MS, a phenomenon similar to that seen in the San Antonio Heart Study.[22] People with higher BMI or WC had been found to have an increased risk of high blood pressure, high FSG and dyslipidemia, and a high probability of health benefit from WC or BMI reduction with improved MS and reduction in cardiovascular risk factors.[22-24]

Our results are not representative of the whole Taiwan population, because our subjects received health assessments at a private health screening center. They, therefore represent a higher socioeconomic status and a more health aware population. Hence, the incidence estimates in our study population may be lower than that for Taiwan as a whole. Nevertheless, we found that what most influenced the MS was the BMI, and then, secondly, age. While BMI below 18 kg/m^2 is appears the most protective factor against the development of the MS, the other health risks of chronic energy under nutrition (as defined by WHO) and prevailing BMIs in healthy communities, mitigate against this as an acceptable target. Instead, since a BMI above 23 kg/m^2 is a risk factor for the MS in the Taiwanese population studied, a BMI range of about 18-22.9 kg/m^2 may constitute a healthy range and be generally achievable. The MS incidence was not significantly associated in the screened healthy population with education level, alcohol consumption or occupational physical exertion. Men who developed the MS were up to 50% of smokers, with smoking 10 or more cigarettes/day associated with a higher risk of the MS in men, but not in women. It is possible that the homogeneity of our subjects with higher educational background and better health awareness reduced confounding by the sociodemographic characteristics considered.

In conclusion, the incidence of the MS in a large Taiwanese Health Screening Population, not already affected, progressively increased during 4 years of follow-up. The incidence of the MS in the study population is significantly dependent on age and BMI with smoking an added factor of significance in men. It is represented by a relatively high expression of abdominal obesity and, to a lesser extent high FSG and high blood pressure. Extrapolation from the study population to Taiwanese in general would need to take account of the relatively higher socioeconomic status and likely better health awareness of the screened individuals.

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AUTHOR DISCLOSURES

Feng-Yu Yang, Mark L Wahlqvist and Meei-Shyuan Lee, no conflicts of interest.

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Original Article

Body mass index (BMI) as a major factor in the incidence of the metabolic syndrome and its constituents in unaffected Taiwanese from 1998 to 2002

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身體質量指數為 1998-2002 台灣人代謝症候群及其組成發生的一個主要因素

本研究以台灣一大型健檢中心會員定期健檢資料來探討代謝症候群與其組成發生的因素。研究對象為起始無代謝症候群之 9,785 位台灣美兆健檢中心會員，年齡介於 19 至 84 歲，於 1998 至 2002 年間有定期接受健康檢查者。代謝症候群組成包括了腹部肥胖(女性腰圍≥80 公分，男性腰圍≥90 公分)、高空腹血糖(≥100 mg/dL)、高三酸甘油酯、高密度脂蛋白偏低及血壓偏高，此 5 項異常中符合 3 項者歸為代謝症候群發生。經追蹤 4 年後，研究對象之代謝症候群發生率為 12.7% (男性為 17.5%與女性為 8.3%)。男性在 50-59 歲之前，代謝症候群發生率大於女性，但年齡增加後則反之，顯示更年期前女性受到保護。代謝異常發生以高空腹血糖、血壓偏高與高三酸甘油酯最多，特別在更年期後的女性。在男女性中，代謝症候群的發生與起始身體質量指數及年齡有顯著相關；而在男性中，抽菸也顯著與代謝症候群的發生有關。相對於僅注意代謝症候群及其組成盛行率，台灣更應提供預防代謝症候群發生的資訊及介入措施。

關鍵字：身體質量指數、代謝症候群發生率、代謝異常、台灣。