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ORIGINAL ARTICLE

Factor analysis of modifiable cardiovascular risk factors and prevalence of metabolic syndrome in adult Taiwanese

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Abstract To assess the clustering of modifiable cardiovascular risk factors among Taiwanese adults, we evaluated 579 healthy participants who underwent health examinations between May and December 2007. Exploratory factor analysis was used to examine risk factor clustering. Smoking, alcohol intake, exercise habits, body mass index, waist circumference, total cholesterol, triglycerides, high- and low-density lipoprotein cholesterol, fasting glucose, uric acid, serum hepatic enzymes, and mean arterial pressure were assessed. Separate factor analyses assessed total and low-density lipoprotein cholesterol. Principal components analysis identified five factors for a model without low-density lipoprotein cholesterol and four factors for a model without total cholesterol. Four common factors in both models explained between 51.1 and 51.8% of variance in the original 14 factors. Metabolic factors, hematological factors (white blood cells and platelets), lifestyle factors (smoking and alcohol consumption), and exercise habits and fasting blood glucose explained about 20, 11, 10, 10% of total variance, respectively. In the model without low-density lipoprotein cholesterol, total cholesterol factor explained 8.83% of variance. This study confirmed clustering of established metabolic syndrome components and revealed additional associated cardiovascular disease risk factors, including lifestyle factors, exercise and total cholesterol, which should be targeted in prevention efforts.

Keywords Metabolic syndrome · Cardiovascular disease · Total cholesterol · Risk factors · Factor analysis

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Introduction

Clustering of metabolic risk factors was familiar to 20th century clinicians. Interest increased markedly after Reaven [1] explored insulin resistance in human disease, describing "syndrome X" as a combination of insulin resistance, glucose intolerance, increased triglyceride (TG) levels, decreased high-density lipoprotein cholesterol (HDL-C), and hypertension that signaled increased risk of cardiovascular disease (CVD), and diabetes mellitus (DM). The World Health Organization (WHO) first described "the metabolic syndrome" (MetS) in 1998 [2], to which the European Group for the Study of Insulin Resistance [3] added hyperinsulinemia and waist circumference (WC) to the diagnostic criteria as a specific obesity factor. Factor analysis was employed by some investigators to reveal patterns among correlated metabolic risk factors [4, 5], and "insulin resistance syndrome" was favored as a designation [5]. The definition of the National Cholesterol Education Program Adult Treatment Panel III (NCEP/ATP III) (2001) remains the established standard [6]. In 2005, the American Diabetes Association and the challenges remain about whether MetS is a specific diagnosis and whether its established definition, which leaves out CVD risk factors commonly seen in clinical practice (i.e., elevated total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), uric acid, creatinine, and liver enzymes), is valid or useful in predicting CVD risk. The American Association of Endocrinologists (ACE) recommended modifications to the NCEP definition [7]. In 2005, the American Diabetes Association (ADA) and the European Association for the Study of Diabetes (EASD) also examined the MetS definition, pathogenesis, associated CVD risk factors, and how these might influence treatment goals [8]. Also in 2005, the ADA and the National Heart, Lung, and Blood Institute (AHA/NHLBI) issued a joint statement updating guidelines for diagnosis and management of MetS in adults [9].

Controversies surrounding NCEP/ATP III criteria include: (1) the five criteria and cutoff points appear to be arbitrary and not evidence based, (2) the risk factor values are continuous and must be so considered, not just present or absent, and (3) considering that CVD risk factors were already well recognized in clinical practice, important risk factors such as LDL-C, TC, smoking, family history and age are not included, limiting the usefulness of MetS in predicting risk [10]. Also, MetS and type 2 diabetes are associated with higher levels of serum hepatic enzymes, including alanine aminotransferase (ALT), aspartate aminotransferase (AST), and gamma glutamyltransferase (GGT) [11, 12]. Hyperuricemia is also associated with MetS and increased CVD risk [11, 13].

Factor analysis has examined relationships among CVD risk factors that reflect diverse populations [4, 5, 14–18], but relatively few analyses have evaluated Asian samples [16, 18–20]. This study aimed to explore clustering of modifiable cardiovascular risk factors in Taiwan, an Asian population, by factor analysis, and to determine the prevalence of MetS in our sample. We also considered whether diagnosis and prevention are better served by addressing a syndrome or by targeting associated modifiable CVD risk factors individually.

Patients and methods

Study population

Participants in this cross-sectional study were recruited from the health examination center of Cheng Ching Hospital in Taichung, Taiwan, between May and December 2007. Participants were part of a self-pay health checkup program. The primary inclusion criterion was healthy adult. Of 616 patients seen during the study period, 579 healthy participants were included. Thirty-seven participants were excluded as follows: 30 were taking medications for hypertension, diabetes, and dyslipidemia as well as dietary supplements; 5 were younger than age 20 and 2 had been diagnosed with cancer. The ethics committee of Cheng Ching Hospital approved the study, and all subjects gave written informed consent.

Exposure variables

Lifestyle data (smoking, alcohol consumption, and exercise) and parental history of cerebrovascular disease, coronary artery disease (CAD), diabetes, and hypertension were gathered by study physicians. Subjects completed a questionnaire asking first whether the participant exercised, smoked cigarettes and/or consumed alcohol, and how many times per week they engaged in exercise/consumed alcoholic beverages and/or how many cigarettes they smoked per day on average. Height, weight, WC, and blood pressure were measured by trained nurses, who also took blood samples. WC was measured midway between the costal margin and iliac crest. Body mass index (BMI) was calculated as body weight in kilograms divided by the square of height in meters.

Fasting blood specimens for biochemical tests (2-ml fluoride oxalate tubes) were collected from all participants after an overnight fast of at least 8 h. Blood samples were sent to the hospital clinical laboratory within 1 h for analyses. Biochemical tests were performed using a Hitachi 747 Analyzer (Hitachi Medical Corporation, Beijing, China).

Statistical analysis

Demographic characteristics and cardiovascular variables were compared by sex, using Mann–Whitney *U* test of continuous variables and chi-square tests for categorical variables. Exploratory factor analysis was completed to assess clustering of cardiovascular risk factors. The factor analysis technique elucidates the relationships (intercorrelations) between a large set of observed variables in terms of a smaller set of unobserved hypothetical underlying variables (factors). Factor analysis was done by three main steps: (1) extraction of factors (principal component analysis); (2) rotation of factors to obtain a simple structure that can be easily interpreted; and (3) naming and interpretation of each factor based on estimated values for factor loadings.

Factor extraction refers to identification of "principal components" A principal component reflects a group of variables that act together on a common hypothetical underlying pathological process contributing to disease. Each principal component is assigned an "Eigenvalue," a measure of the amount of variation in the total sample accounted for by each factor (the sum of squared correlations between original independent variables and principal component). A component is retained if it accounts for more of the total variance than any single original variable Eigenvalue $\geq$ 1.0 [21].

After identifying principal components, orthogonal rotation (varimax rotation) was used to obtain "factor loadings." We used an absolute loading value of $\geq$0.50 to interpret the factor pattern. In primary analysis, factors were derived from 18 potential CVD risk factors: WC, BMI, TG, HDL-C, LDL-C, TC, fasting blood glucose, uric acid, smoking, alcohol consumption, exercise, systolic blood pressure (SBP), diastolic blood pressure (DBP), creatinine, AST, ALT, white blood cells (WBC), and platelets (Plt).

We first tested pair-wise correlations. Variables with extremely weak correlations (correlation coefficient <0.2) with all other variables were removed from factor analysis. Because systolic and diastolic blood pressure were highly correlated ($\rho = 0.818$), mean arterial pressure (MAP) ([2 $\times$ diastolic blood pressure + systolic blood pressure]/3), was used in lieu of blood pressure measurements in subsequent analyses. Also, LDL-C and TC were put into different models of factor analysis since model fitness was lacking in the model that included both (Kaiser–Meyer–Olkin or KMO value was reduced steeply from 0.663 to 0.353 after adding LDL), possibly due to co-linearity caused by extremely high correlation ($\rho = 0.914$) between two variables. AST and ALT were also highly correlated ($\rho = 0.800$), so only ALT was used in subsequent analyses. The final set of 14 variables used in factor analyses were WC, MAP, TG level, fasting blood glucose, uric acid, ALT, smoking, alcohol consumption, exercise, HDL-C, WBC, Plt, and (LDL-C or TC). Finding a KMO value greater than 0.6 and a significant Bartlett's test of sphericity ($P < 0.001$) indicated sampling adequacy and lack of an identity matrix. All statistical analyses were performed using SPSS 15.0 software (SPSS Inc., Chicago, IL).

Results

Baseline characteristics and biochemical indices by sex are presented in Table 1. Males had higher values than females in almost all biochemical indices, except for platelet count and HDL-C levels. According to NCEP guidelines for metabolic syndrome (shown in Table 2), greater waist circumference was found in females than in males (14.6 vs. 5.7%, $P < 0.001$); however, higher prevalence of high triglyceride (48.8 vs. 26.9%, $P < 0.001$), SBP (42.2 vs. 27.8%, $P = 0.005$), DBP (26.7 vs. 9.9%, $P < 0.001$), and fasting blood glucose (30.8 vs. 23.1%, $P = 0.047$) were ascertained in men compared with women. Despite higher prevalence among males for most MetS risk factors compared with females, MetS prevalence was similar between genders (Table 2). Correlations among the 18 variables are shown in Table 3. In all subjects, WC, MAP, TG, HDL, LDL, TC, uric acid, and ALT correlated significantly with most variables analyzed. Smoking and fasting blood glucose correlated with approximately half of the variables analyzed.

Results of factor analyses are presented in Table 4. Separate analyses were completed for TC and LDL-C (Table 4). Principal components analysis identified five factors with an Eigenvalue $\geq$1 for the model containing TC and four factors for the model including LDL-C. In both models, four factors were common and combined they explained between 51.08 and 51.81% of variance in the original 14 factors. In all subjects, WC, MAP, ALT, TG level, HDL-C level, and uric acid were together on the first common factor (metabolic factor), similar to the MetS criteria put forth by the NCEP/ATP III Guidelines [6]. This factor explained about 20% of total variance. The second common factor contained WBC and Plt, which explained approximately 11% of total variance. The third common factor consisted of lifestyle habits of smoking and alcohol consumption (10.25–10.53% of variance). The fourth common factor included exercise and fasting blood glucose (around 9–10% of variance). In the model with LDL-C, TC factor explained 8.83% of variance.

Discussion

We examined clustering of modifiable cardiovascular risk factors in a cohort of healthy Taiwanese subjects and

Table 1 Characteristics of 579 subjects

	Female ($n = 212$)	Male ($n = 367$)	P value
Age (years)	48 (38, 55)	48 (40, 55)	0.926
Waist circumference (cm)	76 (71, 84)	86 (81, 92)	<0.001
BMI (kg/m^2)	22 (20, 25)	25.1 (23, 27)	<0.001
Systolic blood pressure (mmHg)	119 (105, 132)	127 (117, 136)	<0.001
Diastolic blood pressure (mmHg)	73 (64, 79)	79 (72, 85)	<0.001
Mean arterial pressure (mmHg)[a]	88 (79, 96)	94 (88, 102)	<0.001
Smoking (Y/N)	13 (6)/199 (94)	148 (40)/219 (60)	<0.001
Alcohol drinking (Y/N)	29 (14)/183 (86)	175 (48)/192 (52)	<0.001
Exercise (times/week)			0.011
No	110 (52)	144 (39)	
1–2	49 (23)	114 (31)	
≥3	53 (25)	109 (30)	
Metabolic syndrome	38 (18)	86 (23)	0.120
Family history			
Diabetes	51 (24)	93 (25)	0.731
Hypertension	72 (34)	144 (39)	0.206
Cerebrovascular disease	28 (13)	47 (13)	0.890
Heart disease	28 (13)	46 (13)	0.815
Platelet (10^3/μl)	264.0 (227.3, 306.8)	245.0 (210.0, 280.0)	<0.001
White blood cell (10^3/μl)	5.8 (4.8, 7.0)	6.2 (5.4, 7.4)	<0.001
Fasting blood glucose (mg/dl)	89.0 (84.0, 97.0)	93.0 (87.0, 103.0)	<0.001
Triglyceride (mg/dl)	100.0 (71.0, 154.5)	145.0 (100.0, 220.0)	<0.001
Total cholesterol (mg/dl)	195.5 (174.0, 224.0)	197.0 (174.0, 220.0)	0.547
HDL-C (mg/dl)	61.0 (51.0, 72.0)	48.0 (41.0, 58.0)	<0.001
LDL-C (mg/dl)	111.0 (92.0, 136.0)	119.0 (97.0, 137.0)	0.031
Uric acid (mg/dl)	4.9 (4.3, 5.6)	6.5 (5.7, 7.7)	<0.001
Creatinine mg/dl)	0.8 (0.7, 0.9)	1.1 (1.0, 1.2)	<0.001
AST (mg/dl)	19.0 (16.0, 24.0)	21.0 (18.0, 28.0)	<0.001
ALT (mg/dl)	18.0 (14.0, 26.0)	26.0 (19.0, 42.0)	<0.001

Data are presented as median (interquartile range, IQR) or subject number (%)

BMI body mass index, *HDL-C* high-density lipoprotein cholesterol, *LDL-C* low-density lipoprotein cholesterol, *AST* aspartate aminotransferase, *ALT* alanine aminotransferase

[a] Mean arterial pressure = [(2 × diastolic blood pressure + systolic blood pressure)/3]

identified CVD risk factors, including lifestyle factors, exercise and total cholesterol, in addition to established MetS components. While numerous studies have performed cluster analysis to evaluate metabolic syndrome [5, 14–18], to our knowledge no report to date has examined modifiable CVD risk factors and reported clustering of five diagnostic indicators suggested in NCEP/ATP III [6] or AHA/NHLBI guidelines [9].

Because of strong correlation between LDL-C and TC, two separate analyses were done, one including TC in candidate variables and one including LDL-C; the former yielded four factors and the latter yielded three. Both analyses revealed a metabolic factor that included NCEP/ATP III established MetS indicators WC, HDL-C, MAP, fasting blood glucose, and TG [6]. The second factor was a lifestyle factor (alcohol consumption and smoking); the third included only TC (in analysis excluding LDL-C), and the fourth was an exercise factor. Factor loadings were highest for WC and blood pressure. Few factor analyses of CVD risk factors have included LDL-C and TC [20, 22], which is surprising because NCEP/ATP III guidelines consider reducing LDL-C to be primary prevention for CVD [6]. Among all cholesterol variables, TC was the primary risk factor for CVD [22].

The importance of elevated blood pressure as a MetS core component has been debated. SBP and DBP are often combined as a CVD risk factor. Orvick et al. [23] identified a metabolic factor and an SBP/DBP blood pressure factor comprising 27% of total variation in elderly men. Two factors were identified in a multiethnic group as a "metabolic" factor (i.e., BMI, WC, fasting and 2-h glucose, and HDL) and a "blood pressure" factor with positive loading of SBP and DBP [24]. Wu et al. [25] identified multiple factors, of which SBP and DBP were a dimension, concluding that MetS was not unified by a single etiology such as insulin resistance. We used mean arterial blood pressure (MAP) in lieu of SBP and DBP, and found that it loaded with the metabolic factor with WC, TG, HDL-C, and

Table 2 Prevalence among subjects of risk factors of metabolic syndrome defined by NCEP guidelines

	Female ($n = 212$)	Male ($n = 367$)	P value
Waist circumference (cm)			<0.001
<88 (women) or 102 (men)	181 (85.4)	346 (94.3)	
≥88 (women) or 102 (men)	31 (14.6)	21 (5.7)	
Triglyceride (mg/dl)			<0.001
<150	155 (73.1)	188 (51.2)	
≥150	57 (26.9)	179 (48.8)	
HDL-C (mg/dl)			0.515
<40 (men) or 50 (women)	165 (77.8)	294 (80.1)	
≥40 (men) or 50 (women)	48 (22.2)	73 (19.9)	
Systolic blood pressure (mmHg)			0.005
<130	153 (72.2)	212 (58.8)	
≥130	59 (27.8)	155 (42.2)	
Diastolic blood pressure (mmHg)			<0.001
<85	191 (90.1)	269 (73.3)	
≥85	21 (9.9)	98 (26.7)	
Fasting blood glucose (mg/dl)			0.047
<100	163 (76.9)	254 (69.2)	
≥100	49 (23.1)	113 (30.8)	
Metabolic syndrome			0.375
No	174 (82.1)	290 (79.0)	
Yes	38 (17.9)	77 (21.0)	

Data are presented as number (%) and tested by chi-square test

HDL-C high-density lipoprotein cholesterol

fasting blood glucose, similar to the findings of the large factor analysis among Taiwanese by Chuang et al. [16].

Although previous reports indicated that MetS prevalence was higher in women in Western countries [26, 27], a large health-exam cohort in Taiwan (24,329 subjects) showed greater prevalence among men (15.5%) than women (10.5%) [16]. Results of other studies in Taiwan were contradictory: the prevalence of MetS was lower in women than in men in a population younger than 50 years [28] and 32.55% in men and 19.76% in women in another recent study [29]. We evaluated the percentage of subjects with each established risk factor and MetS prevalence among our subjects based on the AHA/NHLBI definition of MetS (Table 2), but no significant difference between genders was found. Our results may be explained by distinctions in the MetS definition. Previous studies in Taiwan applied the revised NCEP/ATP III definition adopting Asian criteria for WC and we used the AHA/NHLBI definition [9].

When we isolated MetS components, males had higher prevalence of high triglycerides, hypertension and elevated fasting glucose; females had higher prevalence of increased WC. These results agree with previous reports [28, 29]. Prevalence of a rapidly increasing WC in post-menopausal women showed it to be higher than in men aged 50–55 [28]. The median age of our subjects was 48 years, which may explain the higher prevalence of increased WC among women.

Several factors strengthen confidence in our findings. Factor analyses of CVD risk factors have the potential for highly correlated variables that measure the same trait (e.g., DBP and SBP), creating distinct factors [19]. Studies that did not analyze highly correlated factors separately may actually have reached inappropriate conclusions [30]. We used a single measure of MAP to avoid emergence of a separate factor consisting solely of highly correlated blood pressure measurements. Correlation coefficients for LDL-C and TC were high enough so that analyzing them together might have resulted in insufficient discriminative validity. Separate analysis of TC and LDL-C ensured more accurate factor loadings.

Correlation of MetS with cardiovascular disease is well documented [31]. We grouped four of five parameters of the AHA/NHLBI MetS definition into the first common MetS factor, even though the definition excluded total cholesterol (TC) from the variables. We also included alanine aminotransferase (ALT) and uric acid (UA), which were not the components of AHA/NHLBI MetS definition. ALT is a marker of non-alcoholic liver disease (NAFLD) and recent studies has demonstrated its strong association with MetS factors, type 2 DM and CVD [32]. Recent studies suggest that hyperuricemia may not only be a consequence of insulin resistance states but a significant predictor of MetS development [33]. Elevated UA also predicts mortality in patients with cardiovascular events in

Table 3 Correlation matrix of all variables

	Smoking (cigarettes/day)	Drinking (times/week)	Sport (times/week)	BMI (kg/m^2)	WC (cm)	SBP (mmHg)	DBP (mmHg)	MAP (mmHg)	TC (mg/dl)	TG (mg/dl)	HDL-C (mg/dl)	LDL-C (mg/dl)	AC (mg/dl)	UA (mg/dl)	AST (mg/dl)	ALT (mg/dl)	WBC (10^3/μl)	Plt (10^3/μl)
Smoking (cigarettes/day)	1.000	0.332[a]	−.058	0.100*	0.149[a]	0.011	0.088*	0.058	−0.020	0.244[a]	−0.208[a]	−0.041	0.035	0.177[a]	0.139[a]	0.090*	0.198[a]	−0.065
Drinking (times/week)	–	1.000	0.038	0.084*	0.143[a]	0.104*	0.179[a]	0.152[a]	0.001	0.166[a]	−0.043	−0.040	0.059	0.221[a]	0.113[a]	0.063	0.091*	−0.008
Sport (times/week)	–	–	1.000	0.031	0.019	0.074	0.088*	0.088*	−0.039	−0.037	−0.003	0.018	0.089*	0.032	−0.017	0.039	−0.034	−0.072
BMI (kg/m^2)	–	–	–	1.000	0.775[a]	0.373[a]	0.410[a]	0.409[a]	0.152[a]	0.452[a]	−0.427[a]	0.217[a]	0.326[a]	0.376[a]	0.452[a]	0.317[a]	0.248[a]	−0.019
WC (cm)	–	–	–	–	1.000	0.409[a]	0.424[a]	0.434[a]	0.134[a]	0.469[a]	−0.451[a]	0.194[a]	0.352[a]	0.423[a]	0.455[a]	0.303[a]	0.241[a]	−0.044
SBP (mmHg)	–	–	–	–	–	1.000	0.818[a]	0.939[a]	0.126[a]	0.343[a]	−0.220[a]	0.129[a]	0.356[a]	0.248[a]	0.282[a]	0.241[a]	0.155[a]	−0.059
DBP (mmHg)	–	–	–	–	–	–	1.000	0.963[a]	0.182[a]	0.380[a]	−0.223[a]	0.176[a]	0.339[a]	0.301[a]	0.310[a]	0.254[a]	0.147[a]	−0.064
MAP (mmHg)	–	–	–	–	–	–	–	1.000	0.162[a]	0.384[a]	−0.230[a]	0.158[a]	0.365[a]	0.288[a]	0.309[a]	0.259[a]	0.159[a]	−0.068
TC (mg/dl)	–	–	–	–	–	–	–	–	1.000	0.362[a]	0.077	0.914[a]	0.171[a]	0.150[a]	0.155[a]	0.146[a]	0.081	0.075
TG (mg/dl)	–	–	–	–	–	–	–	–	–	1.000	−0.547[a]	0.342[a]	0.308[a]	0.377[a]	0.400[a]	0.236[a]	0.330[a]	0.058
HDL-C (mg/dl)	–	–	–	–	–	–	–	–	–	–	1.000	−0.130[a]	−0.217[a]	−0.343[a]	−0.320[a]	−0.130[a]	−0.252[a]	−0.032
LDL-C (mg/dl)	–	–	–	–	–	–	–	–	–	–	–	1.000	0.202[a]	0.201[a]	0.175[a]	0.139[a]	0.088*	0.086*
AC (mg/dl)	–	–	–	–	–	–	–	–	–	–	–	–	1.000	0.132[a]	0.223[a]	0.159[a]	0.137[a]	−0.052
UA (mg/dl)	–	–	–	–	–	–	–	–	–	–	–	–	–	1.000	0.339[a]	0.252[a]	0.180[a]	−0.053
AST (mg/dl)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.000	0.800[a]	0.169[a]	−0.048
ALT (mg/dl)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.000	0.017	−0.151[a]
WBC (10^3/μl)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.000	0.314[a]
Plt (10^3/μl)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.000

WC waist circumference, *MAP* mean arterial pressure, *TH* triglyceride, *HDL* high-density lipoprotein, *UA* uric acid, *TC* total cholesterol, *LDL* low-density lipoprotein, *BMI* body mass index, *FBS* fasting blood sugar, *SBP* systolic blood pressure, *DBP* diastolic blood pressure, *AST* aspartate aminotransferase, *ALT* alanine aminotransferase, *Plt* platelet

* Significant correlation, $P < 0.05$

[a] Significant correlation, $P < 0.01$

Table 4 Factor loading rotated using the varimax method

	Model without LDL-C					Model without TC			
	Metabolic factor	Factor 2	Habit factor	Factor 4	TC factor	Metabolic factor	Factor 2	Habit factor	Factor 4
Waist circumstance (cm)	**0.71**	0.10	−0.02	0.27	−0.04	**0.71**	0.08	0.01	0.26
Mean arterial pressure (mmHg)	0.48	0.01	0.04	0.46	0.18	**0.51**	−0.01	0.05	0.44
ALT (mg/dl)	**0.60**	−0.16	0.04	−0.23	0.07	**0.59**	−0.18	0.07	−0.25
Fasting blood glucose (mg/dl)	0.18	0.02	0.12	**0.66**	0.04	0.18	0.02	0.14	**0.67**
Triglyceride (mg/dl)	**0.64**	0.19	0.23	0.08	0.20	**0.64**	0.17	0.26	0.07
Total cholesterol (mg/dl)	0.21	0.10	−0.04	0.02	**0.89**	–	–	–	–
HDL-C (mg/dl)	**−0.66**	−0.22	0.05	−0.10	0.47	**−0.63**	−0.21	0.01	−0.10
LDL-C (mg/dl)	–	–	–	–	–	0.42	0.10	−0.34	0.01
Uric acid (mg/dl)	**0.64**	0.00	0.07	−0.02	0.10	**0.66**	−0.03	0.05	−0.06
White blood cell (10^3/μl)	0.24	**0.78**	0.13	0.08	−0.03	0.26	**0.77**	0.14	0.08
Platelet (10^3/μl)	−0.12	**0.82**	−0.09	−0.14	0.09	−0.08	**0.82**	−0.11	−0.14
Smoking (cigarettes/per day)	0.16	0.14	**0.76**	−0.10	−0.13	0.16	0.15	**0.74**	−0.10
Drinking (times/per week)	−0.01	−0.10	**0.80**	0.12	0.10	0.02	−0.09	**0.75**	0.10
Exercise (times/per week)	−0.16	−0.08	−0.10	**0.68**	−0.08	−0.14	−0.08	−0.14	**0.67**
Variance (%)	19.70	11.15	10.25	9.98	8.83	20.47	10.98	10.53	9.83
Cumulative variance (%)	19.70	30.85	41.10	51.08	59.91	20.47	31.45	41.98	51.81

Bold indicates that the absolute value of the factor loading was ≥0.50. Dash indicates that the variable was not included

BMI body mass index, *TC* total cholesterol, *HDL-C* high-density lipoprotein cholesterol, *LDL-C* low-density lipoprotein cholesterol

diabetes patients [34]. We grouped exercise and fasting blood glucose in the fourth common MetS factor, which is already one parameter in the AHA/NHLBI MetS definition, but it was an independent variable in terms of predicting CVD risk.

Our findings support the concept of clustered risk factors in the currently accepted NCEP/ATP III MetS definition [6], and also support identifying all modifiable CVD risk factors, including lifestyle factors, expanding the standard definition of MetS in practice. Clearly, MetS cannot be considered a precise diagnosis if there are multiple definitions. A standard definition can remind us of the higher risk for CVD or DM in an individual with the defined symptoms while encouraging assessment of all CVD risk factors.

This study has several limitations: (1) Factor analysis itself is subject to limitations such as arbitrary thresholds for inclusion of variables, method of rotation used and minimum factor loading chosen to designate a variable as a primary factor constituent. We used conservative factor loading cut points and employed widely used and accepted analysis techniques. (2) Because our healthy study participants were recruited from general health examinations, our findings may not be generalizable to other populations such as patients with CVD or diabetes. (3) Medication use by study participants was not recorded and certain medications may influence MetS risk factors. (4) Cross-sectional study precludes establishing a temporal relationship between studied MetS components.

We examined clustering of CVD risk factors in a Taiwanese sample, and confirmatory factor analysis is needed to assess the robustness of our findings in an independent data set. The sample size was somewhat small and further similar and larger-scale studies are warranted.

In conclusion, this study confirmed clustering of established metabolic syndrome components and revealed additional associated CVD risk factors, including lifestyle factors, exercise and total cholesterol, which we suggest should be targeted in prevention efforts. Our findings highlight CVD risk factors included and excluded in the MetS definition, providing implications for future research and a guide for clinical practice. Early identification and treatment of the modifiable risk factors identified in this study, especially multiple CVD risk factors, may be of utmost importance in prevention efforts.

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