Prevalence, agreement and classification of various metabolic syndrome criteria among ethnic Chinese: A report on the hospital-based health diagnosis of the adult population

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Received 20 July 2006; received in revised form 19 December 2006; accepted 9 January 2007

Available online 8 February 2007

Abstract

Objectives: Many criteria of metabolic syndrome have been made available to practitioners in the recent past. This study has been designed to investigate the distribution, agreement and classification patterns of these criteria among the ethnic Chinese population.

Methods: A total of 6610 (women, 42.5%) adults (mean, 52.3 years) were recruited from the hospital-based health diagnosis program during 2004. We divided criteria of metabolic syndrome into two groups: those with a major component required (WHO, EGIR, AACE, IDF) and those with equal component (ATP III, AHA, with modifications).

Results: The highest standardized rates were in Asian AHA criterion, up to 29.8% in men and 25.6% in women. The lowest rates were in WHO criterion, 8.8% in men and 8.0% in women. The κ values using all criteria were 0.59 in men and 0.65 in women and decreased in the major component group (0.50 in men, 0.54 in women), while increased in the equal component group (0.83 in men, 0.81 in women). Using hierarchical cluster analysis and dendrograms, two large clusters were identified in men (major components and equal components); however, mixed sub-clusters of major and equal components apparently grouped by insulin resistance and obesity criteria in women.

Conclusions: There is substantial agreement and grouping of metabolic syndrome models among ethnic Chinese.

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Keywords: Metabolic syndrome; Cross-sectional study; Agreement; Classification

1. Introduction

Metabolic syndromes have placed a great burden on public health and clinical practice [1], and their high prevalence and impact on atherosclerotic risk are proven among different ethnic populations [2–4]. Also, many criteria for metabolic syndrome have been made available in the recent past. These criteria have also been classified into two groups. One group

emphasizes one major criteria, including insulin resistance or central obesity, plus other atherosclerotic components. It includes definitions from the World Health Organization (WHO) [5], the European Group for Study of Insulin Resistance (EGIR) [6], American Association of Clinical Endocrinologists (AACE) [7] and the International Diabetes Federation (IDF) [8]. The other group treats all atherosclerotic risk components equal, defining metabolic syndrome if there are more than or equal to three components of high blood pressure, dyslipidemia, obesity and hyperglycemia. It includes definitions from the National Cholesterol Education Program (NCEP) Adult Treatment Panel III (ATP III) [9] and the American Heart Association/National Heart,

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Lung, and Blood Institute (AHA/NHLBI) criteria [10]. Ethnic variations in obesity definition for central obesity by waist circumference and general obesity by body mass index (BMI) roles introduced complications [11]. Consensus on metabolic syndrome definitions and clinical implications are still arguable [12,13]. The above various criteria confuse health professionals, especially in non-Caucasian populations, such as with ethnic Chinese [14,15]. First, we do not know the consistency and agreement among the above criteria and potential influence of each criterion. Second, the underlying groups or clusters of metabolic syndrome models are unknown. Although previous analytic techniques such as factor analysis and classification methods have been applied in clarifying the dimensions of metabolic syndrome components [16,17], there are no available reports on the consistency and grouping of various criteria.

This study explored the complexity of different metabolic syndrome criteria in the ethnic adult Chinese population. First, we estimated the age standardized prevalence rates; then quantified the degree of agreement among available metabolic syndrome criteria. We identified the influence of specific criterion of metabolic syndromes and classified these criteria by their similarity, grouping into several sub-clusters among ethnic Chinese.

2. Methods

2.1. Study design and population

The study design was a cross-sectional study and the 6610 adult (women: 42.6%) participants were recruited from the Health Management Center of one tertiary hospital from January 2004 to December 2004. Details of socioeconomic status, along with medical and medication histories were collected by questionnaires, and standardized clinical procedures were undertaken. We excluded the participants with concurrent severe medical diseases such as cancer and heart failure. The participants signed informed consent forms, and the protocol was approved by the Institutional Research Board of the hospital. Details of subjects' medical histories such as medication, hospitalization and smoking status were asked in the structural questionnaires. Standardized procedures of physical examination, such as anthropometric measures and blood pressure, were performed [18,19]. Blood pressure was measured in the resting position by trained medical assistants. BMI was calculated as weight (in kg)/square of height (in m). Waist circumference was measured midline between the low costal margin and superior posterior iliac crest.

2.2. Blood sampling and analytic methods

The procedures of blood sampling and analytic methods are described in previous studies [20,21]. In brief, blood samples were collected from each participant after they had

fasting status at least 12 h. Serum total cholesterol levels were measured using the CHOD-PAP method (Boehringer, Mannheim, Germany). HDL-C was measured following precipitation of apolipoprotein B-containing lipoproteins with phosphotungstic acid and magnesium ions (Boehringer, Mannheim, Germany). Triglyceride concentrations were measured by the GPO-DAOS method (Wako Co., Japan). All of the lipids mentioned above were measured using a Hitachi 7450 automated analyzer (Hitachi, Japan). LDL-C concentrations were calculated using the Friedewald formula. All the measures of both samples were carried out in the single hospital. The coefficient of variation was 5%.

2.3. Criteria of metabolic syndrome

We defined 10 criteria for metabolic syndrome, grouped into two categories (Table 1). One category included a major component hyperglycemia, insulin resistance in WHO [5], EGIR [6], AACE [7], and central obesity in IDF [8], plus two other components. We excluded patients with diabetes in the criteria of EGIR and AACE. The other category included original ATP III [9] and AHA/NHLBI criteria [10], where metabolic syndrome was defined as more than or equal to three components, considering all components are equal. Besides, we used modified criteria for Asian population in ATP III [14], AHA/NHLBI, and BMI ATP III criteria. For original ATP III criteria, a participant with three of the following was defined as having metabolic syndrome: (1) blood pressure of at least 130/85 mmHg or undergoing treatment for hypertension; (2) serum triglyceride of at least 150 mg/dL; (3) HDL cholesterol of <40 mg/dL in men and <50 mg/dL in women; (4) fasting glucose of 110 mg/dL or more; (5) central obesity, waist circumference greater than 102 cm in men and 88 cm in women. Modified Asian ATP III criteria are the same as the original ATP III except for a waist circumference greater than 90 cm in men and 80 cm in women [15]. For evaluating general obesity such as BMI roles in predicting metabolic syndrome, we added BMI as a general obesity component by following ATP III-like criteria. One is to treat BMI ≥ 27 kg/m² only (ATP III/BMI), and another is to treat BMI or waist circumference as proposed by Taiwan Bureau of Health Promotion [22].

2.4. Statistical analysis

We performed a three-part analysis. First, we estimated the prevalence rates of various metabolic syndromes, specified by genders. The age standardized prevalence rates and 95% confidence intervals were also estimated by the world reference population. The age standardized prevalence rates were compared among the 10 criteria-defined rates among the study subjects. Second, we used κ statistics to evaluate the agreement and relative importance among different criteria [23]. We specified the metabolic syndrome as binary categories, and estimated the gender-specific κ values. We put all 10 criteria together, then separated the 10 criteria into

Table 1
Definitions of 10 metabolic syndrome criteria in the study population

Clinical measure	WHO (1998)	EGIR (1999)	ATP III, original (2001)	ATP III, Asian (2004)	AACE (2003)	IDF (2005)	AHA/NHLBI (2005), original	AHA/NHLBI (2005), Asian	ATP III/BMI (2004)	Taiwan (2004)
Body weight	BMI >27 kg/m ²	WC >90 cm in men or 80 cm in women	WC ≥102 cm in men or ≥88 cm in women	WC ≥90 cm in men or ≥80 cm in women	BMI ≥25 kg/m ²	Major: WC ≥90 cm in men or ≥80 cm in women	WC ≥102 cm in men or ≥88 cm in women	WC ≥90 cm in men or ≥80 cm in women	BMI >27 kg/m ²	BMI >27 kg/m ² or WC ≥90 cm in men or ≥80 cm in women
Lipid-TG	≥150 mg/dL	≥150 mg/dL	≥150 mg/dL	≥150 mg/dL	≥150 mg/dL	≥150 mg/dL	≥150 mg/dL	≥150 mg/dL	≥150 mg/dL	≥150 mg/dL
Lipid-HDL	<35 mg/dL in men or <40 mg/dL in women	<40 mg/dL in men or women	HDL-C <40 mg/dL in men or <50 mg/dL in women	HDL-C <40 mg/dL in men or <50 mg/dL in women	HDL-C <40 mg/dL in men or <50 mg/dL in women	HDL-C <40 mg/dL in men or <50 mg/dL in women	HDL-C <40 mg/dL in men or <50 mg/dL in women	HDL-C <40 mg/dL in men or <50 mg/dL in women	HDL-C <40 mg/dL in men or <50 mg/dL in women	HDL-C <40 mg/dL in men or <50 mg/dL in women
Blood pressure	≥140/90 mmHg or on medication	≥140/90 mmHg or on medication	≥130/85 mmHg	≥130/85 mmHg or on medication	≥130/85 mmHg or on medication	≥130/85 mmHg or on medication	≥130/85 mmHg or on medication	≥130/85 mmHg or on medication	≥130/85 mmHg or on medication	≥130/85 mmHg or on medication
Glucose	Major: IGT (≥127), IFG (≥110), T2DM (≥127 mg/dL)	Major: post-2h glucose >127 mg/dL	IFG (≥110) or DM	IFG (≥110) or DM	Major: IGT (≥127), IFG (≥110)	IFG (≥100) or DM	IFG (≥100) or DM	IFG (≥100) or DM	IFG (≥110) or DM	IFG (≥110) or DM
Other	Urine protein ≥30 mg/dL	DM excluded	DM excluded	DM excluded	Urine protein ≥30 mg/dL, DM excluded					DM

Abbreviation—BMI: body mass index; DM: diabetes mellitus; HDL: high density lipoprotein cholesterol; IFG: impaired fasting glucose; IGT: impaired glucose tolerance; TG: triglyceride; WC: waist circumference.

two groups, specified by major components or not. The κ statistics estimated the agreement and concordance of classifying all criteria together [24]. Furthermore, we performed the sensitivity analysis to detect the influence of specific criterion by re-calculating the κ values by deleting this specific criterion. The percentage of κ values was considered as the influence effect of specific criterion.

Third, we performed hierarchical cluster analysis to classify these criteria into several sub-clusters. The goal of cluster analysis is to classify data into homogenous groups or clusters. Before analysis began, all data was considered as separated clusters. Between-groups linkage was used as the method for combining clusters, and its purpose was to minimize the average distance between all pairs of items in which one member of the pair was from each of the items. The distance is the measure of how far apart two objects are, and similarity measure is a measure of closeness. The squared Euclidean distance using standardized data was chosen as the measure of similarity, and the squared Euclidean distance is the sum of the squared differences over all the variables. Cluster analysis was capable of classifying complex components such as dietary constituents [25], microarray genomic profile data [26] and exploratory factors for metabolic syndrome [17]. It was capable of defining similarity and dissimilarity in various constituents, and this non-parametric classification technique provided a robust method of grouping and testing for the degree of similarity among studied variables. This method gives hints on the underlying structure and similarity of metabolic syndrome criteria. The dendrogram tree patterns for classifying these variables were used to visualize the underlying cluster and sub-cluster structures.

All statistical analyses were performed using SAS Version 9.1 (SAS Institute, Inc., Cary, NC) and STATA Version 9.1 (Stata Corp., College Station, TX).

3. Results

Table 2 showed the basic characteristics of study participants. Men were older, and had higher waist circumference, blood pressure, triglyceride, LDL cholesterol, glucose, and lower BMI and HDL cholesterol concentrations than women. Men had higher prevalence rates of work jobs, married, smoking, drinking habits and body mass index than women. Among the distribution of components of metabolic syndrome, men had higher rates of high blood pressure, triglyceride, and glucose and lower rates of central obesity and low HDL cholesterol than women. The gender specific prevalence rates of metabolic syndrome by different criteria are presented in Table 3. The highest standardized rates were in Asian AHA/NHLBI criterion, up to 25.7% in men and 21.5% in women, and the lowest rates were in WHO criterion, 8.8% in men and 8.0% in women. Men had higher age-adjusted prevalence rates of metabolic syndrome than women when equal component criteria were used, while women had higher rates when the IDF and EGIR were used.

Table 2
Basic characteristics in the study participants, specified by genders

	Men (N = 3793)		Women (N = 2817)		P
	Mean	S.D.	Mean	S.D.	
Age (year)	52.0	12.3	50.4	12.2	<.0001
BMI (kg/m ²)	24.5	3.0	22.8	3.4	<.0001
WC (cm)	84.9	8.8	79.1	9.2	<.0001
Systolic BP (mmHg)	127.0	14.4	118.7	16.8	<.0001
Diastolic BP (mmHg)	76.2	9.9	70.0	10.1	<.0001
Total cholesterol (mg/dL)	201.8	35.4	203.6	38.4	0.052
Triglyceride (mg/dL)	133.5	84.3	101.4	66.4	<.0001
HDL cholesterol (mg/dL)	38.8	7.7	46.3	9.5	<.0001
LDL cholesterol (mg/dL)	119.9	31.0	112.4	32.9	<.0001
Fasting glucose (mg/dL)	95.5	23.5	91.1	20.6	<.0001
	Men (N = 3793), %		Women (N = 2817), %		P
Occupation					<.0001
No job	4.3		6.9		
Labor work	6.2		2.7		
Non-labor work	89.5		68.4		
Housekeeping	0.0		21.9		
Marry status					<.0001
Single	10.6		17.0		
Married	88.5		81.3		
Divorced or spouse deceased	0.9		1.7		
Smoking (current)	20.7		3.8		<.0001
Alcohol drinking (regular)	67.4		38.5		<.0001
High BP	47.5		29.5		<.0001
High triglyceride	28.8		14.8		<.0001
Low HDL cholesterol	60.6		66.7		<.0001
Central obesity: original	2.8		14.9		<.0001
Central obesity: Asian	24.4		42.0		<.0001
High glucose	22.7		14.6		<.0001
High BMI ≥ 27	18.7		10.6		<.0001

Abbreviation—BMI: body mass index; WC: waist circumference; BP: blood pressure; HDL: high density lipoprotein; LDL: low density lipoprotein.

Agreement among these criteria by κ values and the percentage change of κ by deleting one criterion are presented in Table 4. For 10 criteria, women had higher κ values than men (0.65 versus 0.59), indicating higher consistency in women than in men. The range of percentage change of κ was around 1–5%, without large influence from the criteria. We strat-

ified the criteria into two groups by types of components: major component or equal component groups. We found that the κ values decreased to 0.50–0.54 in the major component group, and increased to 0.83–0.81 in the equal component group. Among cases in the major component group, κ values increased from 0.50 to 0.77 in men and 0.54 to 0.71

Table 3
Gender specific prevalence rates and corresponding 95% confidence interval (CI) (%) of metabolic syndrome by different criteria in the study population

Criteria	Men				Women			
	Crude	Age-standardized	Low 95% CI	High 95% CI	Crude	Age-standardized	Low 95% CI	High 95% CI
WHO (1998)	11.2	8.8	7.9	9.7	9.1	8.0	7.1	9.0
EGIR (1999)	11.8	9.2	8.3	10.1	12.2	10.7	9.6	11.7
ATP III (2001) original	18.5	15.9	14.7	17.2	15.7	13.3	12.2	14.4
ATP III (2001) Asian	26.6	23.3	21.8	24.8	23.4	19.8	18.5	21.1
AACE (2003)	16.9	13.0	12.0	14.0	16.0	13.7	12.6	14.9
IDF (2005)	18.1	16.2	14.9	17.6	22.4	19.0	17.7	20.3
AHA, NHLBI (2005) original	22.2	18.8	17.5	20.2	18.0	15.1	13.9	16.2
AHA, NHLBI (2005) Asian	29.8	25.7	24.2	27.3	25.6	21.5	20.2	22.8
ATPBMI (2004)	24.0	21.7	20.2	23.2	14.8	12.4	11.3	13.5
TAIWAN (2004)	27.7	24.5	23.0	26.1	23.4	19.9	18.6	21.2

World population as a reference population for age standardized rates.

Table 4

Interrater agreement of different criteria of metabolic syndrome by κ values, each cell presenting the κ when deleting this criterion

Criteria	Men		Women	
	κ	% change of κ by deleting one criterion	κ	% change of κ by deleting one criterion
All 10 criteria	0.59		0.65	
WHO (1998)	0.62	5.0	0.69	5.0
EGIR (1999)	0.63	5.9	0.68	4.8
ATP III (2001) original	0.58	2.1	0.64	1.7
ATP III (2001) Asian	0.56	5.0	0.63	3.5
AACE (2003)	0.62	5.0	0.68	3.9
IDF (2005)	0.62	4.0	0.65	0.5
AHA, NHLBI (2005) original	0.58	1.9	0.64	1.8
AHA, NHLBI (2005) Asian	0.57	3.8	0.64	2.7
ATPBMI (2004)	0.57	3.8	0.65	0.8
TAIWAN (2004)	0.57	4.5	0.63	3.5
Major criteria: WHO, EGIR, AACE, IDF	0.50		0.54	
WHO (1998)	0.42	16.3	0.52	3.7
EGIR (1999)	0.42	16.3	0.47	12.4
AACE (2003)	0.42	16.8	0.48	11.2
IDF (2005)	0.77	54.1	0.71	31.9
Equal component: ATP III, AHA, Taiwan	0.83		0.81	
ATP III (2001) original	0.85	2.4	0.82	0.6
ATP III (2001) Asian	0.81	2.2	0.80	1.9
AHA, NHLBI (2005) original	0.85	2.2	0.82	0.4
AHA, NHLBI (2005) Asian	0.83	0.0	0.81	0.0
ATPBMI (2004)	0.82	0.9	0.83	2.5
TAIWAN (2004)	0.81	1.7	0.80	1.9

in women when deleting IDF criterion, and the percentage change of κ values was 54.1% in men and 31.9% in women, indicating disagreement of IDF with other criteria. The higher percentage change of κ values with the sensitivity analyses for the IDF definition in major component groups can be explained by the reason that central obesity is the necessary component in the IDF definition, while the other major components require hyperglycemia or insulin resistance, instead of central obesity. The high κ values among equal components (0.80–0.85) demonstrated consistent agreement among ATP,

AHA and BMI components. Also, the κ values among equal components were similar between genders.

Hierarchical cluster analysis and dendrograms using average linkage between groups in the study population is shown in Fig. 1. For men, there were two large clusters: major components and equal components. Four sub-clusters were classified and identified clearly. Among them, AACE and IDF together were different from EGIR and WHO sub-clusters, and the modified Asian criteria formed another sub-cluster, different from the original Caucasian waist circumference

Fig. 1. Hierarchical cluster analysis and dendrograms using average linkage between groups in the study population, specified by men (right) and women (left).

criteria sub-cluster. The cluster pattern and dendrogram in women were somewhat different from men. Although there was also classification by two clusters in women, the four sub-clusters were different than in men. IDF formed as an independent sub-cluster, separated from other major component criteria, which formed a distinct sub-cluster. In addition, IDF sub-clusters closely related to modified Asian criteria equal component sub-clusters. The cluster and sub-cluster patterns did not change when the cut-off point for BMI changed to 25 kg/m² (data not shown).

4. Discussion

This is the first report, according to the authors' knowledge, that quantifies the consistency and agreement of various metabolic syndrome models, demonstrating specific model influence on the consistency. We found substantial consistency among these criteria, almost perfect among ATP-like models. Also, we clustered these models into two groups by their similarity. The IDF model was not consistent with other models, and BMI is consistent with waist circumference components in predicting metabolic syndrome.

It is a complex task summarizing the available criteria for metabolic syndrome up to date. The present time is suitable for performing a critical appraisal of metabolic syndrome [27]. Our contribution is to compare the age-standardized prevalence rates of various metabolic syndrome criteria in the same population. It will be helpful to clinicians and provide public health professionals with additional consideration towards the implications of different criteria.

Compared with other ethnic populations, ethnic Chinese are known to have low rates of diabetes and metabolic syndrome [28], although the burden varies in different areas [29]. Among Chinese, globalization and economic progress has increased much throughout the recent years, and the burdens of obesity and diabetes has taken its toll on public health. Geographical location, economic development and lifestyle patterns play an important role in the prevalence of diabetes and metabolic syndrome. Health promotion programs, such as weight reduction and physical activity, should be implemented for general population, and risk reduction on atherosclerotic burden will be helpful for public health.

Evidence for variation on metabolic syndrome criteria among ethnic Chinese was noted. First, various criteria of metabolic syndrome elicited differential sensitivity and specificity for incident diabetes among 627 high-risk adults in Beijing area [30]. There was heterogeneity for major components criteria: AACE had the highest sensitivity but lowest specificity, and EGIR had the lowest sensitivity but highest specificity for incident diabetes among ethnic Chinese. Second, Wang et al. demonstrated AACE-defined metabolic syndrome had the highest relative risk to predict incident diabetes in the 5-year follow-up period [31]. They found that WHO, EGIR, AACE, IDF and AHA criteria were not predictors of incident CHD events, partly due to missing important

components in these criteria. Our prospective cohort data demonstrated ATP III criteria had the significant predictor for CHD and stroke events [32]. Further investigation on the heterogeneity of various metabolic syndrome criteria is necessary.

The fact of differences in men and women in terms of metabolic syndrome criteria implied that gender difference on metabolic syndrome burdens. The phenomenon was complicated when age and metabolic syndrome components were considered. For example, IDF criteria did not match to other criteria in our study, and the results were compatible with Japanese population [33,34]. Furthermore, elder women were the highest prevalent rates, indicating that menopause might play an important factor for insulin resistance. Overall men had biological susceptibility for atherosclerosis, and the gender difference decreased among older groups [35]. We stratified the study participants into several sub-clusters, which had rather homogenous patterns. Among men, the patterns of sub-clusters were compatible with original grouping, i.e. major components or equal components. But women's pattern was rather complicated, with IDF criterion merged with Asian ATP criteria. Among 3508 adults in the French communities, increased body weight, waist circumference and low HDL cholesterol elicited more contribution for metabolic syndrome in women than in men. Men's blood pressures were significantly more important contributors than women's blood pressure [36]. The discrepancy of atherosclerotic risk factor between genders should be taken into consideration in clinical care and public health prevention programs. We found that higher percentage change in κ values for the IDF definition in the major component groups, but not when the 10 criteria are evaluated together. The reason was that the IDF definition requires the presence of central obesity, while the other major component definitions require hyperglycemia/insulin resistance. We hypothesize that the difference in waist circumference cut-off point is responsible for the lack of consistency among the Chinese population. From the routine health examination data, the proposed cut-off 85 cm in men and 80 cm in women for waist circumference criteria were proposed for diagnosis of metabolic syndrome among Japanese population, which had the optimal predictive ability for other risk factors [37].

We investigated different influences of BMI or waist circumference component for obesity criteria. General obesity indicated by high BMI values, were strongly associated with risky cardiovascular biomarkers in western countries [35]. Also, BMI was proven as good criteria for screening Japanese population for metabolic syndrome [33], and the national survey data in Taiwan has demonstrated a significant relationship between BMI and waist circumference [38]. In general survey in adult Taiwanese, general obesity was as important as central obesity for ischemic stroke [39]. We considered that BMI, as a general obesity marker, was still important for cardiovascular disease risk.

The limitations of this study are as follows: First, the recruitment strategy of the study population was from health

examination program from one tertiary hospital, and the participants had a higher socioeconomic status than the general community population. The socioeconomic levels of our study samples were high, with 74% above a college education and 71% with business or other official work. The extrapolation of the results to the general population should be taken into careful consideration. Second, the κ statistics, dendrograms and cluster analysis did not provide formal test statistics for significant hypothesis testing. Therefore, the study results should be considered as exploratory and hypothesis generating, not hypothesis testing. Also, the κ statistics treats all criteria symmetrically, and it might not be applicable when one or more of these criteria are viewed as a standard.

In conclusion, there was substantial agreement and grouping of metabolic syndrome models among the ethnic Chinese population. Prospective studies should be planned to investigate the impact on cardiovascular disease incidence.

Acknowledgments

We thank the cardiologists at National Taiwan University Hospital for their assistance in this study. This study was supported by grants from the National Science Council (NSC 93-2314-B-002-218, NSC 94-2314-B-002-290) in Taiwan.

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