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An evaluation of the International Diabetes Federation definition of metabolic syndrome in Chinese patients older than 30 years and diagnosed with type 2 diabetes mellitus

Bin Lu[a,b], Yehong Yang[a,b], Xiaoyan Song[a,b], Xuehong Dong[a,b], Zhaoyun Zhang[a,b], Linuo Zhou[a,b], Yiming Li[a,b], Naiqing Zhao[c], XiXing Zhu[a,b], Renming Hu[a,b,*]

[a]*Department of Endocrinology and Metabolism, HuaShan Hospital, Shanghai 200040, China*
[b]*Institute of Endocrinology and Diabetology at Fudan University, Shanghai 200032, China*
[c]*Department of Public Health Statistics, Fudan University, Shanghai 200032, China*

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Abstract

The objective of the study was to determine the most accurate metabolic syndrome (MS) definition among the definitions proposed by the International Diabetes Federation (IDF), the Third Report of the National Cholesterol Education Program Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III [ATPIII]), and the World Health Organization (WHO) and to evaluate the cutoff point of waist circumference using the IDF definition for optimally defining MS in the Chinese population. One thousand thirty-nine Chinese patients older than 30 years and diagnosed with type 2 diabetes mellitus were investigated by randomized cluster sampling in the Shanghai downtown, and 1008 patients were analyzed in this study. Body mass measurements, resting blood pressure, fasting blood measures, and carotid atherosclerotic measurements including common carotid artery intima-media thickness (IMT) and carotid plaque were investigated. The IDF definition was compared with the other 2 definitions, and the carotid atherosclerosis was evaluated among the patients according to these definitions. (1) The MS prevalence was 50.0%, 55.7%, and 70.0% under the IDF, ATPIII, and WHO definitions, respectively. (2) The percentage of all the participants categorized as either having or not having the MS was 69.9% (under the IDF and ATPIII definitions) and 70.2% (under the IDF and WHO definitions). (3) Common carotid artery IMT of patients with MS determined by the IDF definition was thicker than those determined by the WHO and ATPIII definitions, and the percentage of carotid plaque of patients with MS determined by the IDF definition was greater than those determined by the WHO and ATPIII definitions. (4) When the cutoff point of waist circumference in men determined by the IDF definition was modified from 90 to 85 cm, common carotid artery IMT of the emerging male patients with MS was thicker than that of the male patients with MS determined by the original IDF definition. In conclusion, the prevalence of MS was 50.0%, 55.7%, and 70.0% under the IDF, ATPIII, and WHO definitions, respectively. The preferable IDF definition served as a better predictor of cardiovascular disease risk in the Chinese patients diagnosed with type 2 diabetes mellitus compared with the ATPIII and WHO definitions. The modified cutoff point of waist circumference in men under the IDF definition specific for the Chinese population (from 90 to 85 cm) might be more suitable for predicting atherosclerosis.

1. Introduction

Metabolic syndrome (MS) is a cluster of dangerous myocardial infarction risk factors: diabetes and impaired glucose regulation, central obesity, hypertension, and dyslipidemia. People with MS are at an increased risk for cardiovascular disease and for increased mortality [1-4].

Although clustering of some metabolic abnormalities was recognized as early as 1923, the coining of the term *syndrome X* in 1988 by Reaven [5] renewed the impetus to conducting research in this syndrome. As an understanding of the dimensions of this syndrome is critical for allocating both health care and research resources, the World Health Organization (WHO) initially proposed a definition for MS in 1998 [6] and, more recently, the Third Report of the National Cholesterol Education Program Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III [ATPIII])

* Corresponding author. Department of Endocrinology and Metabolism, HuaShan Hospital, Shanghai 200040, China.
E-mail address: renminghu@fudan.edu.cn (R. Hu).

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provided a working definition of MS [7]. However, no standard definition has been routinely used, and a universally accepted definition of MS is needed, which has been demonstrated in many studies [8,9]. In 2005, the International Diabetes Federation (IDF) published a new worldwide definition of MS intended to be applicable to various ethnic groups [10]. The new definition is similar to the ATPIII definition, but has significant difference. Notably, central obesity (defined by waist circumference with ethnic modification in its thresholds) was treated as a prerequisite risk factor for the diagnosis of the syndrome in the new definition. Lately, additional analysis from a Japan Diabetes Complications Study has shown that the new worldwide IDF definition of MS is not a better diagnostic predictor of cardiovascular disease in the Japanese diabetic patients than the existing definitions, and the new definition's lower prediction power for cardiovascular disease seemed to have been derived from the indispensability of the waist circumference component [11].

Therefore, we set out to accomplish several goals in this study. Firstly, we calculated the estimates of the prevalence of MS by applying the ATPIII, WHO, and new IDF definitions in the Chinese patients diagnosed with type 2 diabetes mellitus. Secondly, we compared the new international definition with the previous ones and evaluated the predictive power for cardiovascular disease of these definitions to determine the most accurate MS definition in the Chinese patients diagnosed with type 2 diabetes mellitus. Thirdly, we evaluated the cutoff point of waist circumference using the new definition because MS diagnosis by the new definition was highly dependent on waist circumference.

As a cross-sectional study, our study was unable to evaluate cardiovascular events prospectively, so we adopted surrogate markers for atherosclerotic cardiovascular disease. Measurement of the intima-media thickness (IMT) of carotid artery by ultrasonography is a noninvasive and quantitative method of evaluating early atherosclerotic changes in the vasculature [12-14]. Carotid artery IMT is an established risk factor and a surrogate marker for atherosclerotic cardiovascular disease [15], and an increase in carotid artery IMT is associated with an increased risk of myocardial infarction and stroke even in the absence of obstructive luminal disease of carotid arteries [16-19]. Carotid plaque is also a marker of atherosclerotic change [20].

2. Study design and methods

2.1. Study design

A cross-sectional study to evaluate the prevalence of diabetic complications in the Chinese patients older than 30 years and diagnosed with type 2 diabetes mellitus was planned in the Shanghai downtown. We selected our subjects by randomized cluster sampling. According to estimated diabetic nephropathy prevalence of 33% in China [21,22], an admissible error of 0.03 (about 10% prevalence of diabetic nephropathy), and for a precision of 0.05, a sample of 944 patients was estimated ($n = 1.96^2 \times 33 \times 67/3^2 = 944$). Twenty residential areas administered by 20 resident committees were sampled randomly in the downtown of Shanghai because about 60 diagnosed diabetic patients lived in a residential area administered by a resident committee.

Questionnaires were sent to every household in the 20 residential areas and were collected by primary care clinicians and endocrinologists to identify the history of diabetes. One thousand one hundred twenty Chinese patients diagnosed with type 2 diabetes mellitus were identified by the questionnaires. Finally, 1039 (92.7%) Chinese patients diagnosed with type 2 diabetes mellitus were included in our study. All the patients had signed informed consent and were recruited consecutively from February 1 to July 31, 2004. A panel of investigators was composed of 10 general practitioners and 12 endocrinologists.

Additional analysis of the new MS definition based on the diabetic complications study was completed.

2.2. Measurement

The body height and weight of the subjects, wearing light clothing and without their shoes on, were measured on a health scale (Horse Head TS120, Shanghai, China). The body mass index was calculated as the weight in kilograms divided by the square of height in meters. Trained endocrinologists measured waist circumference at the umbilical level in the late exhalation phase while the subjects are standing using a calibrated plastic tape measure to the nearest 0.1 cm. Trained endocrinologists measured hip circumference at the point where the buttocks extended the maximum using a calibrated plastic tape measure to the nearest 0.1 cm. Waist-to-hip ratio was calculated from waist circumference divided by hip circumference. Three readings of systolic and diastolic blood pressures of the patients were obtained, and the average of the last 2 measurements was used.

2.3. Laboratory assays

The patients who lived in the same residential area went to a vicinal community hospital collectively on a visit day for tests, and fasting blood samples of these patients were obtained. Fasting plasma glucose concentration was estimated by glucose oxidase method (GOX0560, Shanghai Jingyuan Medical Appliances, China) on an analyzer (Hitachi 7600-020, Hitachi High-Technologies Corp, Shanghai, China). Fasting serum insulin concentration was estimated by radioimmunoassay (DSL-1600, Diagnostic Systems Laboratories, Texas). Homeostasis model assessment of insulin resistance index (HOMA-IR) was calculated from fasting plasma glucose and insulin with the formula: HOMA-IR = fasting insulin (μU/mL) $\times$ fasting plasma glucose (mmol/L)/22.5 [23]. Serum cholesterol (CHOD-PAP method, CHO0560, Shanghai Jingyuan Medical Appliances,

Table 1
The definitions of all the components of MS defined by the IDF, ATPIII, and WHO

	MS definitions		
	IDF	ATPIII	WHO
Waist circumference	Chinese men: ≥90 cm Chinese women: ≥80cm	Men: >102 cm Women: >88 cm	Men WHR: >0.9 Women WHR: >0.85
BMI			>30 kg/m^2
Triglyceride	>1.7 mmol/L or treatment of hypertriglyceridemia	≥1.7 mmol/L	≥1.7 mmol/L
HDL-C	Men: <0.9 mmol/L; women: <1.1 mmol/L or treatment of low HDL cholesterol	Men: <1.04 mmol/L; women: <1.30 mmol/L	Men: <0.9 mmol/L; women: <1.0 mmol/L
Blood pressure	≥130/85 mm Hg or treatment of hypertension	≥130/85 mm Hg	≥140/90 mm Hg
Glucose	Fasting plasma glucose ≥5.6 mmol/L or diagnosed with type 2 diabetes mellitus	Fasting plasma glucose of ≥6.1 mmol/L	Type 2 diabetes mellitus
Urinary albumin-creatinine ratio			≥30 mg/g

BMI indicates body mass index.

Shanghai, China), serum triglycerides (GPO-PAP method, TGP0560, Shanghai Jingyuan Medical Appliances), high-density lipoprotein (IRC method, 21200AMZ00404000, Daiichi Pure Chemicals, Shanghai, China), and low-density lipoprotein (CAT method, 20900AMZ00550000, Daiichi Pure Chemicals) of all the patients were estimated on an analyzer (Hitachi 7600-020). Serum creatinine and urinary creatinine (Sarcosine Oxidase-PAP method, S708, Shanghai Kehua Dongling Diagnostic Products, Shanghai, China) were measured on an analyzer (Hitachi 7600-020). Glycated hemoglobin was estimated by high-pressure liquid chromatography using a machine (HLC-723G7, Tosoh, Shanghai, China). First morning urine sample was collected 3 times in a period of 3 months and urinary albumin measured by radioimmunoassay (Beijing Atom High-Tech, Beijing, China). Urinary albumin-creatinine ratio was calculated from urinary albumin divided by urinary creatinine. Of 3 urinary albumin-creatinine ratios collected in a period of 3 months (≥30 mg/g), 2 were categorized as albuminuria according to the screening protocol proposed by the American Diabetes Association [24].

2.4. Ultrasonography and image analysis

Carotid ultrasonography was performed using a machine (Acuson Sequoia 512, Acuson). The criteria used to select this machine included the following: accurate delineation of near and far wall boundaries; accurate plaque detection; simultaneous color Doppler; and detection and quantification of early subintimal change. Trained and certified sonographers conducted the studies. Ultrasound scanning protocol in our study was modified in terms of procedures used in previous studies [25-28].

A lateral view of bilateral images of common carotid arteries (1 cm proximal to the dilatation of the carotid bulb), carotid bulb (identified by the loss of the parallel wall present in the common carotid artery), and internal carotid artery (1 cm distal to the tip of the flow divider that separates the external and internal carotid arteries) were obtained. Sonographers recorded the images and completed ultrasound readings.

Intima-media thickness is the distance between the lumen-intima interface and the media-adventitia interface [29,30]. Common carotid artery IMT was defined as the mean of the maximum IMT in both right and left sides of common carotid artery. The plaque of carotid artery (common carotid artery, carotid bulb, and internal carotid artery) is defined as a localized protrusion of the internal part of the vessel wall into the lumen of 50% of the surrounding IMT value [31,32].

2.5. Metabolic syndrome definitions

Table 1 shows the definitions of all the components of MS according to the IDF, ATPIII, and WHO.

2.5.1. New IDF definition

A patient with MS should have central obesity (defined as waist circumference of ≥90 cm for Chinese men and ≥80 cm for Chinese women) plus any of 2 of the following 4 components:

1. Raised triglyceride level: more than 1.7 mmol/L, or specific treatment of this lipid abnormality.
2. Reduced high-density lipoprotein: less than 0.9 mmol/L in men and less than 1.1 mmol/L in women, or specific treatment of this lipid abnormality.
3. Raised blood pressure: systolic blood pressure ≥130 or diastolic blood pressure ≥85 mm Hg, or treatment of previously diagnosed hypertension.
4. Raised fasting plasma glucose: 100 mg/dL or higher (5.6 mmol/L), or previously diagnosed type 2 diabetes mellitus.

2.5.2. Adult Treatment Panel III definition

A patient with MS should have 3 or more of the following components:

1. Central obesity: waist circumference or more than 102 cm in men and more than 88 cm in women.
2. Hypertriglyceridemia: 1.7 mmol/L or higher.
3. Low high-density lipoprotein: less than 1.04 mmol/L in males and less than 1.30 mmol/L in females.
4. High blood pressure: 130/85 mm Hg or higher.
5. Raised fasting glucose of 110 mg/dL or higher (6.1 mmol/L).

Table 2
Clinical characteristics of men and women

Variables	Men (n = 389)	Women (n = 619)	*P*
General information			
Age (y)	65.68 ± 12.13	66.47 ± 11.15	.291
Duration (y)	7.81 ± 7.76	7.99 ± 6.78	.703
Body mass measurements			
Waist circumference (cm)	86.84 ± 9.12	83.27 ± 9.23	<.01*
BMI (kg/m^2)	24.56 ± 2.99	25.14 ± 3.60	<.01*
WHR	0.90 ± 0.07	0.86 ± 0.07	<.01*
Blood pressure (mm Hg)			
Systolic blood pressure	138.66 ± 20.41	140.62 ± 20.69	.141
Diastolic blood pressure	82.52 ± 11.06	81.63 ± 11.10	.213
Fasting blood measures			
High-density lipoprotein (mmol/L)	1.22 ± 0.34	1.38 ± 0.38	<.01*
Triglyceride	1.81 ± 1.26	1.94 ± 1.30	.105
Low-density lipoprotein (mmol/L)	2.94 ± 0.78	3.12 ± 0.91	<.01*
Cholesterol (mmol/L)	5.10 ± 1.03	5.52 ± 1.16	<.01*
Fasting plasma glucose (mmol/L)	8.87 ± 3.43	8.70 ± 3.09	.44
HbA_{1c} (%)	7.35 ± 1.74	7.15 ± 1.58	.068
Urea nitrogen (mmol/L)	6.51 ± 1.91	5.99 ± 1.58	<.01*
Creatinine (μmol/L)	80.30 ± 24.27	60.95 ± 15.62	<.01*
Atherosclerotic measurements			
Common carotid artery IMT (mm)	0.98 ± 0.44	0.92 ± 0.39	0.03*
Plaque of carotid artery	63.8%	63.8%	1.00

HbA_{1c} indicates glycated hemoglobin.
* $P < .05$, significantly different between men and women.

2.5.3. World Health Organization definition

A patient with MS should have type 2 diabetes mellitus or IGT plus 2 or more of the following components:

1. Central obesity: body mass index of more than 30 nbsp;kg/m^2 or waist-to-hip ratio of more than 0.9 for males and more than 0.85 females.
2. Dyslipidemia: raised triglyceride level of 1.7 mmol/L or higher, and/or reduced high-density lipoprotein of less than 0.9 mmol/L in males and less than 1.0 nbsp;mmol/L in females.
3. High blood pressure: systolic blood pressure of $\geq$140 or diastolic blood pressure of $\geq$90 mm Hg.

Table 3
Clinical characteristics of patients with MS defined by the IDF, ATPIII, and WHO

Variables	MS-IDF (n = 504)	MS-ATPIII (n = 561)	MS-WHO (n = 706)	*P*
General information				
Age (y)	67.67 ± 11.27	66.80 ± 10.99	67.50 ± 10.86	.373
Duration (y)	7.83 ± 6.87	7.67 ± 6.89	8.29 ± 7.30	.272
Body mass measurements				
Waist circumference (cm)	90.65 ± 7.12*	87.81 ± 9.07	86.75 ± 8.91	<.01
BMI (kg/m^2)	26.60 ± 3.22*	25.85 ± 3.39†	25.50 ± 3.40	<.01
Waist-to-hip ratio	0.90 ± 0.06	0.89 ± 0.07	0.89 ± 0.06	.061
Blood pressure (mm Hg)				
Systolic blood pressure	144.95 ± 18.18	144.12 ± 18.59	146.19 ± 18.43	.129
Diastolic blood pressure	83.47 ± 10.39	83.81 ± 10.61	84.22 ± 10.82	.476
Fasting blood measures				
High-density lipoprotein (mmol/L)	1.27 ± 0.34	1.16 ± 0.28†	1.28 ± 0.37	<.01
Triglyceride	2.13 ± 1.39	2.45 ± 1.43†	2.14 ± 1.38	<.01
Low-density lipoprotein (mmol/L)	3.12 ± 0.90	3.10 ± 0.95	3.08 ± 0.92	.839
Cholesterol	5.45 ± 1.16	5.42 ± 1.21	5.44 ± 1.19	.918
Fasting plasma glucose (mmol/L)	8.78 ± 2.89	8.98 ± 3.13	9.01 ± 3.23	.389
HbA_{1c} (%)	7.25 ± 1.48	7.27 ± 1.55	7.35 ± 1.62	.469
Urea nitrogen (mmol/L)	6.11 ± 1.63	6.11 ± 1.73	6.25 ± 1.78	.25
Creatinine (μmol/L)	67.35 ± 19.37	68.48 ± 21.68	69.24 ± 23.11	.326
HOMA-IR (mean)	4.89	4.91	4.68	.462
Atherosclerotic measurements				
Common carotid artery IMT (mm)	1.04 ± 0.50*	0.96 ± 0.41	0.99 ± 0.45	<.01
Plaque of carotid artery	74.8%*	59.6%	62.7%	<.01

* $P < .05$, significantly different from patients with MS determined by the ATPIII and WHO definitions.
† $P < .05$, significantly different from patients with MS determined by the IDF and WHO definitions.

Table 4
Prevalence of MS and its components

Variables	Men (%)	Women (%)	Total (%)
Body mass measurements			
Waist circumference (men, ≥90 cm; women, ≥80 cm)	38.6	64.9	54.8
Waist circumference(men >102cm, women >88cm)	4.1	30.2	20.1
Body mass index >30 kg/m^2	3.9	8.6	6.7
Waist-to-hip ratio (male, >0.9; female, >0.85)	46.5	55.7	52.2
Body mass index >30 kg/m^2 or waist-to-hip ratio (male, >0.9; female, >0.85)	48.1	61.1	56.1
Resting blood pressure			
Systolic blood pressure ≥140 mm Hg or diastolic blood pressure ≥90 mm Hg	60.4	60.7	60.6
Systolic blood pressure ≥130 mm Hg or diastolic blood pressure ≥85 mm Hg	75.8	76.9	76.5
Blood lipid measures			
Low levels of high-density lipoprotein (men, <0.9 mmol/L; women, <1.1 mmol /L)	10.0	17.8	14.8
Low levels of high-density lipoprotein (men, <1.04 mmol/L; women, <1.30 mmol/L)	36.5	41.2	39.4
Triglyceride >1.7 mmol/L	38.6	46.5	43.5
Triglyceride ≥1.7 mmol/L	39.6	46.8	44.0
Triglyceride ≥1.7 mmol/L or low levels of high-density lipoprotein (men, <0.9 mmol/L; women, <1.0 mmol/L)	41.9	48.1	45.7
Albuminuria	46.5	51.5	49.6
MS			
IDF definition	35.2	59.3	50.0
ATPIII definition	47.0	61.1	55.7
WHO definition	65.8	72.7	70.0

4. Urinary albumin of ≥20 μg/min or urinary albumin creatinine ratio of ≥30 mg/g.

2.6. Statistical analysis

All statistical analysis was performed using SPSS 11.0 software (SPSS, Chicago, IL). We calculated the prevalence of MS according to the 3 definitions. The χ^2 test and 1-way analysis of variance were respectively used to study the association of MS with both qualitative and quantitative variables. Data were presented as mean ± SD or percentage.

3. Results

A final sample of 1039 patients was investigated. A total of 1008 patients including 389 male patients and 619 female patients were analyzed in an additional analysis of diabetic complications study based on data integrity. The mean age of these 1008 patients was 66.17 ± 11.54 years and the duration of diabetes was 7.92 ± 7.17 years.

3.1. Prevalence of MS

Table 2 shows the clinical characteristics of the male and female patients. The male patients had greater waist circumference, waist-to-hip ratio, serum urea nitrogen, and serum creatinine, and the female patients had greater body mass index, high-density lipoprotein, low-density lipoprotein, and serum cholesterol. No significant difference was revealed in blood pressure and plasma glucose between men and women. As shown in Table 3, we compared the clinical data in patients with MS according to the new IDF, ATPIII, and WHO definitions. Our results indicated that patients with MS determined by the IDF definition had greater waist circumference and body mass index and patients with MS determined by the ATPIII definition had higher triglyceride and lower high-density lipoprotein levels.

Table 4 shows the prevalence of MS and its components. Of the diabetic patients, 50.0%, 55.7%, and 70.0% were categorized as having MS using the IDF, ATPIII, and WHO definitions. The prevalence of MS in women was much higher than that in men under all 3 definitions ($P < .01$). The low prevalence of central obesity as defined by ATPIII was largely caused by the fact that only 4.1% of men had waist circumference of more than 102 cm and 30.2% of the women had waist circumference of more than 88 cm. As a component of MS according to the WHO definition, albuminuria was present in 49.6% of the study population.

3.2. Concordance between the new IDF definition and the other 2 definitions

As described in Table 5, the agreement rate, in other words, the percentage of the participants categorized as

Table 5
Agreement between IDF definition and the other 2 definitions

	IDF	ATPIII	Agreement[a]	IDF = yes, ATPIII = no	ATPIII = yes, IDF = no
Men	35.2 ± 2.4	47.0 ± 2.5	67.1 ± 2.4	10.5 ± 1.6	22.4 ± 2.1
Women	59.3 ± 2.0	61.1 ± 2.0	71.7 ± 1.8	13.2 ± 1.4	15.0 ± 1.4
Total	50.0 ± 1.6	55.7 ± 1.6	69.9 ± 1.4	12.2 ± 1.0	17.9 ± 1.2
	IDF	WHO	Agreement	IDF = yes, WHO = no	WHO = yes, IDF = no
Men	35.2 ± 2.4	65.8 ± 2.4	63.8 ± 2.4	2.8 ± 0.8	33.4 ± 2.4
Women	59.3 ± 2.0	72.7 ± 1.8	74.3 ± 1.8	6.1 ± 1.0	19.5 ± 1.6
Total	50.0 ± 1.6	70.0 ± 1.4	70.2 ± 1.4	4.9 ± 0.7	24.9 ± 1.4

Data are expressed as percentage ± SE.
[a] Percentage of participants who were classified as either having or not having the MS under both definitions.

Table 6
Atherosclerotic measurements between patients with MS and those without

Variables	MS	Non-MS	P
IDF			
Common carotid artery IMT (mm)	1.04 ± 0.50*	0.87 ± 0.32	<.01†
Plaque of carotid artery	74.80%*	32.40%	<.01†
WHO			
Common carotid artery IMT (mm)	0.99 ± 0.45	0.87 ± 0.40	<.01†
Plaque of carotid artery	62.70%	32.30%	<.01†
ATPIII			
Common carotid artery IMT (mm)	0.96 ± 0.41	0.87 ± 0.45	<.01†
Plaque of carotid artery	59.60%	46.00%	<.01†

* $P < .05$, significantly different between patients with MS determined by the IDF definition and patients with MS determined by the ATPIII and WHO definitions.

† $P < .05$, significantly different between patients with MS and those without.

either having or not having MS under IDF and ATPIII definitions, was 69.9%. One hundred twenty-three patients (12.2%) had MS under the IDF definition but not under the ATPIII definition, and 180 patients (17.9%) had MS under the ATPIII definition but not under the IDF definition. All 123 patients only had waist circumference of ≤102 cm (male) and 88 cm (female) under the IDF definition but not the ATPIII definition.

The agreement rate under the IDF and WHO definitions was 70.2%. Forty-nine patients (4.9%) had MS under the IDF definition but not under the WHO definition, and 251 patients (24.9%) had MS under the WHO definition but not under the new IDF definition. Among 251 patients diagnosed as having MS only under the WHO definition but not under the IDF definition, 247 patients (98.4%) had waist circumference of less than 90 cm (male) and less than 80 cm (female).

3.3. Predictive power of the new IDF definition for cardiovascular disease

Carotid plaque was significantly correlated with common carotid artery IMT by Spearman correlation (correlation coefficient, 0.280; $P < .01$). As shown in (Tables 2, 3, and 6), common carotid artery IMT of the male patients was thicker than that of the female patients, but no similar result in the percentage of carotid plaque was obtained.

As shown in (Tables 2, 3, and 6), common carotid artery IMT of patients with MS was thicker than that of patients without MS under all 3 MS definitions, and the percentage of carotid plaque of patients with MS was higher than that of patients without MS determined by all 3 MS definitions. However, common carotid artery IMT of patients with MS determined by the IDF definition was thicker than those determined by the WHO and ATPIII definitions (1.04 vs 0.99 mm and 1.04 vs 0.96 mm, respectively; $P < .01$). The percentage of carotid plaque of patients with MS determined by IDF definition was higher than that determined by the WHO and ATPIII definitions (74.8% vs 62.7% and 74.8% vs 59.6%, respectively; $P < .01$).

3.4. Evaluation of the cutoff point of waist circumference determined by the new IDF definition

There was a disparity between the cutoff point of waist circumference in the Chinese population and that in the Japanese population determined by the new IDF definition.

The cutoff point of waist circumference (male, ≥85 cm; female, ≥90 cm) specific for the Japanese population was recommended by the IDF definition, so we evaluated whether this cutoff point of waist circumference (male, ≥85 cm; female, ≥90 cm) served as a better predictor of cardiovascular disease risk in the Chinese patients diagnosed with type 2 diabetes mellitus.

When the cutoff point of waist circumference in men was modified from 90 to 85 cm according to the IDF definition, the prevalence of MS reached up to 55.3% from 35.2% in men and 78 new patients with MS emerged. Common carotid artery IMT of the emerging male patients with MS was thicker than that determined by the original IDF definition (1.14 ± 0.49 vs 1.07 ± 0.40 mm, $P < .01$), and the percentage of carotid plaque of the emerging male patients with MS was a little higher than that of the male patients with MS determined by the original IDF definition (80.4% vs 72.8%, $P < .05$).

When the cutoff point of waist circumference in women was modified from 80 to 90 cm according to the IDF definition, the prevalence of MS decreased from 59.3% to 24.2% and 217 patients with MS determined by the original IDF definition were diagnosed as patients without MS using the modified IDF definition. The patients with MS who had disappeared were the patients diagnosed as having MS by the original IDF definition but categorized as without MS by the modified IDF definition. Common carotid artery IMT of the patients with MS who had disappeared was similar to that of the female patients with MS determined by the original IDF definition (1.01 ± 0.28 vs 1.02 ± 0.27 mm, $P > .05$), and the percentage of carotid plaque of the female patients with MS who had disappeared was similar to that of the female patients with MS determined by the original IDF definition (74.3% vs 75.5%, $P > .05$).

4. Discussion

The prevalence of MS keeps increasing in diabetic patients. The Botnia study in Finland showed that the prevalence of MS under the WHO definition in men and women was 78% and 84% in type 2 diabetic patients [33]. Another study in Europe [34] revealed that the prevalence of the MS in a population-based cohort of type 2 diabetic patients was 75.6%. However, in African diabetic patients, 2 studies indicated that the prevalence of MS was 43% [35] and 25.2% [36], respectively. Our results showed that the prevalence of MS among type 2 diabetic patients was 50.0%, 55.7%, and 70.0% according to the IDF, ATPIII, and WHO definitions, respectively. Our data indicated that

the prevalence of MS in the Chinese patients diagnosed with type 2 diabetes mellitus was much lower than that in Europe, but higher than that in Africa. The disparity of MS prevalence might be because of the study design, sample selection, the year when the study was conducted, the precise definition of the MS used, dietary habits, nutritional status, and the age and sex structure of the population itself except for ethnics.

The identical components (central obesity, blood pressure, triglyceride, and high-density lipoprotein) were used to determine MS in the new IDF and ATPIII definitions among these diabetic patients. The cutoff points of blood pressure, triglyceride, and high-density lipoprotein were similar in the 2 MS definitions, so that central obesity was the key component of inducing disparity in diagnosing MS by the new IDF and ATPIII definitions. As shown in our study, the prevalence of central obesity in the male Chinese patients older than 30 years and diagnosed with type 2 diabetes mellitus defined by ATPIII was only 4.1%, even far lower than that in the male American population without diabetes (31.0% in whites, 32.8% in non-Hispanic whites, and 31.2% in Mexican Americans) defined by ATPIII [37]. As shown in Table 4, the prevalence of body mass index of 30 kg/m^2 (3.9%) or more in men was similar to that of waist circumference of more than 102 cm defined by the ATPIII (4.1%). However, WHO (regional office for the Western Pacific) had recommended the cutoff point for obesity (body mass index, $\geq$25 kg/m^2) based on risk factors and morbidities in the Asian population [38], and the prevalence of body mass index of 25 kg/m^2 or more was 41.9% in male patients, far higher than 4.1%. So, the cutoff point of waist circumference determined by the ATPIII definition might not be suitable for the Chinese population. Our results indicated the higher prevalence of MS determined by the ATPIII definition than by the new IDF definition, and it might be due to central obesity not as a mandatory component of MS in ATPIII definition.

The agreement between the WHO and IDF definitions was only 63.8% as shown in our study. Our results demonstrated that 98.4% of these patients diagnosed with MS only under the WHO definition but not the IDF definition had waist circumference of less than 90 cm in men and less than 80 cm in women. Therefore, the different definitions of central obesity proposed by the IDF and WHO definitions might be a considerable cause of the low concordance in the diagnosis of MS determined by the IDF and WHO definitions.

Compared with the ATPIII and WHO definitions, the new IDF definition might be suitable for the diagnosis of MS in the Chinese population. Firstly, mounting evidence has revealed that central obesity is a major risk factor for type 2 diabetes mellitus and cardiovascular disease [39]. Obesity is associated with all the risk factors of MS [40], and ongoing research [41] has revealed several possible connections that seem to have been mediated by products released by adipose tissue. Central obesity as a prerequisite risk factor of MS determined by the IDF definition might be rational. The core of MS definition should shift from hyperglycemia to obesity. Secondly, central obesity is determined by waist circumference in the IDF definition. Many data show that waist circumference is more predictive of cardiovascular disease risk than body mass index in the Western populations [42,43], and a recent study has shown that waist circumference also adds additional risk information to that of body mass index in the Chinese adults [44]. Thirdly, the IDF definition is also simple for practice. Finally, better predictive power for cardiovascular disease of the new IDF definition has also been revealed in our study.

The cutoff point of waist circumference in the Chinese population (90 and 80 cm in males and females, respectively) is determined by IDF definition. Pan [45] agreed with the waist circumference criteria by comparing the age-standardized prevalence of MS among 2500 Taiwanese adults (during 1993-1996) with Americans of African or white origin (during 1988-1994). However, our study has revealed that the cutoff point of waist circumference determined by the IDF definition specific for the Chinese population might not serve as the best predictor of cardiovascular disease risk by evaluating common carotid artery IMT and carotid plaque. Our results have indicated waist circumference ($\geq$85 cm in males and $\geq$80 cm in females) might be more suitable for predicting atherosclerosis in the Chinese population. Whether the modified IDF definition could predict atherosclerosis optimally needs further prospective study.

In conclusion, the prevalence of MS in the Chinese patients diagnosed with type 2 diabetes mellitus is lower than that in Europe, but higher than that in Africa. Furthermore, the disparity of the definitions of central obesity is a considerable cause of the low concordance in the diagnosis of MS. However, the preferable IDF definition served as a better predictor of cardiovascular disease risk in the Chinese patients diagnosed with type 2 diabetes mellitus compared with the ATPIII and WHO definitions. We suggest the modified cutoff point of waist circumference in men determined by the IDF definition specific for the Chinese population (from 90 to 85 cm) might be more suitable for predicting atherosclerosis.

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