RESEARCH ARTICLE

Prevalence of metabolic syndrome using WHO, ATPIII and IDF definitions in Asian Indians: The Chennai Urban Rural Epidemiology Study (CURES-34)

M. Deepa[1]
S. Farooq[1]
M. Datta[2]
R. Deepa[1]
V. Mohan[1]*

[1]*Madras Diabetes Research Foundation, Gopalapuram, Chennai, India*

[2]*Department of Epidemiology, The Tamil Nadu Dr M.G.R. Medical University, Chennai, India*

*Correspondence to: Dr V. Mohan, Chairman & Chief of Diabetology, Dr Mohan's Diabetes Specialities Centre & Madras Diabetes Research Foundation, 4, Conran Smith Road, Gopalapuram, Chennai-600 086, India. E-mail: mvdsc@vsnl.com

Abstract

Aim   To compare the prevalence of metabolic syndrome (MS) using the World Health Organisation (WHO), Adult Treatment Panel III (ATPIII) and International Diabetes Federation (IDF) criteria of MS in an urban south Indian population, and their ability to identify coronary artery disease (CAD) in males and females.

Methods   Chennai Urban Rural Epidemiology Study (CURES) is one of the largest epidemiological studies on diabetes carried out in India, in which 26 001 individuals aged ≥20 years were screened using systematic random sampling method. Every tenth subject recruited in Phase 1 of CURES was requested to participate in Phase 3, and the response rate was 90.4%. An oral glucose tolerance test (OGTT) was performed in all individuals except self-reported diabetic subjects. Anthropometric measurements and lipid estimations were done in all subjects and the prevalence of MS estimated using the three criteria. Diagnosis of CAD, made by resting 12 lead ECG, was compared by the three criteria of MS.

Results   MS was identified in 546 subjects (23.2%) by WHO criteria, 430 subjects (18.3%) by ATPIII criteria and 607 subjects (25.8%) by IDF criteria. Only 224 of these subjects were identified by all the three criteria. There was an increased risk of probable CAD in MS subjects diagnosed by WHO criteria (odds ratio (OR) 3.86, 95% Confidence Interval (CI), 2.37–6.29, $p < 0.001$), compared to ATPIII criteria (OR 2.19, 95% CI 1.30–3.67, $p < 0.05$) and IDF criteria (OR 1.90, 95% CI 1.16–3.12, $p < 0.05$). The WHO criteria marked out a much higher population for CAD risk compared to ATPIII and IDF criteria in males, but not in females.

Conclusion   In Asian Indians, the WHO, ATPIII and IDF criteria of MS identify different individuals. The WHO criteria identify a greater number of CAD subjects in males, but not in females. Copyright © 2006 John Wiley & Sons, Ltd.

Keywords   metabolic syndrome; Asian Indians; WHO criteria; ATPIII criteria; IDF criteria; coronary artery disease

Introduction

Metabolic syndrome (MS) refers to a clustering of metabolic risk factors including central obesity, glucose intolerance, hyperinsulinemia, low HDL

cholesterol, high triglycerides and hypertension [1]. People with MS are twice as likely to die from, and three times as likely to develop, myocardial infarction (MI) or stroke compared to people without MS [2]. They also have a five-fold greater risk of developing type 2 diabetes (if not already present) [3]. MS is increasingly being recognised as a risk factor for cardiovascular disease (CVD) [2] and cardiovascular mortality [4]. Unfortunately, there is no internationally agreed definition for MS and, hence, estimates of MS vary substantially across populations depending on the criteria used. The World Health Organisation (WHO) proposed a definition of MS in 1999 [5] and the National Cholesterol Education Program Expert Panel (NCEP) and Adult Treatment Panel III (ATPIII) published a working definition in 2001 [6]. Recently, the International Diabetes Federation (IDF) Consensus group has come out with another definition [7]. The aim of the present study is to compare the prevalence of MS in an urban South Indian population using the WHO, ATPIII and IDF definitions and their ability to identify coronary artery disease (CAD) in males and females. There are few reports on the prevalence of MS using all three definitions and none from India, which currently has the largest number of people in the world with diabetes [8].

Study design

The Chennai Urban Rural Epidemiology Study (CURES) is a large cross-sectional study done on a representative population of the metropolitan city of Chennai (formerly Madras) in southern India with a population of 4.3 million people. The detailed study design of CURES is described elsewhere [9] and the sampling frame is shown in our website http://www.mvdsc.org/mdrf/WORLD/pages/chennai.html. Briefly, of the 155 Corporation wards in Chennai, 46 wards were randomly selected to provide a total sample size of 26 001 individuals ≥20 years of age. The institutional ethical committee approval was obtained and informed consent was obtained from all study subjects.

Phase 1 of CURES was conducted in the field and involved a door-to-door survey of 26 001 individuals. A detailed questionnaire was administered to all study subjects to collect information regarding demographic, socio-economic, behavioural and health status. A fasting capillary blood sugar, blood pressure and basic anthropometric measures were done in all eligible individuals.

Phase 2 of CURES deals with studies on the prevalence of microvascular and macrovascular complications of diabetes. Phases 1 and 2 are not discussed further in this article.

In Phase 3 of CURES, every tenth subject recruited in Phase 1 ($n = 2600$) was invited to our centre for detailed anthropometric measurements and biochemical tests. Of these, 2350 participated in the study (response rate: 90.4%).

All the study subjects underwent an oral glucose tolerance test (OGTT) using a 75 g glucose load, except self-reported diabetic subjects for whom fasting venous plasma glucose (PG) was measured. The fasting blood sample was taken, after ensuring 8 h of overnight fasting, for estimation of PG and serum lipids using a Hitachi 912 Autoanalyser (Roche Diagnostics GmbH, Mannheim, Germany) utilising kits supplied by Boehringer Mannheim (Mannheim, Germany). Glycated hemoglobin (HbA_{1c}) was measured by the High-Pressure Liquid Chromatography (HPLC) method using the Variant machine (BIORAD, Hercules, California).

Anthropometric measurements including weight, height, waist and hip measurements were obtained using standardised techniques [9]. The blood pressure was recorded in the right upper limb in the sitting position, to the nearest 2 mmHg, using a mercury sphygmomanometer (Diamond Deluxe BP apparatus, Pune, India).

Definitions

Body mass index (**BMI**) was calculated using the formula: weight (Kg)/height (m)^2.

Waist circumference

The waist was measured using a non-stretchable fibre measuring tape. The subjects were asked to stand erect in a relaxed position with both feet together on a flat surface; one layer of clothing was accepted. Waist girth was measured as the smallest horizontal girth between the costal margins and the iliac crests at minimal respiration.

Hip circumference

Hip measure was taken as the greatest circumference at the level of greater trochanters (the widest portion of the hip) on both sides. Measurements were made to the nearest centimeter.

Waist and hip ratio (**WHR**) was calculated by dividing waist circumference (cm) by hip circumference (cm).

Blood pressure was recorded in the sitting position in the right arm, to the nearest 1 mmHg, using the mercury sphygmomanometer. Two readings were taken 5 min apart and mean of the two was taken as the blood pressure.

Diabetes

Diagnosis of diabetes was on the basis of the WHO Consulting group criteria, that is, 2 h post load PG (2 h PG) ≥11.1 mmol/L. Impaired glucose tolerance (IGT) was diagnosed if the 2 h PG was ≥7.8 mmol/L and <11.1 mmol/L and normal glucose tolerance (NGT) if 2 h PG was <7.8 mmol/L [10].

Coronary artery disease (CAD)

A resting 12-lead electrocardiogram (ECG) was carried out on 2199 subjects (response rate: 85%).

Possible CAD was diagnosed on the basis of a documented past history of MI or drug treatment for CAD and/or Minnesota codes 1-1-1 to 1-1-7 (Q-wave changes), 4-1 to 4-2 (ST segment depression) or 5-1 to 5-3 (T-wave abnormalities).

Probable CAD was diagnosed on the basis of documented history of MI or the presence of Q-waves on ECG.

Criteria for metabolic syndrome

The three criteria used for defining MS are shown in Table 1.

Insulin resistance for the WHO criteria was calculated using the homeostasis assessment (HOMA) model using the following formula: fasting insulin (μLU/mL) $\times$ fasting glucose (mmol/L)/22.5. Subjects whose HOMA insulin resistance values were above the 4th quartile for the non-diabetic population (i.e. >2.58) were considered to have insulin resistance (homeostasis assessment insulin resistance (HOMA-IR)).

Statistics

Statistical analyses were performed using SPSS for Windows version 10.0 software (SPSS Inc., Chicago, Illinois). t tests were used for continuous variable and chi-square test for proportions. Kappa (κ) statistics was used for finding the agreement between the three definitions. P-value <0.05 was considered significant.

Results

The mean age of the study population ($n = 2350$) was 40 ± 13 years and 47% ($n = 1096$) of the subjects were

males. Figure 1 shows that the prevalence and number of individuals with MS were 23.2% ($n = 546$), 18.3% ($n = 430$) and 25.8% ($n = 607$) according to the WHO, ATPIII and IDF definitions respectively. Only 224 subjects were identified to have MS by all three criteria. The prevalence of MS was higher in females by ATPIII criteria (males, 17.1%, females, 19.4%, $p = 0.149$) and IDF criteria (males, 23.1%, females, 28.2%, $p = 0.005$), but it was higher in males by WHO criteria (males, 27.3%, females, 19.7%, $p < 0.001$).

Table 2 shows that subjects having MS according to WHO criteria were older (47 ± 12 years; $p < 0.05$) and had significantly lower BMI ($p < 0.05$), waist ($p < 0.05$) and hip circumference ($p < 0.05$) compared to those with MS based on IDF and ATPIII criteria. Subjects with MS based on IDF criteria had significantly lower values of fasting PG ($p < 0.05$) and glycated haemoglobin ($p < 0.05$) compared to those with MS based on ATPIII and WHO criteria. Mean serum triglyceride levels
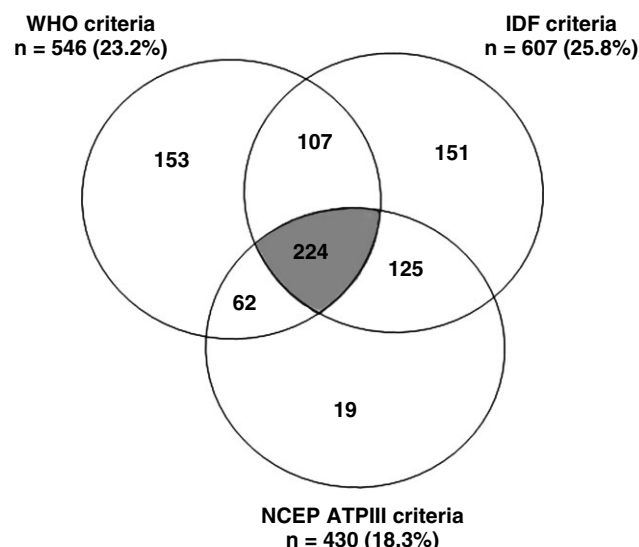

WHO criteria
n = 546 (23.2%)

IDF criteria
n = 607 (25.8%)

153 107 151

224 125

62

19

NCEP ATPIII criteria
n = 430 (18.3%)

Figure 1. Venn diagram showing the overlapping of subjects with metabolic syndrome based on the three definitions

Table 1. Definitions of the metabolic syndrome

	Risk factors	IDF consensus (2005)	ATPIII criteria (2001)	WHO criteria (1999)
1	Obesity/abdominal obesity	Waist circumference $\geq$90 cm (m), $\geq$80 cm (f) – South Asians	Waist circumference $\geq$102 cm (m), $\geq$88 cm (f)	Body mass index (BMI) $\geq$30 kg/m^2 and/or waist-to-hip ratio >0.90 (m), >0.85 (f)
2	Blood pressure	$\geq$130/$\geq$85 mmHg	$\geq$130/$\geq$85 mmHg	$\geq$140/$\geq$90 mmHg or on medication
3	Fasting glucose	$\geq$5.6 mmol/L or pre-existing diabetes	$\geq$6.1 mmol/L or on medication for diabetes	Diabetes, impaired glucose tolerance or insulin resistance
4	Microalbuminuria	Not used for diagnosis	Not used for diagnosis	Urinary albumin excretion rate $\geq$20 μg/min
5	Triglycerides	$\geq$1.7 mmol/L	$\geq$1.7 mmol/L	Triglycerides $\geq$1.7 mmol/L and/or HDL-C <0.91 mmol/L (m), <1.01 mmol/L (f)
6	HDL cholesterol	<1.04 mmol/L (m), <1.3 mmol/L (f)	<1.04 mmol/L (m), <1.3 mmol/L (f)	
	Metabolic syndrome – definition	Abdominal obesity plus two or more risk factors	At least three risk factors	Diabetes, impaired glucose tolerance or insulin resistance plus any two or more risk factors

Table 2. General characteristics of the subjects with metabolic syndrome

Variables	Subjects with metabolic syndrome		
	WHO	IDF	ATPIII
N	546	607	430
Male (%)	299 (54.8)	253 (41.7)	187 (43.5)
Age (years)	47 ± 12*†	44 ± 11	45 ± 12
Body mass index (kg/m²)	24.7 ± 3.5*†	25.7 ± 3.1	25.6 ± 3.5
Waist circumference (cm)	90.7 ± 9.1*†	92.9 ± 7.7	92.7 ± 9.0
Hip circumference (cm)	96.2 ± 8.3*†	99.5 ± 7.3	98.9 ± 8.7
Waist-to-hip ratio	0.94 ± 0.08	0.94 ± 0.08	0.94 ± 0.08
Systolic blood pressure (mmHg)	130 ± 21	129 ± 19	131 ± 17
Diastolic blood pressure (mmHg)	81 ± 11	80 ± 11	81 ± 10
Fasting plasma glucose (mmol/L)	7.0 ± 3.2*	6.2 ± 2.6	7.0 ± 3.3*
Total cholesterol (mmol/L)	5.13 ± 1.07	5.03 ± 0.98	5.09 ± 1.0
Triglycerides (mmol/L)	2.10 ± 1.32	1.98 ± 1.19	2.26 ± 1.30*
HDL cholesterol (mmol/L)	1.02 ± 0.23	1.02 ± 0.21	0.98 ± 0.19
LDL cholesterol (mmol/L)	3.15 ± 0.95	3.09 ± 0.89	3.07 ± 0.91
HbA₁C (%)	7.4 ± 2.1*	6.8 ± 1.7	7.4 ± 2.1*

*$p < 0.05$ compared to IDF criteria.
†$p < 0.05$ compared to ATPIII criteria

($p < 0.05$) were higher in subjects with MS defined by ATPIII criteria than by IDF criteria. Waist-to-hip ratio, systolic and diastolic blood pressure, serum cholesterol and HDL cholesterol did not differ in individuals identified by the three criteria.

According to the WHO criteria, obesity was present in 57% (males, 65.8% and females, 49.4%), dyslipidemia in 41.7% (males, 46.7% and females, 37.4%), raised blood pressure in 20% (males, 23.2% and females, 17.2%) and microalbuminuria in 13.7% (males, 12.1% and females, 15.0%) of the study population.

Impaired fasting glucose (IFG) (including self-reported diabetes) was detected in 20.9% (males, 24.2% and females, 18.0%) and 14.7% of individuals (males, 17.8% and females, 12.0%) on the basis of IDF and ATPIII criteria respectively. Abdominal obesity was present in 49.2% (males, 38.5% and females, 58.3%) and 18.5% (males, 6.2% and females, 29.2%) of the subjects on the basis of IDF and ATPIII criteria, respectively. Raised blood pressure was seen in 31.2% (males, 35.3% and females, 27.6%), increased triglycerides in 25.2% (males, 31.0% and females, 20.1%) and decreased HDL cholesterol levels in 63.5% (males, 55.4% and females, 70.6%) of the subjects, which is similar using both ATPIII and IDF criteria. It was also noted that 78.6%, 84.1% and 80.3% of the subjects had at least one abnormality and 1.7%, 2.7% and 1.2% had all five abnormalities according to WHO, IDF and ATPIII criteria, respectively (not shown in table). The prevalence of MS increased with age until the age of 69 and decreased thereafter in all three groups. Even in the age group of 20–29 years, the prevalence of MS ranged from 5.1–8.9% depending on the criteria used to define MS (Figure 2).

The κ statistics for agreement between IDF with that of ATPIII and WHO criteria were 0.58 ($p < 0.001$) and 0.44 ($p < 0.001$), respectively. The agreement between ATPIII and WHO criteria was 0.48 ($p < 0.001$).

Possible coronary artery disease was present in 185 subjects (62 men, 33.5%), and 37.3%, 23.8% and 32.4% of these subjects were identified by WHO, ATPIII and IDF criteria, respectively. It is possible that subjects with T-wave changes (Minnesota codes 5–1 to 5–3)
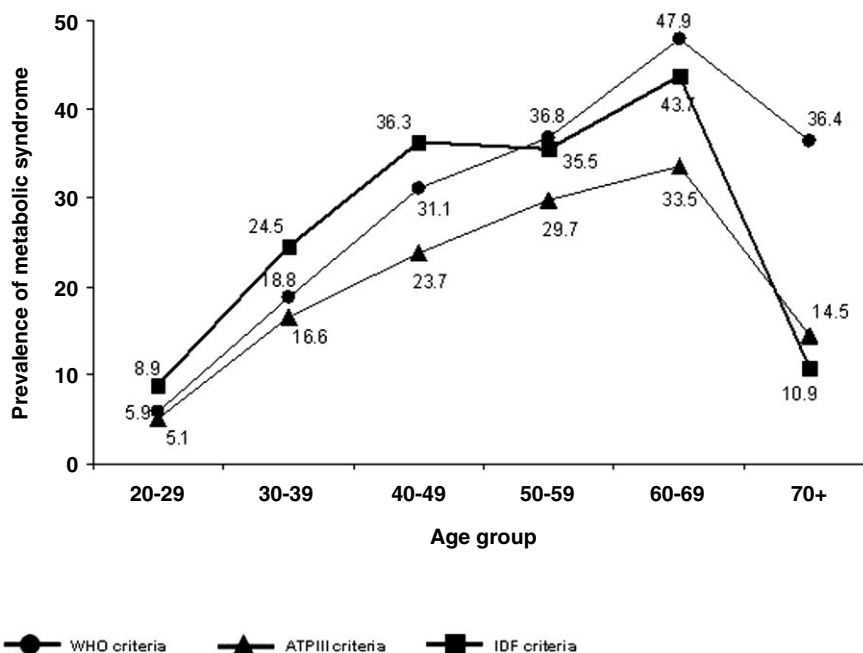

Figure 2. Prevalence of metabolic syndrome by age group

may not have CAD because T-wave changes could be nonspecific. Hence, further analyses were restricted to those with documented MI or those who had Q-waves (probable CAD). Probable CAD was present in 68 subjects (38 men, 55.9%), and 52.9%, 32.4% and 39.7% of these subjects were identified by WHO, ATPIII and IDF definitions of MS, respectively. There was an increased risk of CAD in subjects with MS diagnosed by WHO criteria (odds ratio (OR): 3.86, 95% Confidence Interval (CI), 2.37–6.29, $p < 0.001$), compared to MS subjects diagnosed by ATPIII criteria (OR 2.19, 95% CI 1.30–3.67, $p < 0.05$) and IDF criteria (OR 1.90, 95% CI 1.16–3.12, $p < 0.05$) (Table 3). Of the male subjects with 'possible' or 'probable' CAD, the WHO criteria identified 56.5% and 63.2%, respectively, compared to 19.4% and 23.7% by ATPIII criteria and 33.9% and 36.8% by IDF criteria (Figure 3(a) and (b)). However, among females, there was no difference in the identification of CAD by the three criteria – 'possible' CAD (WHO 26.7%, ATPIII 26.0% and IDF 31.7%), 'probable' CAD (WHO 40%, ATPIII 43.3% and IDF 43.3%), (Figure 3(a) and (b)).

Table 3. Logistic regression analysis using coronary artery disease (CAD) as an dependent variable and various MS criteria as independent variables

MS Criteria	ß	S.E	OR (95% CI)	p-value
WHO criteria	1.352	0.248	3.86 (2.37–6.29)	<0.001
ATPIII criteria	0.781	0.265	2.19 (1.30–3.67)	0.003
IDF criteria	0.642	0.253	1.90 (1.16–3.12)	0.011

Discussion

Different definitions of MS have been laid down by the WHO, European Group for the Study of Insulin Resistance (EGIR) ATPIII, American Association of Clinical Endocrinologists (AACE), and the IDF. In the present study, the most commonly used definitions of MS (WHO, ATPIII and IDF) were used. These three definitions agree on essential components – glucose intolerance, obesity, hypertension and dyslipidemia – but they differ in the cut-off points for the criteria of each component of the cluster and the method of combining them to define MS. The definition used in the WHO report centres on diabetes and insulin resistance, whereas the ATPIII guidelines give equal weightage to abdominal obesity, hypertension, hyperglycemia, hypertriglyceridemia and low HDL cholesterol. The IDF is closest to ATPIII in that it includes the same variables, but it differs in that central obesity is an essential component. Also, the waist measurement is set at a lower level than in ATPIII and it is ethnic-specific. The fasting hyperglycemia is set at the new American Diabetes Association (ADA) cut-off point for IFG. Moreover, it does not include any measure of insulin resistance, and hyperglycemia is not an obligatory component, which sets it apart from the WHO and EGIR definitions. Although the prevalence of MS varies according to the definition used, the WHO and ATPIII definitions identify people at increased risk for developing CVD and all the causes of mortality and for developing diabetes [11].
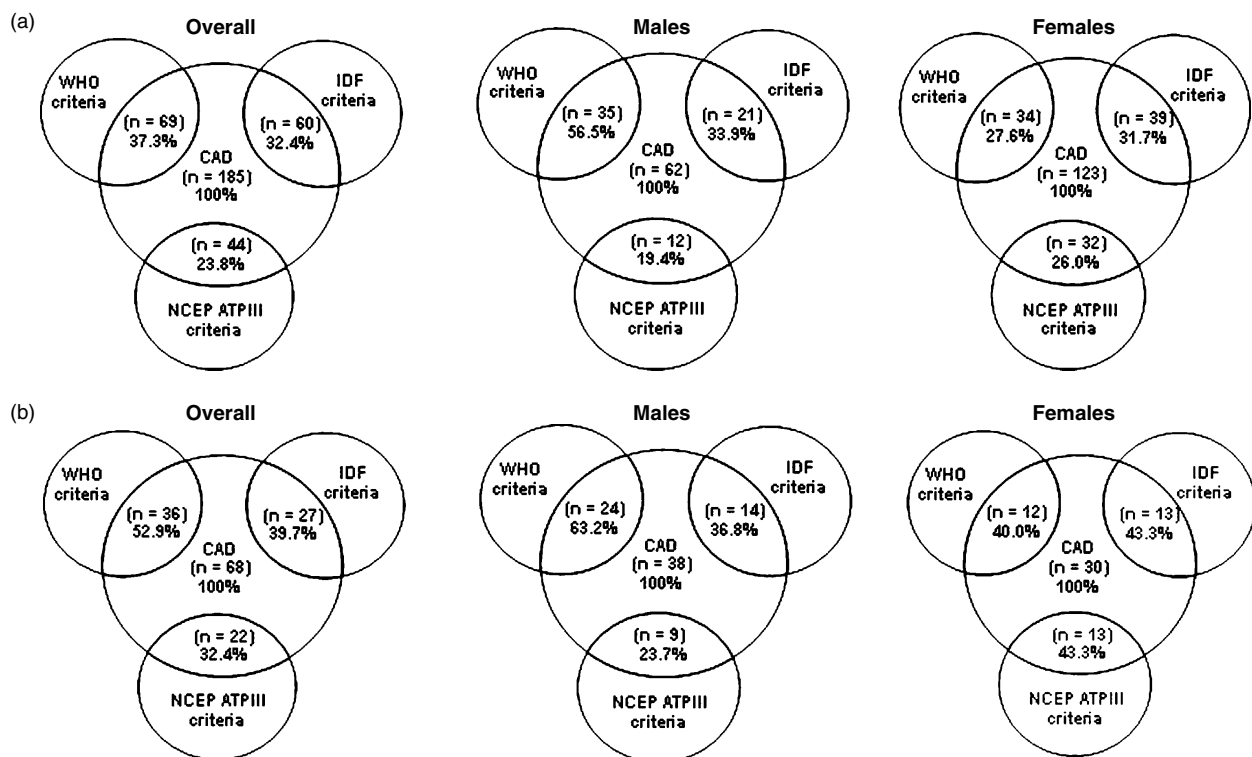

Figure 3. Identification of coronary artery disease by different criteria of metabolic syndrome

Most of the earlier reports on MS have been based on studies on Europeans. Asian Indians have very high rates of diabetes [8] and premature CAD [12]. Also, different waist cut-offs have been proposed for Asians [13]. The IDF and WHO have called for more studies on MS using different criteria for MS in different ethnic groups. This study provides the first report on the prevalence of MS among Asian Indians using the three definitions (WHO, ATPIII and IDF). We found the prevalence of MS in our study population to be 23.2%, 18.3% and 25.8% using the WHO, ATPIII and IDF definitions, respectively.

Table 4 presents a survey of the literature showing the prevalence of MS reported in different populations. In previous studies, the prevalence of MS has varied widely, primarily owing to different definitions of the syndrome or selection of different subgroups. Very few studies have been done in India on the prevalence of MS and most were done using ATPIII criteria and one study using EGIR criteria. The prevalence of MS in the present study is much lower than that reported in an earlier study in urban Indian adults aged 20–75 years, in which the prevalence was reported to be 41.1% [14]. However, that study was done in a smaller sample size ($n = 475$), used the modified ATPIII criteria and excluded self-reported diabetic subjects. The age-adjusted prevalence of MS based on ATPIII criteria in Jaipur (urban North Indian population) was 24.9% [15]. In the Chennai Urban Population Study (CUPS), the prevalence of MS as defined by EGIR was found to be 11.2% (18.7% in the middle-income and 6.5% in the low-income groups), showing a significant difference even within an urban environment in different socio-economic groups [16].

Results of the Singapore National Health Survey shows a higher prevalence of MS among the Asian Indians (28.8%) compared to Malays (24.2%) and Chinese (14.8%) [21]. It is noteworthy that the prevalence rates

Table 4. Prevalence of metabolic syndrome from various studies

Reference	City, country	Year	Age (years)	Sample size	MS prevalence (%)	Diagnostic criteria
Abdul-Rahim HF, *et al.*, 2001 [17]	Palestinian	1996–1998	30–65	Urban:492 Rural: 500	17%[a]	WHO
Ford ES, 2003 [11]	US	1988–1994	≥20	8608	ATPIII − 23.9%[b]; WHO − 25.1%[b]	ATPIII & WHO
Al-Lawati JA, *et al.*, 2003 [18]	Nizwa City, Oman	2001	≥20	1419	17%[a]; 21%[b]	ATPIII
Resnick HE, *et al.*, 2003 [19]	Arizona, Oklahoma & Dakota	1988	45–74	2283	35%[a]	ATPIII
Azizi F, *et al.*, 2003 [20]	Tehran, Iran	1999–2001	≥20	9846	30.1%[a]; 33.7%[c]	ATPIII
Tan CE, *et al.*, 2004 [21]	Singapore	1998	18–69	4723	Asian Indians: 28.8%[a]; Malays: 24.2%[a] Chinese: 14.8%[a]	ATPIII
Oh J, *et al.*, 2004 [22]	Korea	1997	30–80	655	Men: 29%[a]; Women: 16.8%[a]	ATPIII [modified]
Ilanne-Parikka P, *et al.*, 2004 [23]	Finland	1992	45–64	2049	Men: 38.8%[a]; Women: 22.2%[a]	WHO
Jaber LA, *et al.*, 2004 [24]	Michigan, US		20–75	542	ATPIII: 23%[b]; WHO: 28%[b]	ATPIII & WHO
Thomas GN, *et al.*, 2005 [25]	Hong Kong	1994–1996	25–74	2843	21.9%[c]	ATPIII [modified]
Son LNTD, *et al.*, 2005 [26]	Ho Chi Minh City, Vietnam	2001	≥20	611	18.5%[a]; 12.0%[c]	ATPIII
Gu D, *et al.*, 2005 [27]	China (Inter-ASIA)	2000–2001	35–74	15 540	Men: 9.8%[c]; Women: 17.8%[c]	ATPIII
Ford ES, 2005 [28]	United States.	1999–2002	≥20	3601	ATPIII: 34.5%[a]; IDF: 39.0%[a]	ATPIII & IDF
Ko GT, *et al.*, 2005 [29]	Hong Kong		18–66	1513	WHO: 13.4%[a]; EGIR: 8.9%[a]; ATPIII: 9.6%[a]	WHO, EGIR & ATPIII [modified]
Adams RJ, *et al.*, 2005 [30]	South Australia		≥18	4060	IDF: 22.8%[a]; ATPIII:15%[a]	IDF & ATPIII
Guerrero-Romero F, *et al.*, 2005 [31]	Northern Mexico (Durango City)		30–64	700	IDF:22.3%[a]; ATPIII:22.6%[a]; WHO: 15.4%[a]	IDF, ATPIII & WHO
Shiwaku K, *et al.*, 2005 [32]	Japan, Korea and Mongolia	1999–2003	30–60	1384	Japanese: 12%[a]; Koreans: 13%[a]; Mongolians: 16%[a]	ATPIII [modified: BMI ≥ 25]
Scuteri A, *et al.*, 2005 [33]	Cardiovascular Health Study (CHS)	1989–1990	≥65	2175	ATPIII: 28.1%[a]; WHO: 21%[a]	ATPIII & WHO
Bo S, *et al.*, 2005 [34]	North-western Italy	2001–2003	45–64	1877	23.1%[a]	ATPIII
Mohan V, *et al.*, 2001 [16]	Chennai, India	1996–1997	≥20	1262	11.2%[a]	EGIR
Ramachandran A, *et al.*, 2003 [14]	Chennai, India	1995	20–75	475	41.1%[a]	ATPIII [modified]
Gupta R, *et al.*, 2004 [15]	Jaipur, India		≥20	1091	31.6%[a]; 24.9%[b]	ATPIII
Present Study	Chennai, India	2002–2004	≥20	2350	WHO: 23.2%[a]; ATPIII: 18.3%[a]; IDF: 25.8%[a]	WHO, ATPIII & IDF

Prevalence of metabolic syndrome: [a]Crude prevalence.
[b]Age-adjusted prevalence; [c]Age standardised prevalence rate.

among Indians in Singapore are similar to the rates in the present study done on urban Indians. The National Health and Nutrition Examination Survey (NHANES) III in the United States shows an age-adjusted prevalence of MS in 23.7% as defined by ATPIII criteria [35]. The prevalence of MS in a subgroup of older participants ($\geq$60 years) from a Cardiovascular Health Study (CHS) was 28.1% by ATPIII criteria and 21.0% by WHO criteria [33]. The MS prevalence among workers aged 30–60 years using ATPIII criteria was reported to be 12% for Japanese, 13% for Koreans and 16% for Mongolians [32]. In the United States, 39% of adults were classified as having MS using the IDF criteria, a figure that is higher than that estimated by the ATPIII definition (34.5%) [29]. Similarly, in a study done in South Australia, the prevalence of MS was higher using the IDF criteria (22.8%) as compared to ATPIII criteria (15%) [30]. This is consistent with the present study, in which the prevalence of MS based on IDF criteria is higher (25.8%) than that estimated by ATPIII criteria (18.3%).

We also found that the prevalence of MS increased with age irrespective of the definitions used. It is noteworthy that 5.1–8.9% of the subjects in the age group 20–29 years had MS, depending on the definition used. The higher prevalence of MS at younger ages in Asian Indians is of particular concern, as it means that they will have a more prolonged exposure to the atherosclerotic risk factors associated with MS. Studies have shown that prolonged exposure to atherosclerotic risk factors before the onset of diabetes could also contribute to the excess mortality in Asian Indians, which was observed in a study that compared Indians, Malays and Chinese [36].

In the present study, the concordance of subjects with MS based on IDF criteria with that of ATPIII and WHO was 0.58 and 0.44, respectively, and only 224 subjects were deemed to have MS based on all three criteria. A study in northern Mexico had shown that the IDF has a high concordance (0.87) with ATPIII definition, identifying similar proportions of subjects with MS and a low concordance (0.51) with the WHO definition. Results of the Cardiovascular Health Study (CHS) show an 80% concordance in classifying subjects by ATPIII and WHO criteria [33]. In the Hoorn study, 60–80% agreement was noted among various definitions such as ATPIII, WHO, EGIR and AACE [37]. Thus, the agreement between different definitions of MS appears to vary in different ethnic groups, which is likely due to the different cut-off points used. Despite the fact that the three criteria share most of the components, they still misclassify a large number of subjects as having MS in this urban south Indian population.

To examine the definition of MS that was more strongly associated with the risk for CVD, we compared the correlation of CAD with MS defined by the three definitions. Overall, the prevalence of CAD was four times higher in subjects with MS diagnosed using the WHO criteria, whereas it was two-fold higher on the basis of IDF and ATPIII criteria. The possible explanation is that since insulin resistance is included as one of its

criteria, the WHO definition may identify people who are more insulin resistant than the other two criteria. Another interesting observation is that the WHO criteria mark out a higher population for CAD risk in males but not in females. The possible explanation for this is that metabolic abnormalities associated with insulin resistance tend to cluster more in males than in females. Lehto *et al* [38] have shown that metabolic abnormalities predict CAD better in males than in females.

The strengths of the present study are that the subjects studied are representative of the urban population of Chennai, the sample size is large ($n = 2350$) and the response rate is very good (90.4%). However, the cross-sectional nature of the design does not allow for cause-effect conclusions to be made.

In conclusion, we report that in this urban adult Asian Indian population, a high prevalence of MS (approximately one-quarter of adults) is seen using all three criteria, although they seem to identify different individuals. Among men, the WHO MS criteria identify a greater number of subjects with CAD, compared to the ATPIII or IDF criteria. However, among women there was no difference in the identification of CAD subjects with respect to the three definitions used.

Acknowledgements

References

1. Reaven GM. Banting lecture 1988: role of insulin resistance in human disease. *Diabetes* 1988; **37**: 1595–1607.
2. Isomaa B, Almgren P, Tuomi T, *et al*. Cardiovascular morbidity and mortality associated with the metabolic syndrome. *Diabetes Care* 2001; **24**: 683–689.
3. Stern MP, Williams K, Gonzalez-Villalpando C, *et al*. Does the metabolic syndrome improve identification of individuals at risk of type 2 diabetes and/or cardiovascular disease? *Diabetes Care* 2004; **27**: 2676–2681.
4. Trevisan M, Liu J, Bashas FB, *et al*. Syndrome X and mortality: a population based study. *Am J Epidemiol* 1998; **148**: 958–966.
5. World Health Organisation. Definition, diagnosis and classification of diabetes mellitus and its complications. Part 1: diagnosis and classification of diabetes mellitus. Report of a WHO consultation. WHO/NCD/NCS/99.2. World Health Organisation: Geneva, 1999.
6. Executive Summary of the Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection. Evaluation and treatment of high blood cholesterol in adults (adult treatment panel III). *JAMA* 2001; **285**: 2486–2497.
7. International Diabetes Federation (2005). New IDF worldwide definition of the metabolic syndrome. *Press Conference, 1ˢᵗ International Congress on "Pre-diabetes" and the Metabolic Syndrome*, Berlin, Germany, April 14, 2005; (www.idf.org).
8. Wild S, Roglic G, Green A, *et al*. Global prevalence of diabetes, estimates for the year 2000 and projections for 2030. *Diabetes Care* 2004; **27**: 1047–1053.
9. Deepa M, Pradeepa R, Rema M, *et al*. The Chennai urban rural epidemiology study (CURES)–study design and methodology (Urban Component) (CURES–1). *J Assoc Physicians India* 2003; **51**: 863–870.

10. Alberti KG, Zimmet PZ. Definition diagnosis and classification of diabetes mellitus and its complications. Part 1: diagnosis and classification of diabetes mellitus, provisional report of a WHO consultation. *Diabet Med* 1998; **15**: 539–553.

11. Ford ES, Giles WH. A comparison of the prevalence of the metabolic syndrome using two proposed definitions. *Diabetes Care* 2003; **26**: 575–581.

12. Anand SS, Yusuf S, Vuksan V, *et al*. Differences in risk factors, atherosclerosis, and cardiovascular disease between ethnic groups in Canada: the study of health assessment and risk in ethnic groups (SHARE). *Lancet* 2000; **356**: 279–284.

13. World Health Organisation, Western Pacific Region. The Asia-Pacific Perspective. Redefining Obesity and its Treatment. WHO/IASO/IOTF: Melbourne: International Diabetes Institute, 2000.

14. Ramachandran A, Snehalatha C, Satyavani K, *et al*. Metabolic syndrome in urban Asian Indian adults–a population study using modified ATPIII criteria. *Diabetes Res Clin Pract* 2003; **60**: 199–204.

15. Gupta R, Deedwania PC, Gupta A, *et al*. Prevalence of metabolic syndrome in an Indian urban population. *Int J Cardiol* 2004; **97**: 257–261.

16. Mohan V, Shanthirani S, Deepa R, *et al*. Intra-urban differences in the prevalence of the metabolic syndrome in southern India–the Chennai urban population study (CUPS No.4). *Diabet Med* 2001; **18**: 280–287.

17. Abdul-Rahim HF, Husseini A, Bjertness E, *et al*. The Metabolic syndrome in the west bank population: an urban-rural comparison. *Diabetes Care* 2001; **24**: 275–279.

18. Al-Lawati JA, Mohammed AJ, Al-Hinai HQ, *et al*. Prevalence of the metabolic syndrome among Omani adults. *Diabetes Care* 2003; **26**: 1781–1785.

19. Resnick HE, Henderson J, Jones K, *et al*. Insulin resistance, the metabolic syndrome and risk of incident cardiovascular disease in non diabetic American Indians–the strong heart study. *Diabetes Care* 2003; **26**: 861–867.

20. Azizi F, Salehi P, Etemadi A, *et al*. Prevalence of metabolic syndrome in an urban population: tehran lipid and glucose study. *Diabetes Res Clin Pract* 2003; **61**: 29–37.

21. Tan CE, Ma S, Wai D, *et al*. Can we apply the national cholesterol education program adult treatment panel definition of the metabolic syndrome to Asians? *Diabetes Care* 2004; **27**: 1182–1186.

22. Oh J, Hong YS, Sung Y, *et al*. Prevalence and factor analysis of metabolic syndrome in an urban Korean population. *Diabetes Care* 2004; **27**: 2027–2032.

23. Ilanne-Parikka P, Eriksson JG, Lindstrom J, *et al*. On behalf of the Finnish diabetes prevention study group. Prevalence of the metabolic syndrome and its components. Findings from a finnish general population sample and the diabetes prevention study cohort. *Diabetes Care* 2004; **27**: 2135–2140.

24. Jaber LA, Xhu Q, Brown MB, *et al*. The prevalence of the metabolic syndrome among Arab Americans. *Diabetes Care* 2004; **27**: 234–238.

25. Thomas GN, Ho SY, Janus ED, *et al*. The US National cholesterol education programme adult treatment panel III (NCEP ATPIII) prevalence of the metabolic syndrome in a Chinese population. *Diabetes Res Clin Pract* 2005; **67**: 251–257.

26. Son Lent, Kuniia D, Hung NTK, *et al*. The metabolic syndrome: prevalence and risk factors in the urban population of Ho Chi Minh City. *Diabetes Res Clin Pract* 2005; **67**: 243–250.

27. Gu D, Reynolds K, Wu X, *et al*, For the InterASIA Collaborative Group. Prevalence of the metabolic syndrome and overweight among adults in China. *Diabetes Res Clin Pract* 2005; **67**: 243–250.

28. Ford ES. Prevalence of the metabolic syndrome defined by the international diabetes federation among adults in the U.S. *Diabetes Care* 2005; **28**: 2745–2749.

29. Ko GT, Cockram CS, Chow C, *et al*. High prevalence of metabolic syndrome in Hong Kong Chinese – comparison of three diagnostic criteria. *Diabetes Res Clin Pract* 2005; **69**: 160–168.

30. Adams RJ, Appleton S, Wilson DH, *et al*. Population comparison of two clinical approaches to the metabolic syndrome. Implications of the new international diabetes federation consensus definition. *Diabetes Care* 2005; **28**: 2777–2779.

31. Guerrero-Romero F, Rodriguez-Moran M. Concordance between the 2005 International diabetes federation definition for diagnosing metabolic syndrome with the national cholesterol education program adult treatment panel III and the world health organization definitions. *Diabetes Care* 2005; **28**: 2588–2589.

32. Shiwaku K, Nogi A, Kitajima K, *et al*. Prevalence of the metabolic syndrome using the modified ATPIII definitions for workers in Japan, Korea and Mongolia. *J Occup Health* 2005; **47**: 126–135.

33. Scuteri A, Najjar SS, Morrell CH, *et al*. The metabolic syndrome in older individuals: prevalence and prediction of cardiovascular events. *Diabetes Care* 2005; **28**: 882–887.

34. Bo S, Gentile L, Ciccone G, *et al*. The metabolic syndrome and high C-reactive protein: prevalence and differences by sex in a southern-European population-based cohort. *Diabetes Metab Res Rev* 2005; **21**: 515–524.

35. Ford ES, Giles WH, Dietz WH. Prevalence of the metabolic syndrome among US adults: findings from the third national health and nutrition examination survey. *JAMA* 2002; **287**: 356–359.

36. Ma S, Cutter J, Tan CE, *et al*. Associations of diabetes mellitus and ethnicity with mortality in a multiethnic Asian population: data from the 1992 Singapore National Health survey. *Am J Epidemiol* 2003; **158**: 543–552.

37. Dekker JM, Girman C, Rhodes T, *et al*. Metabolic syndrome and 10-year cardiovascular disease risk in the hoorn study. *Circulation* 2005; **112**: 666–673.

38. Lehto S, Ronnemaa T, Pyorala K, Laakso M. Cardiovascular risk factors clustering with endogenous hyperinsulinemia predict death from coronary heart disease in patients with type II diabetes. *Diabetologia* 2000; **43**: 148–155.