A Comparison of the New International Diabetes Federation Definition of Metabolic Syndrome to WHO and NCEP Definitions in Chinese, European and South Asian Origin Adults

Nigel Unwin, DM; Raj Bhopal, MD; Louise Hayes, MSc; Martin White, MD; Sheila Patel, PhD; Dalip Ragoobirsingh, PhD; George Alberti, DPhil

Objectives: To compare the prevalence, agreement and phenotypic characteristics in three ethnic groups of the new International Diabetes Federation (IDF) definition of metabolic syndrome (MS) to the World Health Organization (WHO) and national cholesterol education program (NCEP) definitions.

Setting: Newcastle upon Tyne, England.

Design: Cross-sectional surveys.

Participants: Chinese (171 men and 185 women), European (257 men and 301 women), and South Asian (264 men and 295 women) adults, ages 25 to 64 years.

Main Outcome Measures: Anthropometric indices: blood pressure, fasting lipids, urine albumin-to-creatinine ratio, glucose intolerance, insulin resistance.

Results: IDF-defined MS was highly prevalent in all groups, ranging from 12.3% (95% CIs 7.4–17.2) in Chinese men to 45.5% (39.5–51.5) in South Asian men. In women, of all ethnic groups, more than 80% of those with WHO- or NCEP-defined MS also had IDF-defined MS. In men, however, agreement was less good. For example, in each ethnic group, more than a third of those with WHO-defined MS did not have IDF-defined MS. Within each ethnic group, the biological characteristics of those with MS by any definition were largely the same. However, differences existed between ethnic groups. For example, in those with IDF-defined MS, both South Asian men and women had significantly ($P<.05$) higher insulin resistance and significantly lower systolic and diastolic blood pressure than Europeans or Chinese.

Conclusions: Agreement between the IDF and other definitions is better in women than men. The phenotype is similar within each ethnic group whatever the definition, but differs between groups suggesting that risks associated with MS differ by ethnic group. (*Ethn Dis*. 2007;17:522–528)

Key Words: Metabolic Syndrome, Ethnicity, Definitions

From the School of Clinical Medical Sciences, Newcastle University, UK (NU, SP, GA); the Institute of Health and Society, Newcastle University, UK (LH, MW); the Public Health Sciences Section, University of Edinburgh, UK (RB); and the Biochemistry Section, Faculty of Medical Sciences, University of the West Indies, Jamaica (DR).

Address correspondence and reprint requests to Prof Nigel Unwin; Medical School; Framlington Place; Newcastle University; NE2 4HH, UK. +44 (0)191 222 6686; +44(0)191 222 8211(fax); n.c.unwin@ncl.ac.uk

Introduction

The concept of the clustering of CVD risk factors and of metabolic syndrome can be traced to work that is decades old. This includes Vague's description of the metabolic characteristics of android (upper body) obesity, first published in English in the 1950s,[1] and the description by Camus in the 1960s of a "trisyndrome metabolique," consisting of the association of gout, hyperlipidemia and diabetes.[2] The description by Reaven[3] of syndrome X provided a focus that enabled these, and other observations to be brought together under the umbrella of a metabolic or insulin resistance syndrome.[4–6]

Only relatively recently, however, have international or national bodies proposed working definitions of metabolic syndrome. The first was the World Health Organization (WHO) in 1999.[7] Two years later the third Adult Treatment Panel of the United States National Cholesterol Education Program (NCEP) proposed a definition as part of its guidance on the identification and management of dyslipidemia,[8] a definition that was recently modified to use a lower fasting glucose cut point.[9] Other definitions have also been proposed,[10,11] but in 2005, a consensus group of the International Diabetes Federation (IDF) proposed a definition[12] that it hopes will replace other definitions and become an international standard. Unlike previous definitions, it includes ethnic group specific cut points for obesity, using waist circumference, and requires the presence of central obesity. Interestingly, the latest NCEP definition and guidance suggests that a lower waist circumference "can be invoked" for Asian Americans.[9]

The aim of the study reported here was to investigate how the IDF definition of metabolic syndrome (MS) compares to the WHO and NCEP definitions when applied to three ethnic groups. Comparisons were made in terms of the prevalence of MS, to what extent the same individuals are identified as having MS, and the phenotypic characteristics of those individuals. We used a dataset from community-based surveys of Chinese, European, and South Asian origin populations residing in the Northeast region of England.

Methods

Participants and Data Collection - The Newcastle Heart Project

The Newcastle Heart Project is a series of three population-based surveys of Chinese (undertaken 1991 to 1993), European (1993 to 1994) and South Asian origin (1995 to 1997) men and women residing in Newcastle upon Tyne, England. Each of the surveys received local ethical committee approval.

The methods have been described in detail previously elsewhere,[13,14] and are summarized here. All Chinese (people whose ancestral origins are from China) adults, ages 25–64 years, and residing in the city of Newcastle upon Tyne were eligible; they were recruited through a name search of the Family Health Services Authority (FHSA) patient register and community contacts. Three hundred and eighty men and women were seen, estimated to be 70% of the target population.[15]

Age- and sex-stratified random samples of European and South Asian (from the Indian sub-continent) adults, ages 25–74 years, were taken from the FHSA register. For the South Asian study, a name search of the FHSA register was used to identify all South Asian names and this list of names was used as the sampling frame.[16] Overall, 840 and European and 708 South Asian adults were seen (response rates of 66% and 63%, respectively).

Height, weight, waist and hip circumferences were measured. Fasting venous blood was taken for the measurement of glucose, lipids and insulin. In those who did not report a doctor's diagnosis of diabetes, a standard WHO OGTT was performed. Blood pressure was measured twice and the mean of the two measurements used in analysis. A morning spot urine sample was taken for the measurement of albumin and creatinine. Details on the methods of all the measurements and assays have been published previously.[13,14,17]

Definitions of Ethnicity as Used in This Study

Chinese refers to participants who, on the basis of their name, their self-identification, and their appearance, have their ancestral origins in China. European refers to participants whose ancestry was from the European continent. This definition was applied largely by exclusion, ie, by excluding people with Chinese and South Asian names, and any other individuals who, when screened, were clearly of different ancestry. In practice this meant excluding the data of one individual who was found to be of African origin. The highly pragmatic and somewhat unsatisfactory nature of this definition of European ethnicity is acknowledged. South Asian refers to individuals whose ancestral origins are from the same geographical area as current day India, Pakistan and Bangladesh. Ancestral origin for this purpose was defined as having at least three out of four grandparents born in this area.

Definition of Insulin Resistance

The WHO MS definition defines insulin resistance as being the lowest quartile of glucose uptake under hyperinsulinaemic, euglycaemic conditions, for the background population under investigation.[7] For the purposes of this paper, insulin resistance was defined using the Homeostasis Model Assessment (HOMA),[18] based on fasting insulin and glucose. The pragmatic definition of insulin resistance used in this study were values above the upper 25th percentile for HOMA in the non-diabetic combined male and female European population. This value from the European population was applied to the Chinese and South Asian populations to define insulin resistance. The European population value was chosen for two reasons. First, the European population is the majority in this part of England. Second, a single value to define insulin resistance was chosen to be applied to all three ethnic groups in order to reflect differences in insulin resistance between the ethnic groups. Had ethnic group specific cut points been used, each ethnic group would, by definition, have had the same prevalence of insulin resistance.

Analysis and Statistical Methods

The aim of our analyses was to compare the prevalence and characteristics of metabolic syndrome definitions across the three ethnic groups. Analyses were therefore limited to the 25-to-64 year age range for all groups (the age range of the Chinese sample). Analyses were limited to those individuals with complete data on core aspects of the definitions. Thus, all subjects in the analyses had complete data on glucose, lipids, insulin, blood pressure, and anthropometric measures. The three definitions of metabolic syndrome are shown in Table 1. The ethnic group specific cut points for waist circumference were used in applying the IDF definition, ie $\geq$ 90 cm in South Asian and Chinese men, and $\geq$ 94 cm in European men.

The agreement between the definitions was assessed using the kappa statistic. Interpretation of the kappa statistic followed the recommendations of Altman.[19] The statistical significance of differences in the proportions with metabolic syndrome based on the two definitions was evaluated using McNemar's test.[19] Where the number of missing cases for a variable was >10% of the total number within a given sex-ethnic group, the actual number for that variable is given.

The prevalence figures are presented with 95% confidence intervals, calculated using the exact method using the software Confidence Interval Analysis.[20] The prevalence figures were age standardized to the 1991 England and Wales population by applying a weighting variable within SPSS (Chicago, Ill).

RESULTS

The Prevalence of Metabolic Syndrome and Its Components

Tables 2, 3 and 4 show the prevalence of metabolic syndrome and its components for WHO, NCEP (2001 and 2005) and IDF definitions, respectively. There were substantial numbers of missing values for urine albumin to creatinine ratio (ACR) (Table 2). The WHO definition includes, but is

Table 1. Components and definitions of the metabolic syndrome according to the World Health Organization (1999), the National Cholesterol Education Program (2001) and the International Diabetes Federation (2005)

WHO 1999[7]	NCEP 2001 (2005) [8,9]	IDF 2005[12]
Components of the metabolic syndrome		
Insulin resistance (highest quartile for background population)	Abdominal obesity: waist circumference > 102 cm in men; > 88 in women	Abdominal obesity: ethnic group specific cut points*: ⇨ European: men ≥ 94 cm, women ≥ 80 cm; ⇨ S Asian and Chinese: ≥ 90 cm, ≥ 80 cm; ⇨ Japanese: ≥ 85 cm, ≥ 90 cm
Impaired glucose regulation or diabetes (WHO 1999 definitions)	Fasting plasma glucose ≥6.1 $mmoll^{-1}$ or diagnosed diabetes (lowered to 5.6 $mmoll^{-1}$ in 2005)	Fasting plasma glucose ≥ 5.6 $mmoll^{-1}$ or diagnosed diabetes
Central obesity: waist to hip ratio >0.9 in men, >0.85 in women, and/or BMI >30	Raised serum triglycerides: ≥1.7 $mmoll^{-1}$	Raised serum triglycerides: ≥1.7 $mmoll^{-1}$
Raised plasma triglycerides: ≥1.7 $mmoll^{-1}$ and/or low HDL cholesterol: <0.9 $mmol^{-1}$ in men; < 1 $mmoll^{-1}$ in women	Low HDL cholesterol: <1.0 $mmoll^{-1}$ (40 $mgdl^{-1}$) in men; <1.3 $mmoll^{-1}$ (50 $mgdl^{-1}$) in women	Low HDL cholesterol: < 1.0 $mmoll^{-1}$ (40 $mgdl^{-1}$) in men; <1.3 $mmoll^{-1}$ (50 $mgdl^{-1}$) in women
Raised arterial pressure (≥ 140/90 mm Hg) or treated hypertension	Blood pressure ≥ 130/85 or diagnosed and treated hypertension	Blood pressure ≥130/85 diagnosed and treated hypertension
Microalbuminuria (albumin/ creatinine ratio ≥ 30 mg g^{-1})		
Definition of metabolic syndrome		
Glucose intolerance and / or insulin resistance plus at least two of the other features	Presence of three or more of the components	Presence of central obesity plus at least two other components

* For people of sub Saharan African origin, European values are recommended until specific data become available.

not dependent upon, micro albuminuria, defined in this study as a raised ACR. Thus, it is possible that in those individuals with missing ACR values, some would have had a raised ACR and that this, combined with the other WHO criteria, would have classified them as having MS. However, given the relatively low prevalence of raised ACR, and assuming this would be the same in those with missing ACR values, the effect on the overall prevalence of metabolic syndrome would be small (ie, to increase it by one or two percent).

In men, the prevalence of the IDF definition ranged from 12.3% in Chinese to 24.7% in Europeans and up to 45.5% in South Asians. These figures are similar to those for the WHO definition but significantly higher in the Chinese ($P=.003$) and South Asians ($P<.001$) than those for the NCEP 2001 definition. However, the IDF definition was significantly lower than

Table 2. Prevalence of the WHO-defined metabolic syndrome and its components (%)

	Men			Women		
	Chinese	European	S Asian	Chinese	European	S Asian
	n=171	*n*=257	*n*=264	*n*=185	*n*=301	*n*=295
Generalized obesity	4.8 (1.6–8.0)	15.0 (10.6–19.4)	14.5 (10.1–18.8)	2.2 (0.1–4.3)	15.8 (11.7–20.0)	30.8 (25.4–36.1)
Central obesity	52.5 (45.1–60.0)	50.4 (44.3–56.6)	77.6 (72.4–82.7)	46.7 (39.5–53.8)	15.4 (11.3–19.5)	45.6 (39.8–51.4)
Either of above (A)	52.5 (45.1–60.0)	50.4 (44.3–56.6)	77.8 (72.7–82.9)	46.7 (39.5–53.8)	23.9 (19.1–28.8)	56.0 (50.3–61.8)
Hypertension (B)	14.3 (9.1–19.6)	28.6 (23.0–34.2)	15.8 (11.3–20.2)	17.4 (12.0–22.9)	11.1 (7.5–14.7)	15.2 (11.0–19.3)
Low HDL cholesterol	9.4 (5.0–13.8)	12.0 (8.0–16.0)	31.4 (25.7–37.1)	5.5 (2.2–8.8)	8.4 (5.3–11.6)	15.2 (11.0–19.3)
Raised triglycerides	18.7 (12.8–24.5)	35.7 (29.8–41.7)	54.3 (48.2–60.4)	11.3 (6.7–15.8)	29.5 (24.3–34.7)	34.1 (28.6–39.6)
Either of above (C)	24.0 (17.6–30.4)	36.6 (30.6–42.6)	58.7 (52.6–64.7)	14.0 (9.0–18.9)	32.5 (27.2–37.8)	40.6 (34.9–46.3)
Microalbuminuria* (D)	2.4 (0.3–5.1)	3.3 (1.0–5.6)	8.0 (4.6–11.4)	5.7 (1.9–9.6)	5.1 (2.6–7.6)	9.9 (6.3–13.4)
2 or more of A/B/C/D	24.2 (17.8–30.6)	35.8 (29.9–41.7)	55.8 (49.7–61.9)	20.8 (15.0–26.6)	20.4 (15.8–25.0)	37.5 (31.9–43.2)
Insulin resistance	19.9 (13.9–25.9)	32.4 (26.6–38.2)	65.2 (59.4–71.1)	22.4 (16.4–28.4)	24.6 (19.7–29.5)	58.5 (52.7–64.2)
Glucose intolerance	25.5 (19.0–32.0)	35.5 (29.5–41.4)	51.6 (45.5–57.8)	31.1 (24.5–37.7)	23.3 (18.5–28.1)	41.9 (36.2–47.7)
Either of above	34.3 (27.2–41.4)	46.3 (40.1–52.4)	74.7 (69.3–80.0)	39.2 (32.2–46.2)	36.8 (31.3–42.3)	67.3 (61.9–72.8)
Metabolic syndrome†	10.7 (6.1–15.4)	24.9 (19.6–30.3)	49.3 (43.1–55.4)	10.3 (5.9–14.6)	15.8 (11.6–19.9)	33.9 (28.4–39.4)

* Due to missing data, figures for microalbuminuria are based on 127 Chinese, 234 European and 240 South Asian male participants, and 141, 288, 266 females respectively.
† 2 or more of A/B/C/D **and** insulin resistance and/or glucose intolerance
Figures are percentages (95% CIs).

Table 3. Prevalence of the NCEP-defined metabolic syndrome and its components

	Men			Women		
	Chinese	European	S Asian	Chinese	European	S Asian
	n=171	*n*=257	*n*=264	*n*=185	*n*=301	*n*=295
High waist circumference	1.2 (0–2.8)	14.2 (9.9–18.6)	16.3 (11.8–20.9)	14.5 (9.4–19.5)	15.8 (11.7–20.0)	37.7 (32.1–43.3)
Hypertension	27.1 (20.4–33.7)	43.8 (37.7–50.0)	25.6 (20.3–31.0)	27.0 (20.6–33.4)	20.7 (16.1–25.3)	18.8 (14.3–23.4)
Low HDL cholesterol	9.3 (5.0–13.7)	11.5 (7.5–15.4)	29.0 (23.4–34.6)	15.0 (9.9–20.2)	19.3 (14.8–23.8)	40.7 (35.0–46.4)
Raised triglycerides	18.7 (12.8–24.5)	35.7 (29.8–41.7)	54.3 (48.2–60.4)	11.3 (6.7–15.8)	29.5 (24.3–34.7)	34.1 (28.6–39.6)
Glucose intolerance	13.8 (8.7–19.0)	26.8 (21.4–32.3)	32.4 (26.7–38.2)	17.4 (12.0–22.9)	14.1 (10.1–18.0)	20.9 (16.1–25.6)
Metabolic syndrome (2001)	3.6 (0.8–6.4)	22.3 (17.1–27.4)	23.9 (18.7–29.2)	8.8 (4.7–12.9)	14.9 (10.8–18.9)	24.1 (19.1–29.0)
Metabolic syndrome (2005)*	7.0 (3.7–11.9)	30.7 (25.1–36.4)	36.7 (30.9–42.6)	11.4 (6.8–15.9)	19.6 (15.1–24.1)	30.8 (25.1–36.1)

* Using fasting plasma glucose ≥ of 5.6 rather than 6.1 mmoll^{-1} See ''glucose intolerance'' in table 4 for the prevalence of fasting glucose ≥ 5.6 or known diabetes
Figures are percentages (95% CIs)

the NCEP 2005 definition in Europeans. Agreement with the WHO definition was moderate; for example, kappa values 0.51 to 0.65 (Table 5), for more than a third of those with the WHO-defined syndrome not having the IDF defined syndrome. Agreement with the NCEP-defined syndrome for 2001 and 2005 was good only in the Europeans.

In women, the prevalence of IDF-defined MS ranged from 16.5% in Chinese to 23.3 in Europeans, to 38.0% in the South Asians. This was significantly higher than the WHO definition in Chinese (P=.027) and Europeans (P<.001), and than the NCEP 2001 ($P\leq$ .001) and 2005 (P<.05) definition in all groups. Agreement with the IDF definition was moderate to good for all groups for both WHO and NCEP definitions (Table 5). Indeed, with the exception of the Chinese for the WHO-defined MS, more than 80% of those with either WHO-defined or the NCEP-defined MS, by either definition, also had the IDF-defined MS.

Biological and Metabolic Characteristics

The phenotypic characteristics of the different definitions of metabolic syndrome were very similar within each ethnic group, for men and women (Table 6). The only clear difference in men was that the mean waist circumference was higher in the IDF definition compared to the WHO definition, and compared non-significantly to the NCEP definition. In women, waist circumference with the IDF definition tended to be lower than the other definitions but this was not statistically significant.

We found some differences between ethnic groups in the phenotypic characteristics of those with MS (Table 6). For example, insulin resistance, as assessed by HOMA, differed between the ethnic groups, tending to be highest in South Asians and lowest in Chinese. Also, of those with MS, Europeans had the higher body mass indices and South Asians had higher waist-to-hip ratios but lower systolic and diastolic blood pressures.

DISCUSSION

The International Diabetes Federation (IDF) definition of metabolic syndrome is intended to replace other definitions and provide a single practical definition that would be useful in any country, both for clinical purposes and for studying the epidemiology of the syndrome.[12] Our aim in this study was to investigate how this new definition compared to two previously widely disseminated definitions, WHO(1999)[7] and NCEP(2001)[8], and to the recently

Table 4. Prevalence of the IDF defined metabolic syndrome and its components

	Men			Women		
	Chinese	European	S Asian	Chinese	European	S Asian
	n=171	*n*=257	*n*=264	*n*=185	*n*=301	*n*=295
High waist circumference	23.9 (17.5–30.3)	38.1 (32.2–44.0)	61.9 (56.0–67.8)	36.9 (29.9–43.9)	38.4 (32.9–43.9)	69.0 (63.7–74.3)
Hypertension	27.1 (20.4–33.8)	43.8 (37.7–49.9)	25.6 (20.3–30.9)	27.0 (20.6–33.4)	20.7 (16.1–25.3)	18.8 (14.3–23.3)
Low HDL cholesterol	16.3 (10.8–21.8)	20.6 (15.7–25.5)	36.4 (30.6–42.2)	15.0 (9.9–20.1)	19.3 (14.8–23.8)	40.7 (35.1–46.3)
Raised triglycerides	18.7 (12.9–24.5)	35.7 (29.8–41.6)	54.3 (48.3–60.3)	11.3 (6.7–15.9)	29.5 (24.3–34.7)	34.1 (28.7–39.5)
Glucose intolerance	46.6 (39.1–54.1)	65.3 (59.5–71.1)	72.2 (66.8–77.6)	41.8 (34.7–48.9)	53.4 (47.8–59.0)	50.7 (45.0–56.4)
Metabolic syndrome	12.3 (7.4–17.2)	24.7 (19.4–30.0)	45.5 (39.5–51.5)	16.5 (11.2–21.8)	23.3 (18.5–28.1)	38.0 (32.5–43.5)

Figures are percentages (95% CIs)

Table 5. Agreement between IDF-defined metabolic syndrome and WHO and NCEP definitions. Number of cases, kappa statistic (95% CIs), and *P* value for difference in prevalence (based on McNemar's test)

	WHO Definition				NCEP 2001 Definition				NCEP 2005 Definition			
IDF Definition	Yes	No	Total	kappa	Yes	No	Total	kappa	Yes	No	Total	Kappa
MEN												
Chinese												
Yes	11	10	21	0.51	2	19	21	0.10	6	15	21	0.30
No	7	143	150	(.31–.71)	4	146	150	(0–.25)	6	144	150	(.13–.47)
Total	18	153	171	*P*=.6	6	165	171	*P*=.003	12	159	171	*P*=.078
European												
Yes	54	17	71	0.63	48	23	71	0.63	61	10	71	0.69
No	22	164	186	(.44–.81)	13	173	186	(.45–.82)	24	162	186	(.48–.89)
Total	76	181	257	*P* =1.0	61	196	257	*P* =.3	85	172	257	*P* =.004
South Asian												
Yes	112	24	136	0.57	65	71	136	0.40	89	47	136	0.51
No	33	95	128	(.40–.73)	9	119	128	(.27–.53)	18	110	128	(.36–.66)
Total	145	119	264	*P* =.2	74	190	264	*P* <.001	107	157	264	*P* =.006
WOMEN												
Chinese												
Yes	13	15	28	0.52	13	15	28	0.58	17	11	28	0.68
No	4	153	157	(.33–.72)	1	156	157	(.36–.79)	2	155	157	(.44–.93)
Total	17	168	185	*P* =.027	14	171	185	*P* =.001	19	166	185	*P* =.035
European												
Yes	55	33	88	0.67	50	38	88	0.61	64	24	88	0.71
No	4	209	213	(.49–.86)	5	208	213	(.44–.78)	10	203	213	(.51–.75)
Total	59	242	301	*P* <.001	55	246	301	*P*<.001	74	227	301	*P*=.043
South Asian												
Yes	106	31	137	0.68	88	49	137	0.64	110	27	137	0.79
No	16	142	158	(.49–.86)	2	156	158	(.47–.82)	4	154	158	(.55–1)
Total	122	173	295	*P* =.096	90	205	295	*P* <.001	114	181	295	*P*<.001

modified NCEP definition(2005).[9] We used population-based data from three ethnic groups previously shown to have different patterns of glucose intolerance and cardiovascular disease risk factors.

The WHO definition included criteria, such as a measure of insulin resistance, making it impractical for many clinical and epidemiological purposes.[7] The National Cholesterol Education Programs was a more practical definition,[8] and has been used in clinical practice and in epidemiological studies. The IDF definition retains the practical nature of the NCEP definition but differs in two important respects. It insists that central obesity, as assessed by waist circumference, is present, and it provides specific cut points for waist circumference among ethnic groups. Although the most recent NCEP description[9] provides specific cut points for ethnic groups, it only suggests these "can be invoked" and for this reason we chose to examine the impact of the definition according to the lower glucose cut point only.

It is noteworthy, if not surprising, that within each ethnic group the phenotypic characteristics of those with the metabolic syndrome by any definition were largely the same, with the main exception being a larger waist circumference in men with the IDF compared to the WHO-defined syndrome. However, some notable differences existed in phenotypic characteristics of those with MS between ethic groups. For example, South Asians with MS tended to have higher insulin resistance (as assessed by HOMA) and lower blood pressure than those with MS in the other groups. Thus, the risk of adverse outcomes associated with the diagnosis of MS is likely to differ to some extent between these ethnic groups.

In men, the IDF definition, compared to the WHO definition, had little impact on prevalence. However, it was higher in Chinese and South Asian men compared to NCEP(2001), reflecting lower waist cut points in these groups compared to the Europeans. The impact of the IDF definition on prevalence was greater in women than men, being higher than the WHO definition in Chinese and Europeans, and than NCEP, both old and new, in all groups. The agreement between the definitions was also better in women, with the vast majority of those classified by WHO or NCEP also being classified as metabolic syndrome by IDF. In men, this was not the case for a substantial minority of WHO- and NCEP-defined cases.

Our data were collected in the 1990s in the northeast region of England.

Table 6. Selected biological and metabolic characteristics for those with WHO, NCEP and IDF definitions of metabolic syndrome

		Men						Women					
		Chinese		European		S Asian		Chinese		European		S Asian	
		Mean	(95% CIs)	Mean	(95% CIs)	Mean	(95% CIs)	Mean	(95% CIs)	Mean	(95% CIs)	Mean	(95% CIs)
Age (yrs)	WHO	49.8	(44.8–54.8)	52.6	(50.5–54.7)	50.1	(48.4–51.7)	47.4	(42.2–52.5)	54.1	(51.6–56.5)	51.3	(49.7–53.0)
	NCEP01	50.5	(40.6–60.4)	50.9	(48.4–53.4)	51.6	(49.4–53.9)	50.8	(46.5–55.1)	54.4	(51.9–56.9)	51.5	(49.7–53.4)
	NCEP05	51.5	(45.6–57.4)	50.9	(48.8–52.9)	49.9	(47.9–51.9)	51.5	(45.6–57.4)	50.9	(48.8–52.9)	49.9	(47.9–51.9)
	IDF	49.8	(45.4–54.2)	51.8	(49.5–54.1)	50.3	(48.6–52.0)	47.0	(43.2–50.8)	54.0	(52.1–55.9)	50.7	(49.1–52.3)
BMI (kg/m^2)	WHO	27.5	(26.3–28.6)	29.2	(28.4–30.0)	27.7	(27.1–28.3)	27.2	(25.5–28.9)	31.8	(30.3–33.3)	30.8	(29.8–31.7)
	NCEP01	26.6	(24.6–28.6)	29.9	(28.9–30.8)	28.3	(27.5–29.1)	28.0	(26.4–29.6)	32.7	(31.2–34.2)	31.6	(30.6–32.7)
	NCEP05	26.8	(25.2–28.3)	29.1	(28.3–29.9)	28.1	(27.4–28.9)	27.2	(25.8–28.6)	31.7	(30.4–33.1)	31.3	(30.4–32.2)
	IDF	27.9	(27.0–28.8)	30.0	(29.2–30.8)	28.5	(27.9–29.0)	27.2	(26.2–28.1)	31.3	(30.1–32.4)	30.6	(29.9–31.4)
WHR	WHO	0.92	(0.91–0.93)	0.97	(0.96–0.98)	1.00	(0.99–1.00)	0.90	(0.88–0.92)	0.87	(0.85–0.88)	0.92	(0.90–0.93)
	NCEP01	0.90	(0.88–0.92)	0.97	(0.96–0.99)	1.01	(0.99–1.02)	0.89	(0.86–0.91)	0.86	(0.85–0.88)	0.93	(0.91–0.94)
	NCEP05	0.91	(0.89–0.93)	0.97	(0.96–0.98)	1.00	(0.98–1.01)	0.90	(0.88–0.92)	0.85	(0.84–0.87)	0.92	(0.91–0.93)
	IDF	0.93	(0.91–0.94)	0.98	(0.97–0.99)	1.00	(0.99–1.01)	0.88	(0.86–0.90)	0.86	(0.85–0.87)	0.91	(0.89–0.92)
Waist (cm)	WHO	92.4	(90.1–94.8)	100.5	(98.4–102.6)	97.5	(96.1–98.9)	87.7	(84.0–91.4)	94.8	(91.8–97.9)	95.2	(93.4–97.0)
	NCEP01	89.2	(86.0–92.3)	102.6	(100.2–104.9)	99.6	(97.7–101.5)	90.9	(87.7–94.0)	96.6	(93.4–99.8)	97.5	(95.6–99.5)
	NCEP05	91.2	(87.1–95.3)	100.4	(98.3–102.5)	98.6	(96.8–100.5)	89.5	(86.5–92.5)	93.8	(91.0–96.7)	96.4	(94.6–98.2)
	IDF	95.4	(93.4–97.4)	104.0	(102.3–105.6)	99.8	(98.6–101.0)	87.6	(85.4–89.8)	93.4	(91.1–95.6)	94.5	(92.9–96.1)
dBP (mm Hg)	WHO	83.4	(78.3–88.5)	87.3	(85.3–89.4)	74.8	(73.1–76.6)	88.4	(83.1–93.7)	77.3	(74.3–80.2)	73.2	(71.4–75.0)
	NCEP01	78.6	(73.6–83.6)	87.1	(85.1–89.2)	76.4	(74.0–78.7)	90.0	(85.1–94.9)	77.5	(74.5–80.5)	73.2	(71.2–75.1)
	NCEP05	85.4	(80.1–90.7)	87.4	(85.5–89.3)	75.6	(73.7–77.5)	88.5	(83.9–93.1)	77.0	(74.5–79.5)	73.3	(71.4–75.1)
	IDF	85.1	(80.5–89.7)	87.0	(84.9–89.0)	76.2	(74.7–77.8)	86.6	(82.3–90.8)	76.4	(74.3–78.5)	72.9	(71.3–74.5)
sBP (mm Hg)	WHO	138.9	(129.3–148.5)	144.8	(140.8–148.8)	124.7	(121.9–127.5)	140.3	(130.2–150.3)	141.1	(135.3–146.9)	129.0	(124.9–133.0)
	NCEP01	132.7	(123.1–142.2)	146.0	(141.9–150.2)	129.1	(125.0–133.2)	143.5	(133.4–153.6)	140.9	(134.9–147.0)	130.5	(125.8–135.2)
	NCEP05	138.5	(128.6–148.5)	144.5	(141.1–147.9)	126.8	(123.6–130.1)	141.4	(131.8–151.0)	138.5	(133.6–143.4)	129.8	(125.7–133.9)
	IDF	135.6	(128.4–142.8)	143.8	(139.8–147.9)	126.5	(123.8–129.3)	139.3	(131.3–147.2)	136.9	(132.7–141.1)	127.9	(124.2–131.6)
HDL* (mmoll^{-1})	WHO	1.11	(1.01–1.21)	1.12	(1.05–1.20)	1.01	(0.96–1.06)	1.29	(1.16–1.44)	1.29	(1.21–1.38)	1.18	(1.13–1.23)
	NCEP01	0.96	(0.74–1.24)	1.09	(1.02–1.17)	0.94	(0.89–1.00)	1.24	(1.10–1.40)	1.31	(1.22–1.41)	1.12	(1.06–1.17)
	NCEP05	1.03	(0.85–1.25)	1.13	(1.06–1.21)	0.96	(0.91–1.01)	1.26	(1.15–1.39)	1.33	(1.25–1.41)	1.13	(1.08–1.18)
	IDF	1.23	(1.10–1.38)	1.13	(1.06–1.20)	1.01	(0.96–1.06)	1.32	(1.21–1.45)	1.34	(1.27–1.42)	1.17	(1.12–1.21)
Trigs* (mmoll^{-1})	WHO	1.88	(1.58–2.25)	2.29	(2.06–2.55)	2.37	(2.18–2.58)	1.51	(1.19–1.92)	2.19	(1.96–2.45)	1.97	(1.83–2.13)
	NCEP01	2.21	(1.93–2.52)	2.33	(2.05–2.64)	2.78	(2.52–3.07)	1.74	(1.34–2.25)	2.26	(2.04–2.51)	2.05	(1.87–2.25)
	NCEP05	1.87	(1.61–2.17)	2.28	(2.04–2.54)	2.70	(2.49–2.93)	1.64	(1.34–2.01)	2.24	(2.05–2.46)	1.97	(1.81–2.15)
	IDF	1.51	(1.26–1.81)	2.04	(1.81–2.30)	2.48	(2.28–2.71)	1.45	(1.19–1.78)	2.06	(1.88–2.26)	1.92	(1.78–2.07)
HOMA*	WHO	3.18	(2.16–4.70)	3.58	(3.07–4.18)	6.08	(5.41–6.83)	3.61	(2.82–4.61)	4.45	(3.72–5.33)	5.38	(4.79–6.03)
	NCEP01	1.67	(0.72–3.87)	3.63	(2.98–4.41)	7.09	(6.14–8.19)	3.28	(2.39–4.49)	3.96	(3.29–4.76)	5.77	(5.04–6.61)
	NCEP05	2.17	(1.25–3.78)	3.15	(2.66–3.73)	6.30	(5.56–7.14)	2.99	(2.31–3.87)	3.87	(3.28–4.56)	5.43	(4.83–6.11)
	IDF	3.32	(2.50–4.41)	3.55	(2.99–4.21)	5.99	(5.31–6.76)	2.80	(2.28–3.45)	3.60	(3.12–4.17)	5.08	(4.56–5.66)
Diabetes† (%)	WHO	16.7	(3.58–41.4)	27.6	(18.0–39.1)	44.1	(36.1–52.2)	11.8	(1.46–36.4)	30.5	(19.2–43.9)	34.4	(26.0–42.9)
	NCEP01	-	-	21.3	(11.9–33.7)	47.3	(35.6–59.2)	14.3	(1.78–42.8)	25.5	(14.7–39.0)	42.2	(31.9–53.1)
	NCEP05	8.3	(0.21–38.5)	21.2	(13.1–31.4)	42.1	(32.7–51.4)	15.8	(3.39–39.6)	24.3	(15.1–35.7)	36.8	(28.0–45.7)
	IDF	4.8	(0.12–23.8)	21.1	(12.3–32.4)	39.7	(31.5–47.9)	10.7	(2.26–28.2)	20.5	(12.6–30.4)	33.6	(25.7–41.5)

* Geometric means

† Previously diagnosed and diagnosed at screening (following WHO 1999 criteria)

Values are means (95% CIs), geometric means (95% CIs) or percentages (95% CIs) as indicated.

Given the trends in obesity,[21] it is likely that components of the metabolic syndrome are even more common now than when our data were collected. This would underline our key public health messages. It would be unlikely, however, that new data would significantly alter our observations on the relative performance of the three definitions of metabolic syndrome. Clearly, newer studies are needed to confirm, or refute, our observations.

Metabolic syndrome is a highly prevalent condition, with the IDF definition being present in around one in four Europeans and more than one in three South Asians. The value of the concept of metabolic syndrome has been questioned[22] and certainly current data do not fully support the notion of a single cluster of risk factors linked together by a single underlying mechanism. It is also not clear that the syndrome should be a target for treatment over and above treatment of the individual risk factors. If MS becomes a target for screening and clinical intervention, the workload implications are huge. Its main value in clinical terms is to highlight that certain risk factors tend to cluster within individuals and to help focus attention on these at-risk individuals. Its main value in public health terms is to highlight the clustering of risk factors associated with overweight, especially abdominal obesity, and physical inactivity. This clustering is known to be associated with a markedly increased risk of cardiovascular disease and diabetes. Thus, the high prevalence of the syndrome is further evidence of the huge public health need to reduce obesity and increase physical activity.

ACKNOWLEDGMENTS

The authors thank all the subjects who participated in the study, and all the people who assisted with the data collection. The Newcastle Heart Project was funded by grants from the Barclays Trust; UK government Department of Health; and Newcastle RVI Hospital Trustees.

REFERENCES

1. Vague J. The degree of masculine differentiation of obesities: a factor determining predisposition to diabetes, atherosclerosis, gout and uric calculus disease. *Am J Clin Nutr*. 1956;4:20–34.
2. Camus JP. Goutte, diabetes, hyperlipemia: un trisyndrome metabolique. *Revue du Rhumatisme et des Maladies Osteo-Articulaires*. 1966;33:10–14.
3. Reaven G. Role of insulin resistance in human disease. *Diabetes*. 1988;37:1595–607.
4. Haffner S, Valdez R, Hazuda H, Mitchell B, Morales P, Stern M. Prospective analysis of the insulin resistance syndrome (syndrome x). *Diabetes*. 1992;41:715–22.
5. Hjermann I. The metabolic cardiovascular syndrome: syndrome X, Reaven's syndrome, insulin resistance syndrome, atherothrombogenic syndrome. *J Cardiovasc Pharmacol*. 1992;20:S5–S10.
6. Taskinen MR. Strategies for the diagnosis of metobolic syndrome. *Current Opinion in Lipidology*. 1993;4:434–443.
7. World Health Organization. Definition, diagnosis, and classification of diabetes mellitus and its complications. Report of a WHO consultation. Part 1: Diagnosis and classification of diabetes mellitus. Geneva: WHO. 1999.
8. Adult Treatment Panel III. 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.
9. Grundy SM, Cleeman JI, Daniels SR, Donato KA, Eckel RH, Franklin BA, et al. Diagnosis and management of the metabolic syndrome: an American Heart Association/National Heart, Lung, and Blood Institute Scientific Statement. *Circulation*. 2005;112:2735–2752.
10. Balkau B, Charles MA. Comment on the provisional report from the WHO consultation. European Group for the Study of Insulin Resistance (EGIR). *Diabetic Medicine*. 1999; 16:442–443.
11. Einhorn D, Reaven GM, Cobin RH, et al. American College of Endocrinology position statement on the insulin resistance syndrome. *Endocrine Practice*. 2003;9:237–252.
12. Alberti KGMM, Zimmet P, Shaw J. The metabolic syndrome: a new worldwide definition. *Lancet*. 2005;366:1059–1062.
13. Bhopal R, Unwin N, White M, et al. Heterogeneity of coronary heart disease risk factors in Indian, Pakistani, Bangladeshi, and European origin populations: cross sectional study. *BMJ*. 1999;319:215–20.
14. Unwin N, Harland J, White M, et al. Body mass index, waist-hip ratio and glucose intolerance in Chinese and European adults. *J Epidemiol Community Health*. 1997; 51:160–6.
15. Harland J, White M, Bhopal R, Raybould S, Unwin N, Alberti K. Identifying Chinese populations in the UK for epidemiological research: experience of a name analysis of the FHSA register. *Public Health*. 1997;111: 331–7.
16. Chaturvedi N, McKeigue PM. Methods for epidemiological surveys of ethnic minority groups. *J Epidemiol Community Health*. 1994;48:107–111.
17. Fischbacher CM, Bhopal R, Rutter MK, et al. Microalbuminuria is more frequent in South Asian than in European origin populations: a comparative study in Newcastle, UK. *Diabetic Medicine*. 2003;20:31–36.
18. Matthews DR, Hosker JP, Rudenski AS, Naylor BA, Treacher DF, Turner DF. Homeostasis model assessment: insulin resistance and B-cell function from fasting plasma glucose and insulin concentrations in man. *Diabetologia*. 1985;28:412–419.
19. Altman DG. *Practical Statistics for Medical Research*. London: Chapman & Hall, 1991;431–433.
20. Gardner M, Altman D. *Confidence Interval Analysis*. London: British Medical Publications. 1991.
21. Skidmore PM, Yarnell JW. The obesity epidemic: prospects for prevention. *Q J of Medicine*. 2004;97:817–825.
22. Kahn R, Buse J, Ferrannini E, Stern M. The metabolic syndrome: time for a critical appraisal. Joint statement from the American Diabetes Association and the European Association for the Study of Diabetes. *Diabetes*. 2005;28:2289–2304.

AUTHOR CONTRIBUTIONS

Design concept of study: Unwin, Bhopal
Acquisition of data: Unwin, Bhopal, Patel
Data analysis and interpretation: Unwin, Bhopal, Hayes, White, Patel
Manuscript draft: Unwin, Bhopal, Hayes, White, Patel, Ragoobirsingh
Statistical expertise: Unwin, Hayes
Acquisition of funding: Unwin, Bhopal, White
Administrative, technical, or material assistance: Unwin, Patel, Ragoobirsingh
Supervision: Unwin, Bhopal