Original Paper

Prevalence of the Metabolic Syndrome in the United States National Health and Nutrition Examination Survey 1999–2002 According to Different Defining Criteria

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*The authors studied the prevalence of the metabolic syndrome in the 1999–2002 National Health and Nutrition Examination Survey (NHANES) according to the World Health Organization, National Cholesterol Education Program (NCEP), and International Diabetes Federation (IDF) definitions. There was 92.9% agreement between the NCEP and IDF definitions. The IDF prevalence was higher (*p=*0.001) due to more men fulfilling its criteria than the NCEP's (39.9±1.7% vs. 33.6±1.6%;* p=*0.007). If central obesity were not a prerequisite, the IDF prevalence would increase slightly to 40.3±1.1%. Subjects categorized as having the metabolic syndrome under IDF but not NCEP tended to be men, younger, and leaner. Their prevalence of self-reported coronary heart disease was not significantly different from that of other metabolic syndrome patients. Whether waist circumference is a prerequisite does not affect the diagnosis of the metabolic syndrome in the United States. The IDF definition identifies additional individuals at risk for cardiovascular disease. (J Clin Hypertens. 2006;8:562–570)* ©2006 Le Jacq

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The metabolic syndrome is a clustering of abnormalities including obesity, dyslipidemia, abnormal blood glucose, and raised blood pressure.[1] Reaven[2] was the first to draw attention to this syndrome, which he called "Syndrome X." Its importance is increasingly recognized in recent years because of its association with cardiovascular disease and the development of diabetes.[3–7] The metabolic syndrome is almost certainly not a single pathologic entity and, because of its heterogeneity, there have been successive attempts to define it.[8–11] No definition of the metabolic syndrome is entirely satisfactory. What the syndrome is and even its existence is controversial.[12] The World Health Organization (WHO) proposed a definition in 1998.[8] In 2001, 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) (NCEP ATP III) defined the metabolic syndrome in terms of waist circumference, blood pressure, and blood biochemistry.[9] This was adopted by the American Heart Association in 2004, but the fasting glucose cut point was lowered, from ≥110 mg/dL (≥6.1 mmol/L) to ≥100 mg/dL (5.6 mmol/L).[10] In 2005, the International Diabetes Federation (IDF)

notably redefined the metabolic syndrome and made abdominal obesity as measured by waist circumference a prerequisite in the definition.[11] Thus, nonobese persons who were previously classified as having the syndrome will not be so classified under the new IDF definition. On the other hand, the waist circumference thresholds in the IDF definition are lower than those in the NCEP ATP III. Accordingly, we set out to: 1) provide estimates of the prevalence of the metabolic syndrome in the United States using the latest data (1999–2002) from the National Health and Nutrition Examination Survey (NHANES); 2) compare the prevalence of the metabolic syndrome using different definitions; and 3) ascertain whether the new IDF definition applies equally to white, black, and Hispanic Americans.

METHODS

NHANES is a large health and nutritional survey of the civilian noninstitutionalized population of the United States.[13] Its methodology has been described in previous publications and also on its Web site.[14–16] Since 1999, it has become a continuous survey. The 2001–2002 NHANES results are available online.[17] The 1999–2000 and 2001–2002 datasets were combined in our analysis to achieve more accurate and reliable estimates of the prevalence of the metabolic syndrome in different subgroups. All participants gave informed consent, and the study received approval from the Centers for Disease Control and Prevention Institutional Review Board.

Data extracted from the database included age, sex, race/ethnicity, body mass index (BMI), blood pressure, glucose, insulin and lipids, urinary albumin and creatinine, and history of hypertension, diabetes mellitus, coronary heart disease, angina, heart attack, congestive heart failure, and stroke. BMI was defined as weight in kilograms divided by the square of the height in meters. Blood pressure was measured manually by a trained operator according to a standard protocol.

Diabetes was defined as a fasting plasma glucose ≥126 mg/dL (≥7.0 mmol/L) or a plasma glucose ≥200 mg/dL (≥11.1 mmol/L) at 2 hours in a glucose tolerance test. Participants receiving drug treatment for diabetes and self-reported diabetes were classified as having diabetes. Impaired fasting glucose (IFG) was defined as a fasting plasma glucose of 100–125 mg/dL (5.6–6.9 mmol/L). Impaired glucose tolerance (IGT) was defined as a plasma glucose of 140–199 mg/dL (7.8–11.0 mmol/L) at 2 hours in a glucose tolerance test.

WHO Definition

According to the WHO definition,[8] a person has the metabolic syndrome if he or she has diabetes, IGT, IFG, or insulin resistance plus two or more of the following:

- Blood pressure ≥160/90 mm Hg
- Triglyceride concentration ≥150 mg/dL (1.695 mmol/L) and/or high-density lipoprotein (HDL) cholesterol <35 mg/dL (0.9 mmol/L) in men and <39 mg/dL (1.0 mmol/L) in women
- Waist-to-hip ratio >0.90 in men or >0.85 in women and/or BMI >30 kg/m^2
- Urinary albumin excretion rate ≥20 μg/min or an albumin-to-creatinine ratio ≥20 mg/g

Insulin resistance was defined as the upper quartile (≥3.39) of the distribution of the calculated homeostasis model assessment, which is the product of the fasting plasma insulin (mU/L) and fasting plasma glucose (mmol/L) divided by 22.5 after excluding participants with self-reported diabetes or fasting plasma glucose ≥126 mg/dL.[18] In NHANES 1999–2002, glucose tolerance test, waist-to-hip ratio, and urinary albumin excretion rate were not performed. People who had IGT but not IFG or diabetes could not be identified. Therefore, our estimate of the metabolic syndrome by applying the WHO definition to the NHANES data might underestimate the prevalence.

NCEP Definition

A person has the metabolic syndrome according to the NCEP definition[9,10] if he or she has three or more of the following criteria:

- Waist circumference >102 cm in men and >88 cm in women
- Triglyceride concentration ≥150 mg/dL (1.695 mmol/L)
- HDL cholesterol <40 mg/dL (1.036 mmol/L) in men and <50 mg/dL (1.295 mmol/L) in women
- Blood pressure ≥130/85 mm Hg
- Fasting glucose ≥100 mg/dL (5.6 mmol/L)[10]

A participant on drug treatment for hypertension and diabetes would be regarded as fulfilling the blood pressure and fasting glucose criteria, respectively. In the original NCEP ATP III definition, the fasting glucose cut point was ≥110 mg/dL (≥6.1 mmol/L).[9] This was lowered to ≥100 mg/dL in the revised definition.[10]

IDF Definition

According to the IDF definition,[11] a person has the metabolic syndrome if he or she has central obesity (defined as a waist circumference ≥94 cm for male and 80 cm for female Europids [white persons of

European origin regardless of where they live]) and ethnic-specific levels in Chinese, Japanese, and South Asians; together with two of the following:

- Triglyceride concentration ≥1.7 mmol/L (150 mg/dL), or specific treatment for this lipid abnormality
- HDL cholesterol <1.04 mmol/L (40 mg/dL) in men and <1.29 mmol/L (50 mg/dL) in women, or specific treatment for this lipid abnormality
- Blood pressure ≥130/85 mm Hg, or treatment of previously diagnosed hypertension.
- Fasting glucose ≥5.6 mmol/L (100 mg/dL) or previous diagnosis of diabetes or IGT

In our analysis, Europid cut points for waist circumference were used for non-Hispanic whites (≥94 cm in men and ≥80 cm in women). For non-Hispanic blacks, the Sub-Saharan African cut points were used (≥94 cm in men and ≥80 cm in women) whereas for Mexican Americans and other Hispanics, the ethnic South and Central American cut points were used (≥90 cm in men and ≥80 cm in women). For those of other races or multiracial backgrounds (about 3.1% of the total US population), the Europid cut points were used. Agreement between two definitions was the percentage of participants who were classified the same under both definitions.

The laboratory methods are described in detail on the NHANES Web site.[13] Briefly, serum glucose was measured in an enzymatic reaction (Cobas Mira assay, Roche, Basel, Switzerland). Using a Hitachi 704 analyzer, serum triglycerides were measured after hydrolysis to glycerol, while HDL cholesterol was measured after precipitation of other lipoproteins with a heparin-manganese chloride mixture. Insulin was measured by radioimmunoassay (Pharmacia Diagnostics, Uppsala, Sweden). Urinary creatinine was measured colorimetrically on a Beckman Synchron AS/ASTRA clinical analyzer (Beckman Instruments, Brea, CA). Urinary albumin was measured using a Sequoia-Turner fluorometer (Mountain View, CA). The diagnoses of coronary heart disease, angina, congestive heart failure, heart attack, and stroke were reported by the subject. Pregnant women and subjects who fasted <8 hours were not included in the analysis.

Data were analyzed using SAS version 9.1 (SAS Institute Inc., Cary, NC) or, after conversion of files, SPSS (SPSS for Windows, version 13, SPSS Inc., Chicago, IL). We stratified the subjects with respect to race/ethnicity (non-Hispanic white, African American, Mexican American, and other), sex, and age. In NHANES, African Americans, Mexican Americans, and persons aged 60 years or older were oversampled to provide better estimates of these groups. To adjust for oversampling and nonresponse bias, sampling weights were used in the calculation of means (SURVEYMEANS) and in regression analysis (SURVEYREG) to approximate the distribution of the US population in the year 2000.[19] Logistic analysis was performed with coronary heart diseases, angina, congestive heart failure, heart attack, and stroke as dependent variables and age, sex, race/ethnicity, and the metabolic syndrome as predictor variables.

RESULTS

A total of 3584 participants, for whom complete data were available to diagnose the metabolic syndrome according to NCEP and IDF definitions, were included in the analysis. Their characteristics are shown in Table I. The data were adjusted according to the ethnic distribution of the US population. The mean age was 46.1 (SD, 33.5) years. Persons 60 years or older accounted for 21.9% of the population, whereas women accounted for 50.5%. The majority were non-Hispanic whites (73.6%). Non-Hispanic blacks and Mexican Americans formed 10.1% and 6.9% of the population, respectively. The mean BMI was 27.8 (SD, 10.8) kg/m^2. The mean blood pressure was 122.7/72.6 (SD, 25.0/21.3) mm Hg. Diabetes mellitus was present in 8.9% of the population.

Compared with the NCEP and IDF criteria, the WHO criteria identified people with higher BMI and waist circumferences. The reduction of the fasting glucose cut point in the revised NCEP guidelines has the effect of increasing the number of individuals fulfilling the criteria of the metabolic syndrome, from 1156 (28.6%) to 1387 (34.5%), representing a 5.9% increase ($p<0.001$), but there was no significant change in the age, sex, race/ethnic distribution, BMI, or blood pressure ($p>0.05$). The change in the fasting glucose cut point increased the number of people with IFG but reduced the proportion with diabetes.

Table II shows the prevalence of the individual components of the metabolic syndrome using alternate definitions, adjusted for the distribution of the US population. The prevalence of the five components of the metabolic syndrome under the NCEP and IDF definitions in the United States ranged from 33.1% for raised triglycerides to 70.3% for central obesity (IDF criteria). The prevalence of fasting glucose ≥100 mg/dL was 35.3±1.3% but, if ≥110 mg/dL were used as the cut point, the prevalence of fasting glucose would only be 15.5±0.8%. The former seems to be more in line with the prevalence of the other metabolic syndrome components.

Table I. Characteristics of All Participants and Patients With the Metabolic Syndrome According to Different Definitions in the National Health and Nutrition Examination Survey (NHANES) 1999–2002

Characteristics	All Participants	WHO	Original NCEP ATP III*	NCEP**	IDF
Total number	3584	760	1156	1387	1564
Age (yr)	46.1±0.6	52.5±0.8	53.1±0.6	52.9±0.6	52.5±0.5
Age group (yr) (%)					
20–39	39.7±1.5	23.2±2.4	21.3±1.6	21.7±1.4	22.6±1.4
40–59	38.4±1.0	42.1±2.6	42.8±1.7	43.4±1.7	43.8±1.7
≥60	21.9±1.1	34.8±2.5	36.0±2.2	34.9±1.8	33.6±1.7
Women (%)	50.5±0.7	49.0±1.9	53.8±1.9	51.8±1.7	49.4±1.5
Race/ethnicity (%)					
Non-Hispanic white	73.6±2.1	75.1±2.4	73.8±3.1	74.4±2.9	75.0±2.7
Non-Hispanic black	10.1±1.3	9.9±1.5	8.6±1.2	8.2±1.2	7.8±1.2
Mexican American	6.9±0.9	7.3±1.1	6.6±1.0	6.9±1.0	7.2±1.0
Other	9.4±1.9	7.6±2.1	11.1±3.4	10.6±2.9	10.0±2.6
Body mass index (kg/m^2)	27.8±0.2	33.4±0.4†	31.9±0.4	31.7±0.3	31.1±0.3
Waist circumference (cm)	95.4±0.4	109.9±0.9†	107.5±0.9	106.7±0.8	105.5±0.7
Triglycerides (mg/dL)	147.3±3.7	226.3±13.4	232.8±9.9	219.0±8.2	211.8±7.2
High-density lipoprotein cholesterol (mg/dL)	50.7±0.4	43.1±0.7	42.3±0.4†	43.6±0.4	44.3±0.4
Blood pressure (mm Hg)					
Systolic	122.7±0.4	131.6±0.6	131.3±0.6	130.9±0.6	130.5±0.6
Diastolic	72.6±0.4	76.0±0.8	74.8±0.7	74.7±0.6	74.6±0.5
Hypertension (%)	29.1±1.0	64.5±2.3†	57.3±1.8††	53.9±1.8	52.1±1.7
Impaired fasting glucose (%)	27.8±1.2	60.2±2.3††	42.7±1.8††	52.5±1.6	51.0±1.9
Diabetes mellitus (%)	8.9±0.6	15.6±1.8	25.0±1.9††	21.0±1.5	19.2±1.6

Data were weighted to the US population and expressed as percent ± standard error or mean ± standard error. WHO=World Health Organization; NCEP ATP III=Third Report of the National Cholesterol Education Program Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel); IDF=International Diabetes Federation; *the fasting glucose cut point was ≥110 mg/dL; **the fasting glucose cut point was ≥100 mg/dL; $^{\dagger}p<0.01$ vs. the IDF group; $^{\dagger\dagger}p<0.05$

There were some major differences between men and women. Women were more likely to be deemed centrally obese (NCEP criteria: 55.8±1.5% vs. 36.5±1.8%; $p<0.001$; IDF criteria: 77.0±1.4% vs. 63.5±1.5%; $p<0.001$) and have low HDL (39.6±1.5% vs. 34.2±1.4%; $p=0.009$), while men were more likely to have raised triglycerides (36.7±1.8% vs. 29.7±1.0%; $p<0.001$) and raised fasting glucose (42.6±1.8% vs. 28.1±1.3%; $p<0.001$).

For central obesity, raised triglycerides, raised blood pressure, and raised fasting glucose, there was an increase in prevalence with age. The prevalence of raised blood pressure was 77.2±1.9% in persons 60 or older. In contrast, the prevalence of low HDL decreases with age, from 41.0±2.0% in the 20–39 age group, to 35.6±2.3% in the 40–59 age group, to 31.8±1.2% in the 60 years of age and older group ($p<0.001$).

The three racial/ethnic groups differed in the prevalence of the components of the metabolic syndrome. In non-Hispanic blacks, compared with non-Hispanic whites, the prevalence of raised triglycerides (16.0±2.0% vs. 35.1±1.3%; $p<0.001$) and raised fasting glucose (27.6±2.4% vs. 35.4±1.5%; $p=0.006$) was low, while the prevalence of raised blood pressure was high (47.7±2.0% vs. 41.1±1.3%; $p=0.006$). Compared with non-Hispanic whites, Mexican Americans have a higher proportion of patients with low HDL (42.9±2.1% vs. 35.9±1.7%; $p=0.010$) and raised fasting glucose (40.5±2.0% vs. 35.4±1.5%; $p=0.041$), but a lower proportion with raised blood pressure (27.0±2.0% vs. 41.1±1.3%; $p<0.001$).

Table III shows the adjusted prevalence of the metabolic syndrome in men and women of different age groups and race/ethnicity. Compared with the revised NCEP definition, the IDF definition captured a higher proportion of the US adult population (38.9±1.0% vs. 34.5±0.9%; $p=0.001$). This was largely due to more men fulfilling the IDF criteria (39.9±1.7% vs. 33.6±1.6%; $p=0.007$), whereas the prevalence of the metabolic syndrome in women was similar under the two definitions ($p=0.112$). The agreement between the revised NCEP definition and the IDF definition was excellent

Table II. Prevalence of Components of the Metabolic Syndrome Among US Adults Aged 20 Years and Older in the National Health and Nutrition Examination Survey (NHANES) 1999–2002

	n	Central Obesity (NCEP)	Central Obesity (IDF)	Raised Triglycerides (≥150 mg/dL)	Reduced HDL Cholesterol (<40 mg/dL in Men and <50 mg/dL in Women)	Raised Blood Pressure (≥130/85 mm Hg)*	Raised Fasting Glucose (≥100 mg/dL)*
Total	3584	46.2±1.2	70.3±1.0	33.1±1.0	36.9±1.2	40.5±1.1	35.3±1.3
Age group (yr)							
20–39	1160	32.6±1.6	57.2±1.4	24.6±1.4	41.0±2.0	17.7±1.3	18.9±1.4
40–59	1155	51.7±2.5	76.6±1.7	37.2±1.8	35.6±2.3	43.2±1.5	39.7±1.6
≥60	1269	61.3±1.8	83.1±0.9	41.4±1.5	31.8±1.2	77.2±1.9	57.2±1.9
Race/ethnicity							
Non-Hispanic white	1829	46.5±1.6	70.4±1.3	35.1±1.3	35.9±1.7	41.1±1.3	35.4±1.5
Non-Hispanic black	623	49.9±2.0	66.8±1.8	16.0±2.0	32.0±1.8	47.7±2.0	27.6±2.4
Mexican American	881	44.8±1.9	76.3±2.1	37.9±2.1	42.9±2.1	27.0±2.0	40.5±2.0
Men	1818	36.5±1.8	63.5±1.5	36.7±1.8	34.2±1.4	40.8±1.7	42.6±1.8
Age group (yr)							
20–39	622	22.8±2.1	48.7±1.6	29.0±2.1	35.7±2.4	23.6±2.0	25.9±2.3
40–59	571	44.8±3.4	72.9±2.4	44.9±3.1	34.3±2.8	43.5±2.3	49.7±2.2
≥60	625	49.9±2.6	77.4±1.8	37.2±2.9	30.5±2.2	72.8±2.6	64.9±2.3
Race/ethnicity							
Non-Hispanic white	939	39.9±2.2	66.4±1.6	38.4±2.2	34.7±1.9	42.1±2.0	43.8±2.1
Non-Hispanic black	301	29.3±2.9	46.0±2.6	18.9±2.8	22.2±2.6	50.8±3.8	26.9±2.9
Mexican American	451	30.5±2.8	69.3±3.9	41.9±3.2	34.9±2.7	29.1±2.9	48.3±1.8
Women	1766	55.8±1.5	77.0±1.4	29.7±1.0	39.6±1.5	40.2±1.2	28.1±1.3
Age group (yr)							
20–39	538	43.6±2.3	66.7±2.7	19.7±2.0	46.9±2.5	11.0±1.6	11.1±1.5
40–59	584	58.4±3.1	80.2±1.9	29.8±1.8	36.8±2.8	42.8±2.3	30.0±1.8
≥60	644	70.3±1.9	87.7±1.2	44.8±2.3	32.8±1.6	80.6±2.3	51.1±2.9
Race/ethnicity							
Non-Hispanic white	890	53.1±1.9	74.4±1.8	31.8±1.5	37.1±2.1	40.2±1.5	27.1±1.4
Non-Hispanic black	322	67.2±2.5	84.1±2.0	13.7±2.3	40.2±3.0	45.1±2.4	28.1±2.8
Mexican American	430	62.5±3.2	84.9±2.1	33.0±2.9	52.7±2.7	24.4±2.9	30.9±3.2

Data are weighted to the US population and are expressed as mean percentages ± standard error. NCEP=National Cholesterol Education Program; IDF=International Diabetes Federation; HDL=high-density lipoprotein; *participants using antihypertensive or antidiabetic drugs were included as those with raised blood pressure or fasting glucose, respectively

(92.9±0.6%), more so in women (95.9±0.6%) than in men (89.8±1.0%) (p<0.001). We calculated that if central obesity were not a prerequisite in the IDF definition, then the prevalence of the metabolic syndrome in men would increase from 39.9±1.7% to 41.8±1.8% and that, in women, it would increase from 38.0±1.2% to 38.7±1.2%. The agreement would be 98.0±0.4% and 99.3±0.3%, respectively. On the other hand, the agreement between IDF and WHO criteria were poorer; the former doubled the prevalence of the metabolic syndrome (38.9±1.0% vs. 19.4±0.8%; p<0.001).

Table III. Prevalence of the Metabolic Syndrome Among US Adults Aged 20 Years and Older in NHANES 1999–2002

	WHO	NCEP	IDF	Agreement of IDF With WHO	Agreement of IDF With NCEP
Total	19.4±0.8	34.5±0.9	38.9±1.0	78.2±0.9	92.9±0.6
Age group (yr)					
20–39	10.9±1.1	18.9±1.4	22.2±1.3	85.3±1.2	94.5±0.6
40–59	21.2±1.5	39.0±1.8	44.4±2.0	75.4±1.5	92.8±1.0
≥60	33.0±1.9	54.8±1.5	59.7±1.5	69.4±1.5	90.2±1.1
Race/ethnicity					
Non-Hispanic white	19.6±1.0	34.8±1.1	39.7±1.3	77.8±1.1	92.8±0.7
Non-Hispanic black	19.1±2.0	27.9±2.1	30.2±2.0	86.0±1.4	96.7±0.6
Mexican American	20.8±2.0	34.6±2.2	40.9±2.0	77.5±2.1	91.1±0.8
Men	20.1±1.3	33.6±1.6	39.9±1.7	77.1±1.1	89.8±1.0
Age group (yr)					
20–39	11.8±1.6	19.4±1.9	24.5±1.8	83.6±1.5	91.8±1.1
40–59	23.5±2.7	41.2±2.8	48.7±3.3	71.6±2.3	89.0±1.9
≥60	33.4±2.5	49.4±2.2	55.7±1.9	72.4±2.3	86.9±1.6
Race/ethnicity					
Non-Hispanic white	21.0±1.6	36.0±1.9	42.5±2.1	75.1±1.4	89.9±1.2
Non-Hispanic black	17.9±2.1	21.3±2.6	24.0±2.7	88.5±1.5	95.6±1.0
Mexican American	20.6±2.2	32.0±3.5	42.2±3.6	77.0±2.9	85.8±1.4
Women	18.6±0.9	35.3±1.2	38.0±1.2	79.4±1.3	95.9±0.6
Age group (yr)					
20–39	9.9±1.1	18.3±1.6	19.5±1.7	87.2±1.7	97.5±0.7
40–59	19.0±1.6	36.8±2.2	40.3±2.1	78.8±2.1	96.4±1.0
≥60	32.7±2.3	59.1±2.3	62.8±2.4	67.0±2.0	92.7±1.2
Race/ethnicity					
Non-Hispanic white	18.3±1.2	33.7±1.2	36.9±1.4	80.3±1.4	95.6±0.7
Non-Hispanic black	20.2±2.7	33.4±2.6	35.4±2.2	83.8±1.9	97.6±0.9
Mexican American	21.1±3.2	37.9±3.3	39.3±3.4	78.0±3.0	97.5±0.5

Data are weighted to the US population and are expressed as mean percentages ± standard error. NHANES=National Health and Nutrition Examination Survey; WHO=World Health Organization; NCEP=National Cholesterol Education Program; IDF=International Diabetes Federation

Table IV shows the prevalence of self-reported coronary heart disease, angina, congestive heart failure, heart attack, and stroke in those with or without the metabolic syndrome. The adjusted odds ratios for coronary heart disease, angina, congestive heart failure, heart attack, and stroke associated with the metabolic syndrome are also shown. The metabolic syndrome was associated with increased odds for all these conditions. After adjusting for age, sex, and race/ethnicity, the odds ratios remained significant for coronary heart disease, angina, and heart attack.

Table V compares the characteristics of participants who fulfilled both NCEP and IDF criteria with those who fulfilled either the NCEP or the IDF criteria alone. Those who fulfilled the IFD criteria only were more likely to be men in the 20–39-year age group who had a lower BMI, waist circumference, and prevalence of diabetes. The prevalence of self-reported coronary heart disease, angina, congestive heart failure, heart attack, and stroke did not differ significantly between the two groups. The odds ratio and 95% confidence intervals, adjusted for sex, age, and race/ethnicity, comparing fulfilling both NCEP and IDF criteria with fulfilling IDF criteria alone, were 1.05 (0.49–2.24) for coronary heart disease, 1.90 (0.72–4.97) for angina, 1.06 (0.40–2.78) for heart attack, 0.84 (0.32–2.16) for congestive heart failure, 1.52 (0.64–3.64) for stroke, and 0.99 (0.52–1.86) for any of the above conditions. In other words, those 234 NHANES participants who fulfilled IDF criteria but not the NCEP criteria did not differ significantly from the others who fulfilled both criteria in terms of their cardiovascular risk.

Table IV. Prevalence of Self-Reported Coronary Heart Disease, Angina, Heart Attack, Congestive Heart Failure, and Stroke in Patients With or Without the Metabolic Syndrome According to Different Definitions

	Metabolic Syndrome		No Metabolic Syndrome		Unadjusted	Adjusted
	n	Prevalence	n	Prevalence	*p* Value	Odds Ratio*
WHO						
Coronary heart disease	752	5.9±1.1	2571	2.1±0.3	<0.001	1.93 (1.18–3.16)**
Angina	755	5.6±1.0	2573	1.9±0.3	<0.001	2.01 (1.40–2.89)**
Heart attack	759	6.7±0.8	2579	1.9±0.3	<0.001	2.43 (1.72–3.43)**
Congestive heart failure	754	3.7±0.9	2577	1.2±0.2	0.007	2.04 (1.13–3.67)**
Stroke	757	4.2±0.8	2580	1.3±0.2	<0.001	2.26 (1.35–3.77)**
Any of the above	742	12.8±1.2	2560	4.9±0.5	<0.001	1.87 (1.40–2.50)**
NCEP						
Coronary heart disease	1373	5.1±0.6	2190	2.1±0.4	<0.001	1.61 (1.03–2.50)**
Angina	1377	5.0±0.6	2191	1.8±0.3	<0.001	1.80 (1.27–2.56)**
Heart attack	1384	5.3±0.6	2195	2.1±0.4	<0.001	1.61 (1.09–2.37)**
Congestive heart failure	1378	3.2±0.5	2194	1.3±0.2	0.004	1.61 (0.98–2.63)
Stroke	1384	3.2±0.5	2195	1.5±0.3	<0.001	1.23 (0.70–2.15)
Any of the above	1360	10.5±1.0	2181	5.2±0.6	<0.001	1.28 (0.93–1.75)
IDF						
Coronary heart disease	1549	5.1±0.6	2014	1.9±0.3	<0.001	1.65 (1.09–2.51)**
Angina	1554	4.7±0.6	2014	1.8±0.3	<0.001	1.56 (1.08–2.25)**
Heart attack	1561	5.3±0.7	2018	1.9±0.3	<0.001	1.75 (1.13–2.70)**
Congestive heart failure	1555	3.4±0.6	2017	1.0±0.2	<0.001	2.07 (1.18–3.63)**
Stroke	1559	2.9±0.5	2020	1.6±0.3	0.026	1.01 (0.56–1.85)
Any of the above	1535	10.3±1.0	2006	4.9±0.5	<0.001	1.27 (0.95–1.71)

Data were weighted to the US population and expressed as mean percentages ± standard error or odds ratio (95% confidential interval). WHO=World Health Organization; NCEP=National Cholesterol Education Program; IDF=International Diabetes Federation; *odds ratios were adjusted for sex, age, and race/ethnicity; **significant odds ratio (p<0.05)

DISCUSSION

NHANES is the largest nationally representative survey of the general population in the United States. Our estimate of the prevalence of the metabolic syndrome is therefore based on the most up-to-date information. Combining the 1999–2000 and 2001–2002 datasets enabled us to perform analysis in racial/ethnic subgroups.

The WHO definition, which is historically very important, is difficult to implement today because fewer glucose tolerance tests are performed and insulin sensitivity is rarely measured in clinical practice. Moreover, the definition of raised blood pressure, ≥160/90 mm Hg, needs to be revised and brought in line with current hypertension guidelines. The WHO definition identifies people with higher BMI and waist circumference and, in the NHANES population, these people have an odds ratio of over two for stroke. In contrast, the odds ratio for stroke was one if the IDF definition was used.

Whereas the WHO and NCEP ATP III criteria capture different populations,[20] our analysis showed that the revised NCEP and the IDF definitions are quite consistent, with 92.9% agreement.[21] It turns out that in the United States, 70% of the general population has central obesity according to IDF criteria and so the requirement to fulfill the waist circumference criterion is inconsequential. However, in other ethnic populations, such as in Asians, the new IDF waist circumference criteria may significantly alter the prevalence of the metabolic syndrome and our perspective of it.

With the large and representative database, we are able to draw some conclusions regarding the influence of sex, age, and race/ethnicity on the prevalence of the metabolic syndrome. Under the definitions, women were more likely to be deemed centrally obese and have low HDL. It is noteworthy that men and women have different cut points for these two criteria. Arguably, the differences in cut points accounted for the higher proportions of women fitting these criteria. Revision of the gender-specific criteria might be considered.

Our analysis confirms the well known observation that the prevalence of hypertension and diabetes increases with age. Three quarters of people aged 60 or older have raised blood pressure (≥130/85 mm Hg), making it not a very specific

Table V. Comparison of the Characteristics of Participants With the Metabolic Syndrome Identified by Both the NCEP and IDF Definition With Those Identified by the NCEP or the IDF Definition Alone

	NCEP and IDF	NCEP Only	IDF Only
Total number	1330	57	234
Age (yr)	52.9±0.5	53.2±2.4	50.1±1.4
Age group (yr) (%)			
20–39	21.3±1.3	33.0±8.4	30.0±3.9*
40–59	44.1±1.6	25.7±8.9*	42.1±4.3
≥60	34.6±1.7	41.3±7.2	27.9±3.7
Women (%)	52.8±1.7	26.2±7.9**	29.5±3.8**
Race/ethnicity (%)			
Non-Hispanic white	74.7±2.7	66.6±10.4	76.7±3.8
Non-Hispanic black	8.3±1.3	3.7±1.3*	4.9±1.3
Mexican American	6.9±1.0	7.0±1.9	9.0±1.9
Other	10.1±2.7	22.7±10.8	9.4±3.1
Body mass index (kg/m^2)	32.0±0.3	22.8±0.6**	26.3±0.2**
Waist circumference (cm)	107.6±0.8	85.2±1.3**	93.8±0.6**
Blood pressure (mm Hg)			
Systolic	130.9±0.6	129.9±2.2	127.8±1.5
Diastolic	74.7±0.6	73.4±3.5	73.7±1.2
Diabetes mellitus (%)	20.8±1.6	26.2±7.0	10.5±2.6**
Prevalence of cardiovascular disease (%)			
Coronary heart disease	5.0±0.6	7.5±3.3	5.3±1.7
Angina/angina pectoris	5.0±0.6	7.0±3.1	2.9±1.3
Heart attack	5.2±0.6	5.8±2.9	5.6±2.4
Congestive heart failure	3.3±0.6	2.0±1.4	4.1±1.6
Stroke	3.0±0.5	7.0±3.7	2.0±0.8
Any of the above	10.2±1.0	17.7±4.6	10.7±2.7

Data were weighted to the US population and expressed as mean ± standard error. NCEP=National Cholesterol Education Program; IDF=International Diabetes Federation; *p<0.05; **p<0.01 vs. NCEP and IDF group

criterion. Thus, the blood pressure criterion and, to a smaller extent, the raised fasting glucose criterion, are confounded by age.

In NHANES, minorities, including black and Mexican Americans, were oversampled to enable more accurate estimates for subgroups. Thus, for black Americans, raised blood pressure was a much greater problem than raised fasting glucose, whereas for Mexican Americans, it was the other way round. We previously reported the poor control of blood pressure in black and Mexican Americans.[22] It is worth noting that almost 40% of Mexican Americans have raised fasting glucose. They have a greater tendency toward glucose abnormality for the same degree of central obesity. Our analysis confirms that Mexican Americans should have waist circumference criteria that are different from non-Hispanic white Americans.

Our conclusions are based on data on the US general population. They may not apply to other populations in Europe, Africa, or Asia. In Asia, the criteria for diagnosis of the metabolic syndrome need to be modified, as it is recognized that certain Asian populations have a greater tendency to develop diabetes at modest levels of BMI and waist circumference.[23,24]

In conclusion, the NCEP and the IDF criteria classify more or less the same groups of Americans as having the metabolic syndrome. Whether the waist circumference is a prerequisite does not affect the diagnosis of the metabolic syndrome in the United States. The IDF definition identifies additional individuals who are at risk for cardiovascular disease. Central obesity is a severe problem in the United States, and it may become endemic unless there are drastic changes in diet and lifestyle.

References

1 Meigs JB. Invited commentary: insulin resistance syndrome? Syndrome X? Multiple metabolic syndrome? A syndrome at all? Factor analysis reveals patterns in the fabric of correlated metabolic risk factors. *Am J Epidemiol.* 2000;152:908–911.

2 Reaven GM. Banting lecture 1988. Role of insulin resistance in human disease. *Diabetes.* 1988;37:1595–1607.

3 Wilson PW, Kannel WB, Silbershatz H, et al. Clustering of

metabolic factors and coronary heart disease. *Arch Intern Med*. 1999;159:1104–1109.
4 Isomaa B, Almgren P, Tuomi T, et al. Cardiovascular morbidity and mortality associated with the metabolic syndrome. *Diabetes Care*. 2001;24:683–689.
5 Trevisan M, Liu J, Bahsas FB, et al. Syndrome X and mortality: a population-based study. Risk Factor and Life Expectancy Research Group. *Am J Epidemiol*. 1998;148:958–966.
6 Haffner SM, Valdez RA, Hazuda HP, et al. Prospective analysis of the insulin-resistance syndrome (syndrome X). *Diabetes*. 1992;41:715–722.
7 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.
8 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.
9 National Institutes of Health. *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) Executive Summary*. Bethesda, MD: National Institutes of Health, National Heart, Lung and Blood Institute; 2001. NIH publication 01–3670.
10 Grundy SM, Brewer HB Jr, Cleeman JI, et al. American Heart Association. National Heart, Lung, and Blood Institute. Definition of metabolic syndrome: Report of the National Heart, Lung, and Blood Institute/American Heart Association conference on scientific issues related to definition. *Circulation*. 2004;109:433–438.
11 Alberti KG, Zimmet P, Shaw J, for the IDF Epidemiology Task Force Consensus Group. The metabolic syndrome—a new worldwide definition. *Lancet*. 2005;366:1059–1062.
12 Kahn R, Buse J, Ferrannini E, et al. 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 Care*. 2005;28:2289–2304.
13 National Center for Health Statistics. National Health and Nutrition Examination Survey. Available at: http://www.cdc.gov/nchs/nhanes.htm. Accessed June 24, 2005.
14 Plan and operation of the Third National Health and Nutrition Examination Survey 1988–94. Series 1: programs and collection procedures. *Vital Health Stat 1*. 1994;32:1–407.
15 Ezzati TM, Massey JT, Waksberg J, et al. Sample design: Third National Health and Nutrition Examination Survey. *Vital Health Stat 2*. 1992;113:1–35.
16 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.
17 National Center for Health Statistics. The National Health and Nutrition Examination Survey (NHANES) 2000–2001 Data Files. Available at: http://www.cdc.gov/nchs/about/major/nhanes/NHANES01-02.htm. Accessed June 24, 2005.
18 Matthews DR, Hosker JP, Rudenski AS, et al. Homeostasis model assessment: insulin resistance and beta-cell function from fasting plasma glucose and insulin concentrations in man. *Diabetologia*. 1985;28:412–419.
19 Berglund PA. Analysis of complex sample survey data using the SURVEYMEANS and SURVEYREG procedures and macro coding. In: *Proceedings of the Twenty-Seventh Annual SAS Users Group International Conference*. Cary, NC: SAS Institute Inc; 2002.
20 Ford ES, Giles WH. A comparison of the prevalence of the metabolic syndrome using two proposed definitions. *Diabetes Care*. 2003;26:575–581.
21 Ford ES. Prevalence of the metabolic syndrome defined by the International Diabetes Federation among adults in the US. *Diabetes Care*. 2005;28:2745–2749.
22 Cheung BM, Ong KL, Man YB, et al. Prevalence, awareness, treatment, and control of hypertension: United States National Health and Nutrition Examination Survey 2001–2002. *J Clin Hypertens (Greenwich)*. 2006;8:93–98.
23 Patel A, Huang KC, Janus ED, et al. Is a single definition of the metabolic syndrome appropriate? A comparative study of the USA and Asia. *Atherosclerosis*. 2006;184:225–232.
24 Heng D, Ma S, Lee JJ, et al. Modification of the NCEP ATP III definitions of the metabolic syndrome for use in Asians identifies individuals at risk of ischemic heart disease. *Atherosclerosis*. 2006;186:367–373.