A Comparison of the Prevalence of the Metabolic Syndrome Using Two Proposed Definitions

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OBJECTIVE — To compare the prevalence of the metabolic syndrome using two definitions: one proposed by the Third Report of the National Cholesterol Education Program Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III [ATP III]) and one by the World Health Organization (WHO).

RESEARCH DESIGN AND METHODS — We used data from a nationally representative sample of the noninstitutionalized civilian population of the U.S. from the Third National Health and Nutrition Examination Survey, a cross-sectional health examination survey (1988–1994).

RESULTS — Among 8,608 participants aged ≥20 years, the age-adjusted prevalence was 23.9% using the ATP III definition and 25.1% using the WHO definition. Among all participants, 86.2% were classified as either having or not having the metabolic syndrome under both definitions. Estimates differed substantially for some subgroups, however. For example, in African-American men, the WHO estimate was 24.9%, compared with the ATP III estimate of 16.5%.

CONCLUSIONS — A universally accepted definition of the metabolic syndrome is needed.

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Although clustering of some metabolic abnormalities was recognized as early as 1923 (1), the coining of the term "syndrome X" in 1988 by Reaven (2) renewed the impetus to conduct research concerning this syndrome. In his description of syndrome X, Reaven considered the following abnormalities: resistance to insulin-stimulated glucose uptake, glucose intolerance, hyperinsulinemia, increased VLDL triglycerides, decreased HDL cholesterol, and hypertension. Other metabolic abnormalities that have been considered as part of the syndrome include abnormal weight or weight distribution, inflammation, microalbuminuria, hyperuricemia, and abnormalities of fibrinolysis and of coagulation (3).

People with the metabolic syndrome are at increased risk for cardiovascular disease (4) and for increased mortality from both cardiovascular disease and all causes (5). Other studies also have found that clustering of risk factors proposed to be part of the metabolic syndrome may increase the risk for coronary heart disease (6). In addition, components of the metabolic syndrome are risk factors for diabetes (7).

Because of the increased risk for morbidity and mortality associated with the metabolic syndrome, an understanding of the dimensions of this syndrome is critical both for allocating health care and research resources and for other purposes. However, generating such estimates has been complicated by the use of many definitions of the metabolic syndrome, and no standard definition has been routinely used. The World Health Organization (WHO) initially proposed a definition for the metabolic syndrome in 1998 (8). More recently, the Third Report of the National Cholesterol Education Program Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III [ATP III]) provided a new working definition of the metabolic syndrome (9). Thus, prevalence estimates of the metabolic syndrome in the same population could differ depending on the definition used.

Therefore, we set out to accomplish several goals. First, to examine how prevalence estimates might differ according to the definition used, we calculated estimates of the prevalence of the metabolic syndrome by applying the ATP III and WHO definitions to data from the Third National Health and Nutrition Examination Survey (NHANES III). Second, we aimed to compare the degree to which participants were being similarly or differently classified by the two definitions. Third, little is known about how comparably the two definitions may predict the risk of future morbidity and mortality in a population. Because we were unable to examine this issue prospectively, we compared the cross-sectional associations between the prevalence of cardiovascular disease and the metabolic syndrome using both definitions.

RESEARCH DESIGN AND METHODS

— NHANES III, conducted by the National Center for Health Statistics of the Centers for Disease Control and Prevention, was started in 1988 and completed in 1994. Using a multistage, stratified sampling design, a representative sample of the civilian noninstitutionalized population consisting of 20,050

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Abbreviations: ATP III, Adult Treatment Panel III; HOMA, homeostatis model assessment; NHANES III, Third National Health and Nutrition Examination Survey; WHO, World Health Organization.

A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.

people aged ≥17 years was recruited into the survey. After an interview in the home, participants were invited to attend one of three examination sessions: morning, afternoon, or evening. Some participants who were unable to attend the examination because of health reasons received a limited examination at home. Details about the survey and its methods have been published (10,11).

Metabolic syndrome

According to ATP III criteria (9), a participant has the metabolic syndrome if he or she has three or more of the following criteria:

1. Abdominal obesity: waist circumference >102 cm in men and >88 cm in women
2. Hypertriglyceridemia: ≥150 mg/dl (1.695 mmol/l)
3. Low HDL cholesterol: <40 mg/dl (1.036 mmol/l) in men and <50 mg/dl (1.295 mmol/l) in women
4. High blood pressure: ≥130/85 mmHg
5. High fasting glucose: ≥110 mg/dl (≥6.1 mmol/l)

According to WHO criteria (8), a participant has the metabolic syndrome if he or she has diabetes, impaired glucose tolerance, impaired fasting glucose, or insulin resistance plus two or more of the following abnormalities:

1. High blood pressure: ≥160/90 mmHg
2. Hyperlipidemia: triglyceride concentration ≥150 mg/dl (1.695 mmol/l) and/or HDL cholesterol <35 mg/dl (0.9 mmol/l) in men and <39 mg/dl (1.0 mmol/l) in women
3. Central obesity: waist-to-hip ratio of >0.90 in men or >0.85 in women and/or BMI >30 kg/m^2
4. Microalbuminuria: urinary albumin excretion rate ≥20 μg/min or an albumin-to-creatinine ratio ≥20 mg/g.

Because only fasting glucose values were available for all participants aged ≥20 years, we defined hyperglycemia for analyses involving all participants as a glucose level ≥110 mg/dl (≥6.1 mmol/l) or the current use of antidiabetic medication (insulin or oral agents). Thus, the WHO prevalence estimates for participants aged ≥20 years include patients with diabetes and impaired fasting glucose but not impaired glucose tolerance. For a second set of analyses of participants aged 40–74 years who had an oral glucose tolerance test during the morning examination, we defined diabetes, impaired glucose tolerance, and impaired fasting glucose using the baseline and 2-h glucose concentration measurements as defined by Alberti and Zimmet (8). Participants who reported using insulin did not participate in the oral glucose tolerance test, and therefore we assigned both them and participants using oral antidiabetic medications as having diabetes.

After excluding participants with self-reported diabetes or fasting blood glucose ≥126 mg/dl from our analytic sample, we defined insulin resistance as the upper quartile (≥2.68) of the distribution of the calculated homeostatis model assessment (HOMA) calculated from the following equation: $HOMA_{IR}$ = fasting insulin (μU/ml) × fasting plasma glucose (mmol/l)/22.5 (12). We used an albumin-to-creatinine ratio ≥20 mg/g because a test to determine urinary albumin excretion rate was not administered to participants.

Three readings of systolic and diastolic blood pressure were obtained from participants who attended the mobile examination center. We used the average of the last two measurements. We considered the current use of antihypertensive medication as an indication of high blood pressure. BMI was calculated from measured weight and height (weight in kilograms divided by height in meters squared). The waist circumference was measured at the high point of the iliac crest at minimal respiration to the nearest 0.1 cm. Hip circumference was measured at the maximal extension of the buttocks.

Serum glucose concentration was measured using an enzymatic reaction (Cobas Mira assay). Insulin was measured using a radioimmunoassay (insulin radioimmunoassay kit; Pharmacia Diagnostics, Uppsala, Sweden). Serum triglycerides were measured enzymatically after hydrolysis to glycerol on a Hitachi 704 analyzer (Boehringer Mannheim Diagnostics, Indianapolis, IN). HDL cholesterol was measured after precipitation of other lipoproteins with a heparin–manganese chloride mixture on a Hitachi 704 analyzer. Urinary albumin was measured using a fluorescent immunoassay on a Sequoia-Turner fluorometer (Mountain View, CA). Urinary creatinine was measured by the rate of color formation on a Beckman Synchron AS/ASTRA clinical analyzer (Beckman Instruments, Brea, CA) after creatinine reacted with picrate. Details about the laboratory procedures of all these tests are found elsewhere (11). Participants who responded affirmatively to separate questions about whether they had ever been told by a doctor that they had a heart attack, stroke, or congestive heart failure were considered to have the condition.

Pregnant women and participants who had fasted <8 h were excluded from analyses. We performed a set of analyses on a sample of participants aged 40–74 years who had an oral glucose tolerance test. We calculated the prevalence of the metabolic syndrome by age, sex, and race or ethnicity (white, African-American, Mexican-American, and other). Age adjustment was performed using the age distribution of the U.S. population in the year 2000. Because of the complex sampling design, all analyses were performed using software for the statistical analysis of correlated data (SUDAAN) to obtain proper variance estimates (13).

RESULTS — A total of 8,608 participants aged ≥20 years had complete information for the study variables and were included in the analyses. They included 4,167 men, 4,441 women, 3,500 whites, 2,372 African-Americans, 2,388 Mexican-Americans, and 348 participants of other races or ethnicities. The age-adjusted prevalences of the individual criteria of the metabolic syndrome are listed in Table 1. The high prevalence of central adiposity as defined by WHO was largely driven by the fact that 72.3% (unadjusted) of men had a waist-to-hip ratio >0.90, and 49.6% (unadjusted) of the women had a waist-to-hip ratio >0.85.

We classified 23.9 and 25.1% of the participants as having the metabolic syndrome using the ATP III definition and the WHO definition, respectively (Table 2). Among all participants, 86.2% were similarly classified under the two definitions. Under the ATP III definition but not the WHO definition, 6.2% of participants had the metabolic syndrome, and 7.6% of participants had the metabolic syndrome under the WHO definition but not the ATP III definition. Despite the similar estimates for the entire sample, substantial differences were noted for some subgroups. WHO estimates were similar to the ATP III estimates among whites but were higher for the other race or ethnic groups. The largest difference occurred

among African-American men, of whom 16.5% had the metabolic syndrome using ATP III criteria and 24.9% had the metabolic syndrome using WHO criteria.

Among the participants who were classified as having the metabolic syndrome using the ATP III criteria but not the WHO criteria, 89.0% met at least two of the four WHO criteria but did not have hyperglycemia and were not insulin resistant. Conversely, among the participants who were classified as having the metabolic syndrome using the WHO criteria but not the ATP III criteria, 82.4% had two of the ATP III criteria.

The age-adjusted serum insulin concentrations (mean ± SE) were 104.8 ± 3.5 pmol/l for 2,217 participants who met the ATP III definition of the metabolic syndrome and 50.9 ± 0.8 pmol/l for the 6,391 participants without the metabolic syndrome ($P < 0.001$). The mean age-adjusted HOMA was 4.95 ± 0.16 for participants who met the ATP III definition of the metabolic syndrome and 2.00 ± 0.03 for those without the metabolic syndrome ($P < 0.001$). The age-adjusted proportion of participants with HOMA in the top quintile was 64.1 ± 1.8% for participants who met the ATP III definition of the metabolic syndrome and 12.9 ± 0.7% for those without the metabolic syndrome ($P < 0.001$).

The age-adjusted mean serum insulin concentrations were 113.2 ± 3.1 pmol/l for 2,536 participants who met the WHO definition of the metabolic syndrome and 46.5 ± 0.6 pmol/l for the 6,072 participants without the metabolic syndrome ($P < 0.001$). The mean age-adjusted HOMA was 5.30 ± 0.15 for participants who met the ATP III definition of the metabolic syndrome and 1.81 ± 0.02 for those without the metabolic syndrome ($P < 0.001$). The age-adjusted proportion of participants with HOMA in the top quintile was 81.3 ± 1.6% for participants who met the ATP III definition of the metabolic syndrome and 5.9 ± 0.5% for those without the metabolic syndrome ($P < 0.001$).

Oral glucose tolerance test sample (participants aged 40–74 years)

A total of 2,857 participants were included in these analyses. The age-adjusted prevalences of the metabolic syndrome were 33.9 and 36.9% for the definitions from ATP III and WHO, respectively (Table 3). Of the participants,

Table 1—*Age-adjusted prevalence of individual metabolic abnormalities of the metabolic syndrome as defined by ATP III and WHO among 8,608 U.S. adults aged ≥20 years (NHANES III, 1988–1994)*

	ATP III					WHO					
	Abdominal obesity	Hypertriglyceridemia	Low HDL cholesterol	High blood pressure or medication use	High glucose or medication use	Central obesity	Hyperlipidemia	High blood pressure or medication use	Glucose >110 mg/dl or medication use	Insulin resistance	Albumin-to-creatinine ratio ≥20 mg/g
Total	38.7 ± 0.9	29.8 ± 1.1	37.0 ± 1.3	34.0 ± 0.8	12.6 ± 0.5	67.5 ± 0.9	48.6 ± 1.4	19.0 ± 0.7	12.6 ± 0.5	26.3 ± 0.9	12.6 ± 0.5
Men	30.4 ± 1.2	35.0 ± 1.7	35.1 ± 1.5	38.2 ± 1.4	15.6 ± 0.8	77.3 ± 1.1	49.5 ± 1.7	19.6 ± 1.1	15.6 ± 0.8	28.6 ± 1.3	11.1 ± 0.7
Women	46.7 ± 1.2	24.6 ± 1.0	39.1 ± 1.5	29.4 ± 0.8	9.9 ± 0.6	57.8 ± 1.3	47.8 ± 1.6	18.0 ± 0.8	9.9 ± 0.6	24.2 ± 1.2	14.1 ± 0.7
Race or ethnicity											
White	37.8 ± 0.9	30.9 ± 1.3	37.7 ± 1.6	32.8 ± 1.0	11.9 ± 0.6	66.0 ± 1.1	49.4 ± 1.6	18.2 ± 0.8	11.9 ± 0.6	23.9 ± 1.1	11.6 ± 0.6
African-American	44.8 ± 1.2	17.8 ± 0.8	28.7 ± 1.4	46.6 ± 0.9	15.2 ± 0.9	67.9 ± 0.7	37.1 ± 1.3	29.9 ± 0.9	15.2 ± 0.9	34.5 ± 1.5	17.7 ± 0.9
Mexican-American	45.5 ± 1.3	38.2 ± 1.0	39.9 ± 1.4	36.7 ± 1.2	20.0 ± 1.0	82.9 ± 0.8	56.3 ± 1.3	17.8 ± 1.0	20.0 ± 1.0	40.1 ± 1.0	15.7 ± 1.1
Other	33.8 ± 5.3	27.2 ± 3.3	37.1 ± 4.5	29.7 ± 2.9	14.1 ± 2.0	68.9 ± 2.8	48.0 ± 4.0	13.7 ± 2.1	14.1 ± 2.0	30.2 ± 3.5	14.7 ± 2.1
Men											
White	31.3 ± 1.2	36.8 ± 2.0	36.6 ± 1.7	37.3 ± 1.7	15.6 ± 1.0	78.4 ± 1.3	51.2 ± 1.8	18.8 ± 1.4	15.6 ± 1.0	27.7 ± 1.5	9.9 ± 0.8
African-American	23.5 ± 1.3	21.3 ± 1.2	22.6 ± 1.8	49.6 ± 1.6	14.5 ± 1.1	65.3 ± 1.3	34.0 ± 1.5	30.2 ± 1.3	14.5 ± 1.1	29.3 ± 1.8	18.5 ± 1.3
Mexican-American	30.0 ± 1.9	40.2 ± 1.5	34.1 ± 2.2	39.8 ± 1.8	21.1 ± 1.4	86.7 ± 1.0	52.9 ± 1.8	20.2 ± 1.3	21.1 ± 1.4	37.8 ± 2.0	13.4 ± 1.6
Other	26.6 ± 7.5	29.1 ± 4.0	33.2 ± 5.2	34.3 ± 4.0	14.9 ± 3.4	72.6 ± 4.4	47.0 ± 4.5	16.1 ± 3.2	14.9 ± 3.4	30.1 ± 4.4	13.1 ± 2.9
Women											
White	43.8 ± 1.4	24.8 ± 1.1	39.1 ± 1.9	27.8 ± 0.9	8.4 ± 0.6	53.4 ± 1.5	47.8 ± 2.1	17.1 ± 0.9	8.4 ± 0.6	20.3 ± 1.3	13.5 ± 0.8
African-American	62.3 ± 1.6	14.7 ± 1.0	33.9 ± 1.7	43.8 ± 1.3	15.7 ± 1.4	70.0 ± 1.2	39.7 ± 1.7	29.6 ± 1.3	15.7 ± 1.4	38.7 ± 2.3	17.1 ± 1.0
Mexican-American	63.2 ± 1.8	35.8 ± 1.5	46.6 ± 1.6	32.9 ± 1.2	18.9 ± 1.3	78.6 ± 1.1	60.3 ± 1.5	15.1 ± 1.1	18.9 ± 1.3	42.9 ± 1.7	18.5 ± 1.5
Other	40.4 ± 4.8	26.0 ± 4.4	39.8 ± 4.6	23.8 ± 2.3	14.4 ± 2.9	65.8 ± 5.1	48.5 ± 4.4	10.9 ± 2.3	14.4 ± 2.9	31.0 ± 4.8	16.1 ± 3.5

Data are % ± SE.

Table 2—*Prevalence of the metabolic syndrome using the ATP III and WHO criteria among 8,608 U.S. adults aged ≥20 years (NHANES III, 1988–1994)*

	Age-adjusted			Unadjusted	
	ATP III	WHO	Agreement*	ATP III = yes, WHO = no	WHO = yes, ATP III = no
Total	23.9 ± 0.8	25.1 ± 0.9	86.2 ± 0.7	6.2 ± 0.3	7.6 ± 0.6
Men	24.2 ± 1.2	27.9 ± 1.1	86.1 ± 0.8	5.2 ± 0.4	8.8 ± 0.7
Women	23.5 ± 0.9	22.6 ± 1.1	86.3 ± 0.8	7.2 ± 0.4	6.5 ± 0.7
Race or ethnicity					
White	24.0 ± 1.0	23.8 ± 1.0	86.5 ± 0.8	6.8 ± 0.4	6.7 ± 0.6
African-American	21.9 ± 0.9	28.0 ± 1.2	86.0 ± 1.0	3.8 ± 0.4	10.2 ± 0.8
Mexican-American	32.0 ± 1.4	38.1 ± 1.1	84.2 ± 0.7	4.3 ± 0.5	11.5 ± 0.7
Other	20.3 ± 3.4	26.5 ± 3.0	84.6 ± 2.9	4.7 ± 1.8	10.7 ± 2.5
Men					
White	25.1 ± 1.5	27.6 ± 1.2	86.4 ± 1.0	5.6 ± 0.5	8.0 ± 0.9
African-American	16.5 ± 1.0	24.9 ± 1.3	88.0 ± 1.1	2.1 ± 0.4	9.9 ± 1.0
Mexican-American	28.0 ± 1.9	36.0 ± 1.6	84.5 ± 0.7	3.8 ± 0.6	11.7 ± 0.9
Other	20.8 ± 4.8	28.3 ± 3.6	82.4 ± 3.8	5.3 ± 2.3	12.3 ± 3.0
Women					
White	22.7 ± 1.1	20.3 ± 1.2	86.7 ± 0.9	7.9 ± 0.6	5.4 ± 0.7
African-American	26.1 ± 1.3	30.5 ± 1.8	84.4 ± 1.3	5.2 ± 0.6	10.5 ± 1.2
Mexican-American	36.3 ± 1.5	40.5 ± 1.4	83.8 ± 1.3	4.9 ± 0.7	11.3 ± 1.2
Other	19.9 ± 3.1	24.8 ± 3.3	86.9 ± 3.1	4.1 ± 1.7	9.0 ± 2.8

Data are % ± SE except the difference. *Percent of participants who were classified as either having or not having the metabolic syndrome under both definitions of the metabolic syndrome.

81.9% were similarly classified under either of the two definitions. Under the ATP III definition but not the WHO definition, 7.6% of the participants had the metabolic syndrome, and 10.5% had the metabolic syndrome under the WHO definition but not the ATP III definition.

The age-adjusted mean serum insulin concentrations were 100.3 ± 3.2 pmol/l for 1,036 participants who met the ATP III definition of the metabolic syndrome and 53.0 ± 1.2 pmol/l for 1,821 partici-

Table 3—*Prevalence of the metabolic syndrome using the ATP III and WHO criteria among 2,857 U.S. adults aged 40–74 years who had an oral glucose tolerance test (NHANES III, 1988–1994)*

	Age-adjusted			Unadjusted	
	ATP III	WHO	Agreement*	ATP III = yes, WHO = no	WHO = yes, ATP III = no
Total	33.9 ± 1.5	36.9 ± 1.5	81.9 ± 1.1	7.6 ± 0.6	10.5 ± 0.9
Men	34.8 ± 2.0	41.3 ± 2.3	80.9 ± 1.7	6.4 ± 1.1	12.8 ± 1.3
Women	33.0 ± 1.9	32.7 ± 1.8	82.9 ± 1.3	8.8 ± 0.7	8.4 ± 1.1
Race or ethnicity					
White	34.6 ± 1.8	35.9 ± 1.6	82.2 ± 1.2	8.4 ± 0.8	9.4 ± 0.9
African-American	29.5 ± 1.9	37.5 ± 2.2	80.0 ± 1.4	6.1 ± 0.9	13.9 ± 1.1
Mexican-American	45.5 ± 2.0	53.0 ± 2.0	78.8 ± 2.3	7.0 ± 1.3	14.2 ± 1.7
Other	24.1 ± 4.9	35.9 ± 4.7	81.8 ± 4.4	1.4 ± 0.8	16.9 ± 4.5
Men					
White	36.4 ± 2.5	41.0 ± 2.4	81.6 ± 1.8	7.2 ± 1.3	11.2 ± 1.4
African-American	21.6 ± 2.6	35.3 ± 2.9	77.9 ± 2.0	4.1 ± 1.3	18.0 ± 1.6
Mexican-American	39.4 ± 2.8	48.4 ± 2.6	80.6 ± 3.3	5.9 ± 1.7	13.5 ± 2.6
Other	27.8 ± 6.9	43.7 ± 6.0	76.3 ± 7.1	0.6 ± 0.6	23.1 ± 7.1
Women					
White	32.9 ± 2.1	31.2 ± 2.0	82.9 ± 1.5	9.5 ± 0.8	7.6 ± 1.2
African-American	35.8 ± 2.9	39.4 ± 3.3	81.6 ± 1.8	7.6 ± 1.2	10.8 ± 1.5
Mexican-American	51.9 ± 2.8	58.3 ± 3.5	76.9 ± 2.8	8.2 ± 1.7	15.0 ± 2.1
Other	21.4 ± 6.0	28.2 ± 5.6	87.3 ± 4.4	2.1 ± 1.7	10.6 ± 5.0

Data are % ± SE except the difference. *Percent of participants who were classified as either having or not having the metabolic syndrome under both definitions of the metabolic syndrome.

Table 4—*Prevalence of self-reported heart attack, stroke, and congestive heart failure by metabolic syndrome status defined by the ATP III and WHO among U.S. adults aged ≥20 years (NHANES III, 1988–1994)*

	Metabolic syndrome		No metabolic syndrome				
	Sample size	Age-adjusted prevalence	Sample size	Age-adjusted prevalence	*P*	Sample size	Odds ratio*
ATP III							
Heart attack	2,209	4.5 ± 0.6	6,313	2.9 ± 0.3	0.017	8,372	1.59 (1.12–2.25)
Stroke	2,216	3.0 ± 0.6	6,389	1.3 ± 0.2	0.008	8,455	2.39 (1.40–4.09)
Congestive heart failure	2,210	3.1 ± 0.6	6,387	1.8 ± 0.3	0.056	8,446	1.81 (1.06–3.10)
WHO							
Heart attack	2,515	5.1 ± 0.6	6,007	2.6 ± 0.3	<0.001	8,372	2.03 (1.41–2.91)
Stroke	2,535	2.8 ± 0.4	6,070	1.3 ± 0.2	<0.001	8,455	2.17 (1.47–3.22)
Congestive heart failure	2,528	3.6 ± 0.6	6,069	1.5 ± 0.2	0.002	8,446	2.53 (1.50–4.26)

Data are *n*, % ± SE, or OR (95% CI). *Odds ratio is adjusted for age, sex, race or ethnicity, education, smoking status, cotinine concentration, and non-HDL cholesterol concentration.

pants without the metabolic syndrome ($P < 0.001$). The mean age-adjusted HOMA was 5.16 ± 0.21 for participants who met the ATP III definition of the metabolic syndrome and 2.15 ± 0.05 for those without the metabolic syndrome ($P < 0.001$). The age-adjusted proportion of participants with HOMA in the top quintile was 68.4 ± 2.1% for participants who met the ATP III definition of the metabolic syndrome and 15.8 ± 1.5% for those without the metabolic syndrome ($P < 0.001$).

The age-adjusted mean serum insulin concentrations were 103.3 ± 3.1 pmol/l for 1,180 participants who met the WHO definition of the metabolic syndrome and 49.3 ± 0.8 pmol/l for 1,677 participants without the metabolic syndrome ($P < 0.001$). The mean age-adjusted HOMA was 5.22 ± 0.19 for participants who met the ATP III definition of the metabolic syndrome and 1.97 ± 0.04 for those without the metabolic syndrome ($P < 0.001$). The age-adjusted proportion of participants with HOMA in the top quintile was 78.2 ± 1.6% for participants who met the ATP III definition of the metabolic syndrome and 8.1 ± 0.9% for those without the metabolic syndrome ($P < 0.001$).

Prevalence of self-reported heart attack, stroke, and congestive heart failure

The prevalence of heart attack was 4.5% among participants with the ATP III–defined syndrome, 2.9% among those without the ATP III–defined syndrome, 5.1% among those with the WHO-defined syndrome, and 2.6% among those without the WHO-defined syndrome (Table 4). However, the confidence intervals of the corresponding ATP III and WHO estimates overlap considerably, suggesting that the prevalence of cardiovascular disease is similar. Although the adjusted odds ratios for heart attack and congestive heart failure were higher when we used the WHO definition, the confidence intervals of the odds ratios overlap considerably. However, prevalence estimates for stroke were similar for participants with the metabolic syndrome defined by either definition.

CONCLUSIONS — Under either definition of the metabolic syndrome, its prevalence in the U.S. population is common. We previously reported that ~22% of U.S. adults have the metabolic syndrome according to ATP III criteria (14). The prevalence estimate reported here differs slightly from our earlier estimate because of differences in the analytic sample sizes. Although the two definitions yield similar prevalence estimates for the entire sample (despite considerable differences in the two definitions), the two estimates differed markedly for various population subgroups, especially for some race or ethnic groups. Of the participants, ~80–85% would be classified as having or not having the metabolic syndrome under either definition, suggesting that the two definitions are identifying a similar group of people. However, ~15–20% of participants are classified differently under the two approaches, with roughly half being classified as having the metabolic syndrome under one definition and the other half under the other definition.

That the two definitions classify large numbers of participants as having the metabolic syndrome is perhaps not too surprising, given that the two definitions use many of the same variables: central or abdominal adiposity, dyslipidemia, hypertension, and hyperglycemia. By including insulin resistance explicitly, the WHO definition identifies participants with the metabolic syndrome more directly. In contrast, the ATP III definition does not include a direct measure to identify insulin-resistant people. However, the five ATP III criteria are to some degree associated with insulin resistance. Thus, these criteria may result indirectly in the identification of many participants who are likely to have insulin resistance. The reasons why there is not better agreement are more difficult to discern. However, 80–90% of the participants who are classified as having the metabolic syndrome using one definition but not the other fail to meet one additional criterium that would cause them to meet both definitions of the metabolic syndrome.

The WHO criteria for central obesity appear to account for much of the higher prevalence of WHO-defined metabolic syndrome. The prevalence of central obesity as defined by the WHO among African-American men is about three times higher than the ATP III prevalence of abdominal obesity, compared with the approximate twofold difference in these two measures among the other three groups of men. When we substituted the ATP III abdominal obesity criteria for the WHO criteria, the prevalence of WHO-defined metabolic syndrome for the entire sample dropped to 21.3% from 25.1%. Among African-American men, the prev-

alence decreased to 18.3% from 24.9%. In addition, the higher prevalence of microalbuminuria among nonwhites compared with white participants partially explained the higher prevalence of WHO-defined metabolic syndrome. Among men, African-American men had the highest prevalence of microalbuminuria, whereas among women, Mexican-American women had the highest prevalence. When we recalculated the WHO prevalences without the criteria for microalbuminuria, the prevalences decreased in all groups. For example, the prevalence for African-American men decreased to 23.3% from 24.9%.

Neither definition explicitly includes the use of medications for hypertension, glucose intolerance, or dyslipidemia as part of the definition. We chose to include medications for hypertension and glucose intolerance. We did not do so for dyslipidemia because no specific questions were asked of participants about their use of medications for this purpose. Participants were asked only about cholesterol-lowering medications. We recognize that some of these medications may also lower triglycerides or elevate HDL cholesterol concentrations. To the degree that these medications do so, the ATP III and WHO prevalence estimates would have been underestimated. The criteria for hypertension differ significantly under the two definitions, with the ATP III report advocating the use of 130/85 mmHg and the WHO definition 160/95 mmHg. By including antihypertensive medication use in the definition, our estimates for hypertension using the WHO definition may have been slightly inflated because medication for hypertension probably was prescribed for participants with blood pressure levels between the two thresholds. Consequently, the prevalence estimate for the metabolic syndrome may also have been slightly inflated. Thus, the net effect of these two sources of misclassification may be that the ATP III estimate was slightly underestimated, whereas the two sources of misclassification that affected the WHO prevalence may have cancelled each other to a certain extent.

An important consideration in estimating the prevalence of the metabolic syndrome using the WHO definition is how to operationalize insulin resistance. Different authors have defined insulin resistance using surrogate measures (fasting insulin concentration, HOMA, etc.) in a myriad of ways. A key consideration is how to establish a cut point for these measures, because the choice of a cut point will affect the prevalence estimates of the metabolic syndrome. Typically, this has been done by using some percentile of the distribution of a surrogate measure. Initial inclusion and exclusion criteria at the time of recruitment of study participants and additional inclusion or exclusion criteria applied to the study participants after their recruitment define a final subset of study participants who are used to produce thresholds for insulin resistance.

In an attempt to examine which definition of the metabolic syndrome might be more strongly associated with the risk for cardiovascular disease, we compared the prevalences of self-reported heart attack, stroke, and congestive heart failure for the two definitions of the metabolic syndrome. For self-reported heart attack and congestive heart failure, the WHO definition yielded higher prevalence estimates and odds ratios than those from the ATP III definition, although the confidence intervals were not mutually exclusive. By making insulin resistance one of its criteria, the WHO definition may be including more people with insulin resistance or people who are more insulin resistant than the ATP III definition would include. Findings that insulin resistance is associated with an increased risk for cardiovascular disease events (15,16) could help to explain the slightly higher prevalence estimates of cardiovascular disease among participants with the metabolic syndrome as defined by the WHO. In addition, some evidence suggests that microalbuminuria may be associated with higher relative risks for fatal and nonfatal cardiovascular disease than other components of the metabolic syndrome (4,17). Recent reviews support the notion that microalbumiuria may predict the risk for cardiovascular disease in diabetic and nondiabetic populations, although additional study of this association is still needed (18,19). If microalbuminuria does indeed predict cardiovascular disease risk, this may possibly help to explain why the WHO definition yielded higher prevalence estimates of heart attack and congestive heart failure and higher odds ratios than the ATP III definition. Furthermore, the higher threshold for hypertension used by the WHO definition also may have led to selective enrichment of participants with the metabolic syndrome who are at increased risk for heart disease. However, the stroke prevalence was similar for both definitions. Prospective studies are needed to corroborate these cross-sectional findings and better estimate the risks associated with each definition of the metabolic syndrome.

In conclusion, the prevalence of the metabolic syndrome is common using either the ATP III definition or the proposed WHO definition. Furthermore, both definitions yielded similar estimates for the entire population but masked underlying differences for various population subgroups. However, for clinical, epidemiological, and surveillance purposes, a unified definition may be desirable. Whether clinical implications exist for the 15–20% of participants who would be differently defined by the two definitions is of some concern. Clearly, this group has a number of abnormalities and are likely to benefit from weight control or increases in physical activity.

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