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Prevalence and correlates of metabolic syndrome based on a harmonious definition among adults in the US*

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Abstract

Background: Recently, a Joint Scientific Statement bridged differences between previous definitions of metabolic syndrome. Our objective was to estimate the prevalence of metabolic syndrome in a representative sample of US adults and to examine its correlates.
Methods: We analyzed data for up to 3461 participants aged ≥20 years of the 2003–2006 National Health and Nutrition Examination Survey.
Results: Using waist circumference thresholds of ≥102 cm for men and ≥88 cm for women, the age-adjusted prevalence of metabolic syndrome was 34.3% among all adults, 36.1% among men, and 32.4% among women. Using racial- or ethnic-specific International Diabetes Federation criteria for waist circumference, the age-adjusted prevalence of metabolic syndrome was 38.5% for all participants, 41.9% for men, and 35.0% for women. Prevalence increased with age, peaking among those aged 60–69 years. Prevalence was lower among African American men than White or Mexican American men, and lower among White women than among African American or Mexican American women. In a multivariate regression model, significant independent associations were noted for age (positive), gender (men higher than women), race or ethnicity (African Americans and participants of another race lower than Whites), educational status (inverse), hypercholesterolemia (positive), concentrations of C-reactive protein (positive), leisure time physical activity (inverse), microalbuminuria (positive), and hyperinsulinemia (positive). Additional adjustment for body mass index weakened many of the associations, with educational status and microalbuminuria no longer significant contributors to the model.
Conclusion: Metabolic syndrome continues to be highly prevalent among adults in the US.

Keywords: metabolic syndrome, population surveillance, public health surveillance, risk factors.

Introduction

Metabolic syndrome remains a subject of considerable interest because of the large number of people who have clustering of cardiometabolic factors and because of the increased risk for diabetes and cardiovascular disease.[1,2] First given a definition by the World Health Organization in 1998,[3] metabolic syndrome has been variously defined by major public health and professional organizations (Table 1).[4–10] Recently, an attempt was made to bridge the differences between two of the most commonly used definitions,[11] namely that published by the American Heart Association/National Heart, Lung, and Blood Institute (AHA/NHLBI) in 2005[10] and that published by the International Diabetes Federation (IDF).[9]

Table 1 Definitions of metabolic syndrome*

	WHO 1998[3]	WHO 1999[4]	EGIR 1999[5]	NCEP 2001[6]	NHLBI/AHA 2004[8]	AHA/NHLBI 2005[10]	IDF 2005[9]	Harmonizing definition 2009[11]
Glucose	DM, IGT, or IFG as per WHO criteria	DM, IGT, or IFG as per WHO criteria	FPG ≥ 110 mg/dL	FPG ≥ 110 mg/dL	FPG ≥ 100 mg/dL	FPG ≥ 100 mg/dL or treatment	FPG ≥ 100 mg/dL or previously diagnosed T2DM	FPG ≥ 100 mg/dL or treatment
Insulin resistance	Glucose uptake below lowest quartile	Glucose uptake below lowest quartile	IR or fasting hyperinsulinemia (top 25%)	–	–	–	–	–
Blood pressure	SBP ≥ 160, DBP ≥ 90 mmHg	SBP ≥ 140, DBP ≥ 90 mmHg	SBP ≥ 140, DBP ≥ 90 mmHg or treatment	SBP ≥ 130, DBP ≥ 85 mmHg	SBP ≥ 130, DBP ≥ 85 mmHg	SBP ≥ 130, DBP ≥ 85 mmHg or treatment	SBP ≥ 130, DBP ≥ 85 mmHg or treatment	SBP ≥ 130, DBP ≥ 85 mmHg or treatment
Dyslipidemia	TG ≥ 150 mg/dL and/or HDL-C < 35 mg/dL in men, <39 mg/dL in women	TG ≥ 150 mg/dL and/or HDL-C < 35 mg/dL in men, <39 mg/dL in women	TG > 177 mg/dL or HDL-C < 39 mg/dL or treatment	–	–	–	–	–
Triglycerides	–	–	–	TG ≥ 150 mg/dL	TG ≥ 150 mg/dL	TG ≥ 150 mg/dL or treatment	TG ≥ 150 mg/dL or treatment	TG ≥ 150 mg/dL or treatment
HDL-C	–	–	–	HDL-C < 40 mg/dL in men, <50 mg/dL in women	HDL-C < 40 mg/dL in men, <50 mg/dL in women	HDL-C < 40 mg/dL in men, <50 mg/dL in women or treatment	HDL-C < 40 mg/dL in men, <50 mg/dL in women or treatment	HDL-C < 40 mg/dL in men, <50 mg/dL in women or treatment
Anthropometry	WHR > 0.90 in men, >0.85 in women and/or BMI >30 kg/m^2	WHR > 0.90 in men, >0.85 in women and/or BMI >30 kg/m^2	WC ≥ 94 cm in men, ≥80 cm in women	WC > 102 cm in men, >88 cm in women	WC > 102 cm in men, >88 cm in women	WC ≥ 102 cm in men, ≥88 cm in women; Asian Americans: ≥90 cm in men, ≥80 cm in women	Central obesity: ethnic specific	WC: population and country specific
Microalbuminuria	UAER ≥ 20 μg/min or ACR ≥ 20 mg/g	UAER ≥ 20 μg/min or ACR ≥ 30 mg/g	–	–	–	–	–	–

Table 1 (*Continued*)

	WHO 1998[3]	WHO 1999[4]	EGIR 1999[5]	NCEP 2001[6]	NHLBI/AHA 2004[8]	AHA/NHLBI 2005[10]	IDF 2005[9]	Harmonizing definition 2009[11]
Definition	Glucose intolerance, IGT, or DM and/or IR plus ≥2 other components	Glucose intolerance, IGT, or DM and/or IR plus ≥2 other components	IR or fasting hyperinsulinemia plus ≥2 other components	≥3 of 5 components	≥3 of 5 components	≥3 of 5 components	Central obesity plus ≥2 of another 4 components	≥3 of 5 components
Includes people with diabetes?	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes

*The definition of the American Association of Clinical Endocrinologists has not been included because of complex criteria.[7]

ACR, albumin:creatinine ratio; AHA, American Heart Association; DBP, diastolic blood pressure; DM, diabetes mellitus; EGIR, European Group for the Study of Insulin Resistance; FPG, fasting plasma glucose; HDL-C, high-density lipoprotein–cholesterol; IDF, International Diabetes Federation; IFG, impaired fasting glucose; IGT, impaired glucose tolerance; IR, insulin resistance; NCEP, National Cholesterol Education Program; NHLBI, National Heart, Lung, and Blood Institute; SBP, systolic blood pressure; T2DM, Type 2 diabetes mellitus; TG, triglycerides; UAER, urinary albumin excretion rate; WC, waist circumference; WHO, World Health Organization; WHR, waist:hip ratio.

In 2001, the National Cholesterol Education Program (NCEP) approached the definition of metabolic syndrome by including five factors (waist circumference, triglycerides, high-density lipoprotein–cholesterol (HDL-C), blood pressure, and glucose), establishing a threshold for each factor, and conferring the presence of the syndrome if a person had any three of the five factors.[6] Using the same five factors, the IDF focused on abdominal obesity as the key factor underlying metabolic syndrome, making its presence mandatory.[9] The presence of abdominal obesity plus two or more other abnormalities constituted metabolic syndrome.[9]

The new joint definition[11] maintains the same five factors and thresholds for four of the five factors, but eliminates the IDF requirement for the presence of abdominal obesity, opting instead to adhere to the algorithm of three or more abnormalities of the five originally presented by NCEP in 2001. One of the major distinctions between the two older definitions was the choice of threshold values for abdominal obesity. In addition to ethnic-specific thresholds, the new Joint Scientific Statement now also provides for country-specific thresholds.[11] The aims of the present study were to provide updated estimates of the prevalence of metabolic syndrome among adults in the US using the guidelines of the 2009 Joint Scientific Statement,[11] to examine the impact of using different thresholds for abdominal obesity on the prevalence of metabolic syndrome, and to study some of the correlates of the syndrome.

Methods

In the present study, we used data from the National Health and Nutrition Examination Survey (NHANES) 2003–2006.[12] Participants were recruited using a multistage, stratified sampling design consisting of four stages of selection: (i) counties or small groups of contiguous counties; (ii) a block or group of blocks containing a cluster of households; (iii) households; and (iv) one or more participants from households. Because of the differential probabilities of selection, sampling weights were created that reflected the base probabilities of selection, adjustment for non-response, and post-stratification. Participants were interviewed at home and were invited to attend a mobile examination center, where they were asked to complete additional questionnaires, to undergo various examinations, and to provide a blood sample. The study received human subjects approval, and participants were asked to sign an informed consent form.

Metabolic syndrome was defined using the definition presented in the 2009 Joint Scientific Statement

(Table 1).[11] Waist circumference was measured at the high point of the iliac crest at minimal respiration to the nearest 0.1 cm. Serum triglyceride concentrations were measured enzymatically after hydrolyzation to glycerol, and HDL-C was measured following the precipitation of other lipoproteins with a heparin–manganese chloride mixture. Plasma glucose concentrations were determined using an enzymatic reaction. Up to four attempts were made to collect three blood pressure readings in the mobile examination center. For participants who had three measurements, the average of the last two measures of blood pressure was used; for participants with only two measurements, the last measurement was used, and for participants who had one measurement, that single measurement was used to establish high blood pressure status.

The new definition for metabolic syndrome does not use a single set of criteria for waist circumference. Rather, the definition allows for criteria that are population and country specific. In the US, the 2001 NCEP definition originally set the criteria as >102 cm in men and >88 cm in women.[6] These thresholds evolved to ≥102 cm in men and ≥88 cm in women in 2005 (≥94 cm in men and ≥80 cm in women for Asians living in the US).[10] Because the IDF embraced waist circumference thresholds for racial and ethnic groups that were considerably lower than ≥102 cm in men and ≥88 cm in women, we created three variables for metabolic syndrome that differed only in the application of criteria for waist circumference to examine their impact on prevalence and associations. We defined metabolic syndrome once using a waist circumference of ≥102 cm in men and ≥88 cm in women. We defined metabolic syndrome a second time using a waist circumference of ≥102 cm in men and ≥88 cm in women for participants who were White, African American, or of another race and a waist circumference of ≥90 cm in men and ≥80 cm in women for participants who were Mexican American or another Hispanic ethnicity. Finally, we defined metabolic syndrome a third time using the IDF criteria for waist circumference, namely ≥94 cm in men who were White, African American, or another race or ethnicity, ≥90 cm

Table 2 Age-adjusted and age-specific prevalence of the metabolic syndrome among US adults aged ≥20 years, National Health and Nutrition Examination Survey 2003–2006

	n	Metabolic syndrome*	Metabolic syndrome†	Metabolic syndrome‡
Total	3461	34.3 (1.2)	35.0 (1.1)	38.5 (1.1)
Men	1803	36.1 (1.4)	37.3 (1.3)	41.9 (1.3)
Women	1658	32.4 (1.6)	32.6 (1.6)	35.0 (1.6)
Men				
20–29 years	317	15.0 (2.6)	17.5 (2.6)	19.8 (2.9)
30–39 years	291	27.8 (3.0)	29.3 (3.1)	33.0 (2.9)
40–49 years	311	39.5 (2.4)	40.6 (2.4)	45.9 (2.6)
50–59 years	236	44.6 (3.5)	45.5 (3.4)	49.5 (3.2)
60–69 years	285	59.3 (4.2)	60.1 (4.1)	67.3 (4.1)
≥70 years	363	44.9 (3.3)	45.2 (3.3)	51.9 (2.9)
White	976	38.4 (1.7)	38.4 (1.7)	43.2 (1.7)
African American	345	25.5 (1.9)	25.5 (1.9)	32.5 (2.5)
Mexican American	364	34.4 (2.9)	44.5 (2.8)	44.5 (2.8)
Women				
20–29 years	245	13.7 (2.3)	14.0 (2.3)	15.0 (2.4)
30–39 years	270	16.9 (2.3)	16.9 (2.3)	17.5 (2.6)
40–49 years	306	31.8 (2.7)	31.9 (2.7)	33.4 (2.8)
50–59 years	237	43.3 (4.7)	43.3 (4.7)	46.2 (4.3)
60–69 years	290	55.4 (3.6)	55.4 (3.6)	57.6 (3.7)
≥70 years	310	54.5 (2.8)	54.8 (2.8)	63.5 (2.5)
White	859	31.3 (2.3)	31.3 (2.3)	33.8 (2.3)
African American	352	38.2 (2.0)	38.2 (2.0)	41.1 (2.1)
Mexican American	316	41.9 (2.0)	44.1 (1.8)	44.1 (1.8)

Data show prevalence as a percentage, with the SE in parentheses.

*Metabolic syndrome was defined using waist circumference (WC) criteria of ≥102 cm in men and ≥88 in women.

†Metabolic syndrome was defined using WC criteria of ≥102 cm in men and ≥88 in women for White, African American, and other participants and ≥90 cm in men and ≥80 cm in women for Mexican American and other Hispanic participants.

‡Metabolic syndrome was defined using WC criteria of ≥94 cm in men and ≥80 in women for White, African American, and other participants and ≥90 cm in men and ≥80 cm in women for Mexican American and other Hispanic participants.

in men who were Mexican American or of another Hispanic ethnicity, and ≥80 cm in women.

Major covariates included age, gender, race or ethnicity (White, African American, Mexican American, other Hispanic, other and mixed race), educational status (<high school, high school graduate, >high school), smoking status (never, former, current), blood pressure status, hypercholesterolemia, body mass index (BMI), leisure time physical activity, glycemic status, estimated glomerular filtration rate (GFR), urinary albumin creatinine ratio, C-reactive protein (CRP) concentrations, insulin concentrations, and histories of congestive heart failure, coronary heart disease, angina pectoris, heart attack, and stroke. In addition, we also examined concentrations of HbA1c, low-density lipoprotein–cholesterol (LDL-C), alanine transaminase, aspartate aminotransferase, alkaline phosphatase, γ-glutamyltransferase, lactic dehydrogenase, uric acid, potassium, albumin, and globulin, as well as white blood cell counts. Participants who had smoked at least 100 cigarettes during their lifetime and were currently smoking were designated as current smokers. Those who had smoked at least 100 cigarettes during their lifetime and were not currently smoking were designated as former smokers. Those who had not smoked at least 100 cigarettes during their lifetime were designated as never having smoked. Three levels of blood pressure status were included: normal [systolic blood pressure (SBP) <120 mmHg and diastolic blood pressure (DBP) <80 mmHg], prehypertension (SBP 120–139 mmHg or DBP 80–89 mmHg), and hypertension (SBP ≥140 mmHg or DBP ≥90 mmHg or self-reported current use of antihypertensive medication). The BMI (kg/m^2) was calculated from measured weight and height. Serum concentrations of total cholesterol were measured enzymatically using the Roche Hitachi 717 and 912 instruments (Roche Diagnostics, Indianapolis, IN, USA). Hypercholesterolemia was defined as a concentration ≥200 mg/dL or the self-reported current use of cholesterol-lowering medications. To estimate leisure time physical activity, we calculated the number of minutes per week of moderate and vigorous leisure time physical activity, summed the number of moderate minutes and vigorous minutes multiplied by two, and dichotomized those times into ≥150 or <150 min/week.[13] Four levels of glycemic

Table 3 Age-adjusted and age-specific distribution of the number of metabolic syndrome components among US adults aged ≥20 years, National Health and Nutrition Examination Survey 2003–2006

		Number of components					
	n	0	1	2	3	4	5
Total	3461	21.2 (1.0)	22.9 (0.7)	21.6 (0.8)	19.2 (0.9)	10.6 (0.6)	4.4 (0.4)
Men	1803	19.2 (1.3)	23.1 (1.3)	21.6 (1.1)	20.2 (1.2)	11.4 (1.0)	4.4 (0.6)
Women	1658	23.2 (1.4)	22.9 (1.1)	21.5 (1.2)	18.2 (1.1)	9.9 (0.9)	4.4 (0.6)
Men							
20–29 years	317	37.6 (3.8)	27.4 (2.7)	20.0 (2.5)	11.1 (2.2)	3.5 (1.1)*	0.4 (0.3)*
30–39 years	291	25.9 (2.9)	26.8 (1.7)	19.5 (2.4)	17.4 (2.4)	7.8 (1.8)	2.6 (1.1)*
40–49 years	311	17.7 (2.6)	23.4 (3.2)	19.4 (3.0)	20.3 (2.3)	14.0 (2.4)	5.3 (1.1)
50–59 years	236	12.5 (2.3)	20.4 (2.5)	22.4 (2.7)	24.8 (3.8)	14.8 (3.4)	5.1 (1.4)
60–69 years	285	2.3 (0.9)*	16.9 (3.1)	21.5 (3.0)	30.8 (3.6)	17.5 (3.1)	11.0 (2.5)
≥70 years	363	6.0 (1.4)	18.7 (2.1)	30.4 (3.0)	23.9 (2.7)	15.3 (1.9)	5.7 (1.4)
White	976	19.3 (1.7)	22.4 (1.6)	19.9 (1.4)	21.5 (1.5)	12.2 (1.3)	4.8 (0.8)
African American	345	23.6 (2.0)	24.3 (1.8)	26.5 (2.0)	17.1 (1.6)	6.2 (1.1)	2.3 (0.9)*
Mexican American	364	15.2 (2.3)	28.8 (3.0)	21.6 (2.6)	18.4 (2.2)	11.4 (2.0)	4.5 (1.5)*
Women							
20–29 years	245	41.2 (3.5)	28.7 (2.9)	16.4 (2.5)	10.8 (2.3)	2.2 (0.9)*	0.6 (0.6)*
30–39 years	270	32.2 (3.8)	29.9 (3.3)	21.0 (3.2)	12.2 (1.9)	4.1 (1.5)*	0.7 (0.5)*
40–49 years	306	23.2 (2.5)	21.6 (2.9)	23.3 (3.0)	17.5 (1.9)	11.0 (2.1)	3.4 (1.3)*
50–59 years	237	15.3 (1.8)	18.7 (2.6)	22.7 (4.1)	22.5 (3.3)	12.6 (2.4)	8.1 (2.3)
60–69 years	290	6.9 (1.9)	19.6 (2.8)	18.1 (2.7)	26.1 (2.6)	21.2 (2.7)	8.1 (2.1)
≥70 years	310	5.2 (1.4)	12.6 (2.7)	27.7 (2.4)	28.5 (3.0)	16.2 (2.4)	9.9 (1.6)
White	859	25.9 (1.8)	22.8 (1.6)	19.9 (1.6)	17.2 (1.5)	9.9 (1.3)	4.3 (0.6)
African American	352	11.8 (1.7)	22.4 (2.5)	27.6 (3.1)	25.1 (1.7)	10.0 (1.5)	3.1 (0.7)
Mexican American	316	11.5 (2.1)	20.1 (1.8)	26.4 (1.8)	21.8 (2.4)	13.9 (2.2)	6.3 (1.3)

Data show prevalence as a percentage, with the SE in parentheses.

*Estimate does not meet the standard of statistical reliability and precision (relative SE >30%).

status were created: normoglycemia, impaired fasting glucose (fasting plasma glucose (FPG) 100–125 mg/dL), undiagnosed diabetes (FPG ≥ 126 mg/dL), and previously diagnosed diabetes based on self-reported information. The estimated GFR was calculated using the Chronic Kidney Disease Epidemiology Collaboration equations.[14] Urinary albumin was measured by a solid-phase fluorescent immunoassay, whereas urinary creatinine was measured by a Jaffé rate reaction. Concentrations of CRP were determined by latex-enhanced nephelometry on a Behring Nephelometer (Siemens Healthcare Diagnostics, Deerfield, IL, USA). For the 2003–2004 cycle, concentrations of insulin were measured by the Tosoh AIA-PACK IRI (Tosoh Bioscience, South San Francisco, CA, USA), an immunoenzymometric assay, at the University of Missouri-Columbia (Columbia, MO, USA). For the 2005–2006 cycle, insulin concentrations were measured using the Mercodia Insulin ELISA assay (Mercodia, Winston Salem, NC, USA) at the Fairview Medical Center Laboratory (University of Minnesota, Minneapolis, MN, USA). Based on the results of a cross-over study, regression equations were developed to convert values from one method to those of the other method. The presence of a history of congestive heart failure, coronary heart disease, angina pectoris, heart attack, and stroke was determined from a series of questions posed to participants about whether they had ever been told by a doctor or other health professional that they had one of those conditions.

The analyses were limited to men and non-pregnant women aged ≥20 years who attended the morning examination and had fasted at least 8 h. Age adjustment was performed by the direct method using the projected year 2000 US population. Differences in percentages and means were calculated using Chi-squared

Table 4 Age-adjusted and age-specific prevalence of components of the metabolic syndrome among US adults aged ≥20 years, National Health and Nutrition Examination Survey 2003–2006

		Abdominal obesity*		Abdominal obesity†		Abdominal obesity‡		Hypertriglyceridemia		Low HDL-C		Elevated blood pressure		Hyperglycemia	
	n	%	SE	%	SE	%	SE	%	SE	%	SE	%	SE	%	SE
Total	3461	53.6	1.2	56.8	1.1	73.2	1.0	31.4	1.0	25.4	0.9	30.1	0.9	38.4	1.6
Men	1803	45.8	1.4	50.4	1.3	66.9	1.2	36.5	1.4	22.9	1.5	31.3	1.4	45.8	1.8
Women	1658	61.2	1.5	63.1	1.5	79.5	1.2	26.1	1.1	28.1	1.6	28.6	1.0	31.2	1.6
Men															
20–29 years	317	25.5	2.9	32.3	2.9	44.4	3.1	26.7	3.4	20.6	2.8	8.9	2.1	21.7	2.7
30–39 years	291	40.3	3.7	46.6	3.6	60.6	3.3	32.8	2.7	23.0	3.6	17.4	2.5	36.5	2.9
40–49 years	311	53.9	2.9	58.3	2.9	76.5	2.9	42.5	3.4	28.2	2.9	22.5	2.6	43.2	3.9
50–59 years	236	51.9	3.5	55.3	3.7	73.4	3.4	41.9	3.2	19.5	1.9	42.5	4.3	58.5	3.0
60–69 years	285	60.1	4.3	63.3	4.2	81.2	3.5	45.9	3.0	27.0	1.9	60.0	3.9	70.1	3.5
≥70 years	363	51.6	3.1	53.0	3.1	73.9	2.4	32.9	2.9	18.3	2.2	64.6	2.9	65.2	2.4
White	976	48.6	1.5	48.6	1.5	67.1	1.4	37.6	1.6	24.2	2.0	31.5	1.6	44.7	2.1
African American	345	36.5	2.9	36.5	2.9	57.8	3.0	21.9	2.5	12.6	1.7	37.8	2.6	41.3	2.3
Mexican American	364	38.0	3.8	78.1	2.9	78.1	2.9	44.3	2.9	26.5	3.2	24.9	2.4	50.1	3.3
Women															
20–29 years	245	44.3	3.3	48.5	3.4	63.0	3.2	13.7	2.3	31.8	3.4	2.0	0.8	10.5	1.9
30–39 years	270	56.1	4.6	58.3	4.6	77.0	2.9	20.1	2.8	27.6	3.4	4.1	1.0	16.4	2.4
40–49 years	306	61.9	2.9	63.1	2.9	81.9	2.3	23.7	2.3	31.3	3.0	24.5	2.4	29.9	3.3
50–59 years	237	68.0	3.7	69.7	3.5	84.9	2.8	32.1	4.2	27.9	3.7	43.3	3.8	42.4	3.6
60–69 years	290	76.7	3.1	77.6	3.0	87.5	2.5	43.2	3.9	24.3	3.0	56.0	4.0	51.6	3.7
≥70 years	310	72.1	3.2	72.5	3.2	90.3	2.3	36.7	3.9	21.6	2.4	74.2	2.9	57.3	2.8
White	859	58.6	2.2	58.6	2.2	77.2	1.6	26.8	1.5	27.7	2.0	26.2	1.2	28.7	1.9
African American	352	76.7	2.1	76.7	2.1	88.0	1.9	14.6	1.6	27.2	2.7	47.2	2.5	37.7	2.5
Mexican American	316	75.5	3.2	92.5	1.9	92.5	1.9	34.5	2.1	39.0	3.4	27.4	2.5	41.9	3.5

*Waist circumference criteria of ≥102 cm in men and ≥88 in women.

†Waist circumference criteria of ≥102 cm in men and ≥88 in women for White, African American, and other participants and ≥90 cm in men and ≥80 cm in women for Mexican American and other Hispanic participants.

‡Waist circumference criteria of ≥94 cm in men and ≥80 in women for White, African American, and other participants and ≥90 cm in men and ≥80 cm in women for Mexican American and other Hispanic participants.

LDL-C, low-density lipoprotein–cholesterol.

tests and *t*-tests, respectively. Prevalence ratios using the log-binomial method were calculated to assess the independent association between the presence of metabolic syndrome (dependent variable) and various covariates. SUDAAN (Software for the Statistical Analysis of Correlated Data; Research Triangle Institute, Research Triangle Park, NC, USA) was used for analyses to account for the complex sampling design.

Results

A total of 3959 participants aged ≥20 years attended the morning examination. Excluding pregnant women reduced the number to 3723. Complete data for all components of metabolic syndrome to calculate the prevalence of metabolic syndrome by age groups, gender, and race or ethnicity were available for 3461 participants. Additional losses of sample size occurred for analyses involving covariates.

The age-adjusted prevalence of metabolic syndrome was 34.3% when the 102/88 cm thresholds for waist circumference were used and 35% when thresholds for waist circumference of 90/80 cm for Mexican Americans and other Hispanics were used (Table 2). Using the IDF thresholds for waist circumference boosted the prevalence of metabolic syndrome to 38.5%. Using the definition that used waist circumference thresholds of 102 cm for men and 88 cm for women, the age-adjusted prevalence was 3.7% higher among men than women ($P = 0.063$) and was lower among African American men than White ($P < 0.001$) and Mexican American ($P = 0.010$) men and lower among White women than African American ($P = 0.034$) and Mexican American ($P = 0.004$) women. Prevalence reached a peak among both men and women aged 60–69 years, except among women when the definition that used IDF criteria for waist circumference was used.

Table 5 Age-adjusted means of anthropometric, physiological, and biochemical parameters among US adults aged ≥20 years, according to metabolic syndrome status, National Health and Nutrition Examination Survey 2003–2006

	Metabolic syndrome			No metabolic syndrome			
	n	Mean	SE	*n*	Mean	SE	*P* value
WC (cm)	1311	110.1	0.8	2150	92.0	0.3	<0.001
SBP (mmHg)	1285	127.1	0.5	2141	118.6	0.5	<0.001
DBP (mmHg)	1285	73.5	0.5	2141	68.1	0.4	<0.001
Log TG (mg/dL)	1311	5.2	0.03	2150	4.6	0.01	<0.001
HDL-C (mg/dL)	1311	45.2	0.6	2150	59.6	0.4	<0.001
Glucose (mg/dL)	1311	112.1	1.1	2150	95.6	0.6	<0.001
HbA1c (%)	1309	5.7	0.04	2143	5.3	0.02	<0.001
BMI (kg/m^2)	1309	33.0	0.4	2146	26.3	0.1	<0.001
GFR (mL/min per 1.73 m^2)	1308	93.7	0.6	2142	94.7	0.4	0.123
Log urinary ACR (mg/g)	1307	2.2	0.05	2132	1.9	0.02	<0.001
Total cholesterol (mg/dL)	1311	204.1	1.7	2150	196.7	0.9	<0.001
LDL-C (mg/dL)	1233	117.8	1.5	2133	115.5	1.0	0.188
ALT (U/L)	1299	30.7	0.7	2132	24.2	0.4	<0.001
AST (U/L)	1299	26.8	0.5	2132	24.8	0.4	0.002
ALP (U/L)	1308	71.7	1.2	2142	66.8	0.6	<0.001
GGT (U/L)	1308	38.2	4.1	2142	24.7	0.6	0.002
LDH (U/L)	1298	129.1	1.2	2132	125.8	0.7	0.017
Uric acid (mg/dL)	1308	6.0	0.05	2142	5.2	0.03	<0.001
Potassium (mmol/L)	1308	4.0	0.01	2142	4.0	0.01	0.552
Albumin (g/dL)	1308	41.7	0.1	2142	42.4	0.1	<0.001
Globulin (g/dL)	1307	3.0	0.02	2141	2.9	0.01	<0.001
C-Reactive protein (mg/L)	1311	5.9	0.4	2149	3.8	0.2	<0.001
Leukocytes (×10^9/L)	1311	7.5	0.1	2146	6.6	0.1	<0.001
Log insulin (μU/L)	1303	2.6	0.03	2104	1.7	0.02	<0.001
Cotinine (ng/mL)	1310	74.9	6.1	2147	66.6	4.1	0.241

*Metabolic syndrome defined using waist circumference criteria of ≥102 cm in men and ≥88 in women.
WC, waist circumference; SBP, DBP, systolic and diastolic blood pressure, respectively; TG, triglyceride; HDL-C, high-density lipoprotein–cholesterol; BMI, body mass index; GFR, glomerular filtration rate; ACR, albumin:creatinine ratio; LDL-C, low-density lipoprotein–cholesterol; ALT, alanine aminotransferase; AST, aspartate aminotransferase; ALP, alkaline phosphatase; GGT, γ-glutamyltransferase; LDH, lactate dehydrogenase.

Table 6 Age-adjusted prevalence of metabolic syndrome by selected factors among adults aged ≥20 years, National Health and Nutrition Examination Survey 2003–2006

		Metabolic syndrome*		Metabolic syndrome†		Metabolic syndrome‡	
	n	%	SE	%	SE	%	SE
Education							
<High school	947	38.9	1.8	41.0	1.8	43.8	1.6
High school	862	38.2	1.7	39.0	1.7	43.3	1.7
>High School	1649	31.0	1.8	31.3	1.8	34.5	1.7
Smoking status							
Current	767	32.3	1.5	32.8	1.6	38.1	1.6
Former	947	38.6	2.2	39.4	2.1	42.5	2.6
Never	1745	33.6	1.8	34.5	1.7	37.6	1.5
Blood pressure							
Normal	1296	13.5	1.4	14.3	1.4	15.9	1.5
Prehypertension	874	31.8	1.9	32.5	1.9	38.5	1.7
Hypertension	1291	65.9	3.0	67.1	3.0	70.8	3.0
Total cholesterol (mg/dL)							
<200	1515	29.4	1.4	30.0	1.4	33.0	1.3
≥200	1946	38.7	1.8	39.6	1.7	43.1	1.7
Body mass index (kg/m^2)							
<25	1065	8.7	0.8	8.9	0.8	13.3	1.0
25–<30	1189	32.7	2.1	34.2	2.0	40.1	2.1
≥30	1201	59.8	1.8	60.4	1.8	60.7	1.8
Leisure time physical activity (min/week)							
≥150	1288	27.6	1.6	28.1	1.6	31.9	1.6
<150	2173	38.9	1.3	39.8	1.3	43.1	1.2
Glycemic status							
<100 mg/dL	1930	15.4	1.1	15.7	1.1	18.0	1.1
100–125 mg/dL	1059	57.3	2.4	59.2	2.3	65.6	2.0
Undiagnosed diabetes	117	81.7	4.5	83.7	4.3	86.2	4.2
Previously diagnosed diabetes	352	78.8	5.7	79.0	5.7	81.1	5.7
C-Reactive protein (mg/L)							
<1	913	19.8	1.5	20.4	1.4	24.0	1.3
1–3	1194	33.4	1.6	34.5	1.6	38.3	1.6
>3	1353	46.5	1.7	46.9	1.6	49.9	1.5
Glomerular filtration rate (mL/min per 1.73 m^2)							
<60	324	36.9	7.0	37.0	7.0	40.6	7.0
60–89	1167	36.1	2.4	37.3	2.2	41.3	2.3
≥90	1959	34.8	1.7	35.8	1.7	39.4	1.6
Urinary albumin:creatinine ratio (mg/g)							
<30	3004	32.9	1.3	33.6	1.2	37.0	1.1
30–<300	366	49.7	3.9	50.6	3.8	53.8	4.0
≥300	69	55.9	9.0	56.0	9.0	64.6	9.3
Congestive heart failure							
Yes	105	71.5	9.9	71.6	9.9	72.2	9.8
No	3342	33.8	1.2	34.5	1.1	38.1	1.1
Coronary heart disease							
Yes	159	56.4	6.1	56.4	6.1	58.5	6.1
No	3289	33.7	1.2	34.4	1.1	38.0	1.1
Angina pectoris							
Yes	126	40.3	4.5	40.3	4.5	42.9	4.3
No	3322	33.8	1.1	34.6	1.1	38.1	1.0
Heart attack							
Yes	157	53.8	4.1	53.8	4.1	57.4	3.6
No	3301	33.8	1.1	34.5	1.1	38.0	1.1

Table 6 (*Continued*)

		Metabolic syndrome*		Metabolic syndrome†		Metabolic syndrome‡	
	n	%	SE	%	SE	%	SE
Stroke							
Yes	144	45.3	5.6	45.3	5.6	46.1	5.6
No	3314	33.6	1.1	34.4	1.1	37.9	1.0

*Metabolic syndrome was defined using waist circumference (WC) criteria of ≥102 cm in men and ≥88 in women.
†Metabolic syndrome was defined using WC criteria of ≥102 cm in men and ≥88 in women for White, African American, and other participants and ≥90 cm in men and ≥80 cm in women for Mexican American and other Hispanic participants.
‡Metabolic syndrome was defined using WC criteria of ≥94 cm in men and ≥80 in women for White, African American, and other participants and ≥90 cm in men and ≥80 cm in women for Mexican American and other Hispanic participants.

Among all participants, 21.2% had no cardiometabolic abnormalities and 4.4% had five cardiometabolic abnormalities (Table 3). Using the definition of metabolic syndrome that was based on waist circumference thresholds of 102/88 cm, 88% of participants with metabolic syndrome had abdominal obesity (men 81%; women 96.7%), 69.6% had hypertriglyceridemia (men 72.8%; women 65.9%), 59% had low HDL-C (men 54%; women 65.3%), 50.3% had elevated blood pressure (men 52.7%; women 45.9%), and 68.9% had hyperglycemia (men 71.7%; women 65.2%).

The age-adjusted and age-specific prevalence of the components of metabolic syndrome according to age group, gender, and race or ethnicity are presented in Table 4. Some noteworthy findings include that 92.5% of Mexican American women had abdominal obesity when a threshold of 80 cm was used, 47.2% of African American women had elevated blood pressure, and 50.1% of Mexican American men had hyperglycemia. Furthermore, the prevalence of hypertriglyceridemia was lowest among African American participants compared with White or Mexican American participants. In addition, a lower percentage of African American men had low levels of HDL-C than White or Mexican American men. However, similar percentages of White and African American women had low HDL-C levels. The percentages of abdominal obesity, elevated blood pressure, and hyperglycemia were very high at advanced ages.

Participants with metabolic syndrome were characterized by numerous changes in anthropometric, physiological, and biochemical parameters (Table 5). Only the estimated GFR and concentrations of LDL-C, potassium, and cotinine did not differ between participants with and without metabolic syndrome.

The age-adjusted prevalence of metabolic syndrome was lower among participants whose education continued beyond high school compared with those who had not ($P = 0.013$) or had ($P = 0.003$) graduated from high school, was higher among former smokers than current ($P = 0.027$) or never smokers ($P = 0.063$), increased with level of blood pressure ($P < 0.001$), was higher among participants with hypercholesterolemia than those without hypercholesterolemia ($P < 0.001$), increased with BMI ($P < 0.001$), was lower among participants who did ≥150 min/week of leisure time physical activity compared with those who did not ($P < 0.001$), increased with degree of hyperglycemia ($P < 0.001$), increased with CRP concentrations ($P < 0.001$), increased with the degree of microalbuminuria ($P < 0.001$), and was higher among participants with congestive heart failure ($P = 0.001$), coronary heart disease ($P = 0.001$), heart attack ($P < 0.001$), and stroke ($P = 0.045$) than among participants without those conditions (Table 6).

Table 7 shows independent associations between several factors not directly related or indirectly related through high correlations (such as BMI and waist circumference) to the five factors used to define metabolic syndrome and prevalent metabolic syndrome. Based on the adjusted Wald *F*-tests, significant associations were noted for age (positive), gender (men higher than women), race or ethnicity, educational status, hypercholesterolemia (positive), CRP concentrations (positive), leisure time physical activity (inverse), microalbuminuria (positive), and hyperinsulinemia (positive). In a separate model that also included BMI as a continuous variable, most of the previously significant associations remained so, although the adjusted prevalence ratios weakened in some instances. Educational status, smoking status, and microalbuminuria were not significant contributors to the model.

Discussion

Our analyses using the newest definition of metabolic syndrome and the most recently available data provide the most current estimates of metabolic syndrome

Table 7 Associations between selected characteristics and metabolic syndrome among 3261 US adults aged ≥20 years, National Health and Nutrition Examination Survey 2003–2006

	Metabolic syndrome*			
	Model 1		Model 2	
	Adjusted prevalence ratio (95% CI)	*P* adjusted Wald *F*	Adjusted prevalence ratio (95% CI)	*P* adjusted Wald *F*
Metabolic syndrome*				
Age (years)	1.02 (1.01, 1.02)	<0.001	1.02 (1.02, 1.02)	<0.001
Gender				
Men	1.21 (1.10, 1.33)	<0.001	1.24 (1.11, 1.37)	<0.001
Women	1.00		1.00	
Race or ethnicity				
White	1.00	0.009	1.00	0.001
African American	0.82 (0.72, 0.94)		0.77 (0.68, 0.87)	
Mexican American	0.89 (0.74, 1.07)		0.95 (0.79, 1.15)	
Other	0.56 (0.38, 0.82)		0.62 (0.41, 0.93)	
Education				
<High school	1.00	0.046	1.00	0.109
High school	1.03 (0.90, 1.17)		0.97 (0.86, 1.10)	
>High School	0.88 (0.75, 1.04)		0.87 (0.75, 1.00)	
Smoking status				
Current	0.88 (0.77, 1.00)	0.147	0.97 (0.85, 1.10)	0.851
Former	0.99 (0.88, 1.11)		1.01 (0.88, 1.15)	
Never	1.00		1.00	
Total cholesterol (mg/dL)				
≥200	1.36 (1.20, 1.55)	<0.001	1.31 (1.16, 1.48)	<0.001
<200	1.00		1.00	
C-Reactive protein (mg/L)				
<1	0.46 (0.39, 0.54)	<0.001	0.65 (0.55, 0.76)	<0.001
1–3	0.79 (0.71, 0.87)		0.96 (0.86, 1.07)	
>3	1.00		1.00	
Leisure time physical activity (min/week)				
≥150	1.00	0.001	1.00	0.004
<150	1.25 (1.11, 1.40)		1.19 (1.06, 1.33)	
Urinary albumin (mg/g)				
<30	1.00	0.019	1.00	0.262
30–<300	1.17 (1.02, 1.34)		1.09 (0.94, 1.25)	
≥300	1.37 (1.02, 1.83)		1.16 (0.82, 1.64)	
Insulin (μU/mL)				
≥20	2.07 (1.84, 1.00)	<0.001	1.36 (1.19, 1.57)	<0.001
<20	1.00		1.00	
Body mass index (kg/m^2)	–	–	1.06 (1.05, 1.07)	<0.001
Metabolic syndrome†				
Age (years)	1.02 (1.01, 1.02)	<0.001	1.02 (1.02, 1.02)	<0.001
Gender				
Men	1.24 (1.14, 1.36)	<0.001	1.27 (1.15, 1.41)	<0.001
Women	1.00		1.00	
Race or ethnicity				
White	1.00	<0.001	1.00	<0.001
African American	0.82 (0.72, 0.94)		0.77 (0.68, 0.88)	
Mexican American	1.07 (0.91, 1.27)		1.15 (0.97, 1.35)	
Other	0.73 (0.52, 1.01)		0.80 (0.56, 1.13)	
Education				
<High school	1.00	0.036	1.00	0.078
High school	1.03 (0.90, 1.18)		0.98 (0.87, 1.10)	
>High school	0.88 (0.75, 1.03)		0.86 (0.74, 0.99)	

Table 7 (*Continued*)

	Metabolic syndrome*			
	Model 1		Model 2	
	Adjusted prevalence ratio (95% CI)	*P* adjusted Wald *F*	Adjusted prevalence ratio (95% CI)	*P* adjusted Wald *F*
Smoking status				
Current	0.87 (0.77, 0.99)	0.115	0.96 (0.84, 1.09)	0.783
Former	0.98 (0.88, 1.10)		1.00 (0.87, 1.14)	
Never	1.00		1.00	
Total cholesterol (mg/dL)				
≥200	1.35 (1.19, 1.53)	<0.001	1.31 (1.16, 1.48)	<0.001
<200	1.00		1.00	
C-Reactive protein (mg/L)				
<1	0.48 (0.41, 0.55)	<0.001	0.66 (0.57, 0.77)	<0.001
1–3	0.80 (0.72, 0.88)		0.97 (0.87, 1.09)	
>3	1.00		1.00	
Leisure time physical activity (min/week)				
≥150	1.00	0.001	1.00	0.003
<150	1.25 (1.11, 1.41)		1.20 (1.07, 1.34)	
Urinary albumin (mg/g)				
<30	1.00	0.026	1.00	0.311
30–<300	1.16 (1.02, 1.32)		1.08 (0.94, 1.24)	
≥300	1.34 (1.01, 1.78)		1.15 (0.82, 1.60)	
Insulin (μU/mL)				
≥20	2.05 (1.82, 2.31)	<0.001	1.36 (1.19, 1.55)	<0.001
<20	1.00		1.00	
Body mass index (kg/m^2)	–	–	1.06 (1.05, 1.07)	<0.001
Metabolic syndrome‡				
Age (years)	1.02 (1.01, 1.02)	<0.001	1.02 (1.02, 1.02)	<0.001
Gender				
Men	1.29 (1.17, 1.42)	<0.001	1.31 (1.19, 1.44)	<0.001
Women	1.00		1.00	
Race or ethnicity				
White	1.00	0.006	1.00	<0.001
African American	0.87 (0.78, 0.97)		0.82 (0.74, 0.92)	
Mexican American	0.99 (0.84, 1.16)		1.04 (0.89, 1.22)	
Other	0.67 (0.48, 0.93)		0.72 (0.51, 1.01)	
Education				
<High school	1.00	0.009	1.00	0.045
High school	1.04 (0.93, 1.17)		1.00 (0.90, 1.11)	
>High school	0.89 (0.76, 1.04)		0.87 (0.76, 1.01)	
Smoking status				
Current	0.92 (0.81, 1.03)	0.338	1.00 (0.89, 1.12)	0.983
Former	0.98 (0.87, 1.10)		0.99 (0.86, 1.13)	
Never	1.00		1.00	
Total cholesterol (mg/dL)				
≥200	1.32 (1.18, 1.48)	<0.001	1.28 (1.14, 1.43)	<0.001
<200	1.00		1.00	
C-Reactive protein (mg/L)				
<1	0.51 (0.46, 0.58)	<0.001	0.68 (0.60, 0.76)	<0.001
1–3	0.82 (0.75, 0.90)		0.97 (0.88, 1.07)	
>3	1.00		1.00	
Leisure time physical activity (min/week)				
≥150	1.00	<0.001	1.00	0.002
<150	1.23 (1.11, 1.38)		1.19 (1.07, 1.32)	

Table 7 (*Continued*)

	Metabolic syndrome*			
	Model 1		Model 2	
	Adjusted prevalence ratio (95% CI)	*P* adjusted Wald *F*	Adjusted prevalence ratio (95% CI)	*P* adjusted Wald *F*
Urinary albumin (mg/g)				
<30	1.00	0.006	1.00	0.119
30–<300	1.17 (1.03, 1.33)		1.10 (0.97, 1.25)	
≥300	1.37 (1.10, 1.71)		1.21 (0.93, 1.58)	
Insulin (μU/mL)				
≥20	1.88 (1.67, 2.11)	<0.001	1.33 (1.16, 1.51)	<0.001
<20	1.00		1.00	
Body mass index (kg/m^2)	–	–	1.05 (1.04, 1.06)	<0.001

Each variable is adjusted for all other variables in table.

*Metabolic syndrome was defined using waist circumference (WC) criteria of ≥102 cm in men and ≥88 in women.

†Metabolic syndrome was defined using WC criteria of ≥102 cm in men and ≥88 in women for White, African American, and other participants and ≥90 cm in men and ≥80 cm in women for Mexican American and other Hispanic participants.

‡Metabolic syndrome was defined using WC criteria of ≥94 cm in men and ≥80 in women for White, African American, and other participants and ≥90 cm in men and ≥80 cm in women for Mexican American and other Hispanic participants.

among adults in the US. The prevalence of metabolic syndrome remains high, generally ranging between 34.3% and 38.5% depending on the criteria for abdominal obesity. In 2009, the estimated number of adults aged ≥20 years in the US was approximately 223 million. Thus, the total number of adults in the US who have metabolic syndrome ranges from almost 77 million to almost 86 million. The prevalence of metabolic syndrome from the present study is similar to a recent estimate from the same dataset that used the 2004 National Heart, Lung, and Blood Institute/American Heart Association definition.[15] Although the prevalence of metabolic syndrome increased as expected as the thresholds for waist circumference grew smaller, the associations between metabolic syndrome and important correlates were generally similar for the three variations of the definition we used in the present study.

Despite the high prevalence of metabolic syndrome and the intense interest in this syndrome during much of this decade, recognition by the public appears limited. A survey of 211 097 adults found that only 0.6% reported having metabolic syndrome and <15% of adults were cognizant of metabolic syndrome.[16] The low percentage of respondents in that survey who reported having ever been told that they had metabolic syndrome calls into question how aggressive health care providers are in diagnosing metabolic syndrome.

The new harmonizing definition of metabolic syndrome attempts to bridge differences between two major competing definitions of this syndrome. For countries using the 102/88 cm thresholds for waist circumference, the harmonizing definition is no different than the AHA/NHLBI 2005 definition and, thus, does not represent an advance in the conceptualization of the syndrome. However, for many countries the new definition will produce different prevalence estimates than estimates based on previous definitions by the IDF or NCEP.

Nevertheless, the reconciliation between two of the major definitions of metabolic syndrome should have several salutary effects. Clinicians will no longer have to choose between competing definitions, and it is possible that removing a potential source of diagnostic uncertainty may stimulate health care providers to be more vigilant in looking for the syndrome. A single definition should also facilitate the job of researchers in conducting their research. The principal source of uncertainty in the definition of the syndrome, at least in the US, lies in the criteria to be used in defining abdominal obesity. The recent scientific statement suggested thresholds of 102 cm for men and 88 cm for women in the US.[11] However, the 2005 AHA/NHLBI definition allowed for ethnic-specific thresholds to be used.

Abdominal obesity is the most prevalent component of metabolic syndrome. Even using the most conservative approach to define abdominal obesity, over half the adults in the US have abdominal obesity. Using the IDF criteria, almost three-quarters of adults have abdominal obesity. These stunning estimates underscore the need for effective population strategies to reduce energy intake and increase energy

expenditure. Because a large percentage of adults see a physician every year, health care providers are uniquely situated to treat their patients who have metabolic syndrome. The cornerstone of such treatment is therapeutic lifestyle change. Research has demonstrated that therapeutic lifestyle change can be effective in patients with hypertension, hyperlipidemia, and hyperglycemia.[17]

The associations between metabolic syndrome and demographic, lifestyle, anthropometric, biochemical, and physiological factors that we found in our analyses are consistent with other reports in the literature.[18,19] The demographic patterns are generally similar to those described previously among US adults, except that in the present analysis the prevalence of metabolic syndrome among Mexican American men was lower, but not significantly different, than that among White men.[20] The associations with the biochemical and physiological variables underscore that numerous abnormalities are present in people with metabolic syndrome. Thus, metabolic syndrome is characterized by inflammation, insulin resistance, and, to the extent that microalbuminuria is associated with endothelial dysfunction, by endothelial dysfunction.

In conclusion, the prevalence of metabolic syndrome using the harmonizing definition of metabolic syndrome is high among adults in the US. When less-restrictive definitions of central obesity are applied, the prevalence increases, but associations with important correlates are minimally affected. Major public health and professional organizations continue to endorse the concept of metabolic syndrome, underscoring its seriousness as a public health and clinical issue.[11] To the extent that metabolic syndrome can be viewed as a window on cardiometabolic health, the high prevalence of the syndrome among US adults casts a cloud on the future health of the US population. Increases in the prevalence of diabetes in the US have been documented[21] and further increases are likely if the prevalence of obesity and metabolic syndrome should continue to increase. Decreasing the high prevalence of metabolic syndrome in the US necessitates tackling the obesity epidemic, reducing sedentary behavior, and improving levels of physical activity. Like a hand in a glove, both population-based and individual-based strategies can contribute to achieve these aims.

Disclosure

The contents of this paper have not been published elsewhere. The authors have no conflicts of interest, financial or otherwise, to report.

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