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Cardiometabolic Abnormalities Among Normal-Weight Persons From Five Racial/Ethnic Groups in the United States

A Cross-sectional Analysis of Two Cohort Studies

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Background: The relationship between body weight and cardiometabolic disease may vary substantially by race/ethnicity.

Objective: To determine the prevalence and correlates of the phenotype of metabolic abnormality but normal weight (MAN) for 5 racial/ethnic groups.

Design: Cross-sectional analysis.

Setting: 2 community-based cohorts.

Participants: 2622 white, 803 Chinese American, 1893 African American, and 1496 Hispanic persons from MESA (Multi-Ethnic Study of Atherosclerosis) and 803 South Asian participants in the MASALA (Mediators of Atherosclerosis in South Asians Living in America) study.

Measurements: Prevalence of 2 or more cardiometabolic abnormalities (high fasting glucose, low high-density lipoprotein cholesterol, and high triglyceride levels and hypertension) among normal-weight participants was estimated. Correlates of MAN were assessed by using log-binomial models.

Results: Among participants of normal weight (n = 846 whites, 323 Chinese Americans, 334 African Americans, 252 Hispanics, and 195 South Asians), the prevalence of MAN was 21.0% (95% CI, 18.4% to 23.9%) in whites, 32.2% (CI, 27.3% to 37.4%) in Chinese Americans, 31.1% (CI, 26.3% to 36.3%) in African Americans, 38.5% (CI, 32.6% to 44.6%) in Hispanics, and 43.6% (CI, 36.8% to 50.6%) in South Asians. Adjustment for demographic, behavioral, and ectopic body fat measures did not explain racial/ethnic differences. After adjustment for age, sex, and race/ethnicity–body mass index (BMI) interaction, for the equivalent MAN prevalence at a BMI of 25.0 kg/m^2 in whites, the corresponding BMI values were 22.9 kg/m^2 (CI, 19.5% to 26.3%) in African Americans, 21.5 kg/m^2 (CI, 18.5% to 24.5%) in Hispanics, 20.9 kg/m^2 (CI, 19.7% to 22.1%) in Chinese Americans, and 19.6 kg/m^2 (CI, 17.2% to 22.0%) in South Asians.

Limitation: Cross-sectional study design and lack of harmonized dietary data between studies.

Conclusion: Compared with whites, all racial/ethnic minority groups had a statistically significantly higher prevalence of MAN, which was not explained by demographic, behavioral, or ectopic fat measures. Using a BMI criterion for overweight to screen for cardiometabolic risk may result in a large proportion of racial/ethnic minority groups being overlooked.

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Overweight and obesity are well-known cardiometabolic risk factors (1–3). However, some persons with normal weight have elevated cardiometabolic risk (4–7), and the relationship between excess adiposity and cardiometabolic abnormality may vary by race/ethnicity (4–7). Although some information is available regarding the prevalence and correlates of metabolic abnormality but normal weight (MAN) in non-Hispanic whites, non-Hispanic African Americans, and Mexican Americans (4, 5), no direct comparisons have been made among East or South Asians who are at high risk for cardiometabolic abnormalities, even at relatively low levels of body mass index (BMI) (8–13).

We therefore compared the prevalence of MAN among members of 5 racial/ethnic groups, including 2 Asian subgroups, by using data from 2 large, well-characterized community-based U.S. cohorts. We also examined the correlates associated with MAN in the 4 racial/ethnic minority groups compared with whites. Lastly, we determined the BMI values in the racial/ethnic minority participants that would yield a MAN prevalence equal to that in whites with a BMI of 25 kg/m^2.

Methods

We conducted a cross-sectional analysis of pooled data from MESA (Multi-Ethnic Study of Atherosclerosis) and the MASALA (Mediators of Atherosclerosis in South Asians Living in America) study. To maintain consistency with the lower age limit of MESA participants, we excluded 94 MASALA participants younger than 44 years. Excluded participants differed from those who remained in the study only by age-related clinical outcomes. We compared 803 South Asian participants from MASALA with 2622 white, 803 Chinese American, 1893 African American, and 1496 Hispanic participants from MESA.

MESA Study

The design and conduct of the MESA study have been described elsewhere (14). In brief, study participants included members of 4 racial/ethnic groups

See also:

Summary for Patients 2

(white, Chinese American, African American, and Hispanic) aged 45 to 84 years recruited from the greater New York, New York; Baltimore, Maryland; Chicago, Illinois; Los Angeles, California; Minneapolis–Saint Paul, Minnesota; and Winston-Salem, North Carolina, areas. Baseline data collection and examinations were conducted between July 2000 and July 2002. Questionnaires were used to assess demographic and behavioral characteristics, and seated blood pressure readings, anthropometric measurements, and abdominal and cardiac computed tomography (CT) scans were obtained. Physical activity was assessed by using the Typical Week Physical Activity Questionnaire (15). Fasting serum glucose levels were evaluated by using the glucose oxidase method (Ortho Clinical Diagnostics). Insulin levels were determined by the Access system (Beckman Coulter) and harmonized with an Elecsys assay (Roche Diagnostics). C-reactive protein values were assessed by using a BN II nephelometer (N High-Sensitivity C-reactive protein test, Dade Behring). Total cholesterol and high-density lipoprotein cholesterol (HDL-C) levels were determined by using the cholesterol oxidase method (Roche Diagnostics), and low-density lipoprotein cholesterol concentrations were calculated. Triglyceride levels were measured by using Triglyceride GB reagent (Roche Diagnostics). Usual dietary intake over the past year was assessed by using a 120-item food-frequency questionnaire that was validated in white, African American, and Hispanic populations and modified to include Chinese foods (16).

MASALA Study

The MASALA study involved measures and methods similar to those of MESA to allow for specific cross-racial/ethnic comparisons (17). Its design and objectives also have been described (17). In brief, MASALA studied a community-based sample of South Asian Americans who were aged 40 to 84 years, had no previously known cardiovascular disease, and were living in the greater San Francisco Bay and Chicago areas. To be eligible for the study, participants had to report South Asian ethnicity (defined as having 3 or more grandparents born in India, Pakistan, Nepal, Bangladesh, or Sri Lanka) and be able to speak and read English, Hindi, or Urdu. All other eligibility criteria were identical to those of MESA (17). Recruitment occurred between October 2010 and March 2013. All participants were screened by telephone and invited to either the University of California, San Francisco, or the Northwestern University field center for a baseline clinical examination (17). Bilingual study staff assisted participants in completing the questionnaires, which were the same as those used in MESA. Because dietary intake is distinct in South Asians, the MASALA investigators used the SHARE (Study of Health Assessment and Risk in Ethnic groups) food-frequency questionnaire, which was developed for and validated in South Asians (17). Mean caloric intake was calculated by summing the product of the frequency of consumption, nutrient composition, and portion size of each item across all food items (18).

The protocols used in the MASALA study for seated blood pressure and anthropometry were the same as those used in MESA. After resting in a seated position for 5 minutes, each participant had his or her blood pressure assessed with an automated blood pressure machine (V100 Vital Signs Monitor, GE Healthcare). Seated blood pressure was measured 3 times, and the last 2 readings were averaged to determine systolic and diastolic blood pressure. Participant weight was measured with a standing balance beam or digital scale, height with a stadiometer. Body mass index was calculated as weight in kilograms divided by height in square meters. Waist circumference was determined by using a flexible tape measure at the site of maximum circumference, halfway between the lower ribs and the anterior superior iliac spine. The circumference was measured twice, and the average was used for analysis. Blood samples were collected after a 12-hour overnight fast. Total cholesterol, triglyceride, and HDL-C levels were analyzed by enzymatic methods, and low-density lipoprotein cholesterol concentrations were calculated. Fasting plasma glucose levels were analyzed by using the hexokinase method. Serum insulin was measured by the sandwich immunoassay method (Elecsys 2010, Roche Diagnostics) (19). As in MESA, Luminex adipokine panel A (EMD Millipore) was used to measure adiponectin and resistin levels. The interassay coefficient of variations was 2.34% to 4.12% for adiponectin and 3.25% to 5.03% for resistin (19). Computed tomography scans of the abdomen (Philips Medical Systems, Toshiba Medical Systems, and Siemens Medical Solutions) were used to assess visceral, subcutaneous, and intermuscular fat mass. Noncontrast cardiac CT images were obtained with a cardiac-gated CT scanner (Phillips 16D or Toshiba MSD Aquillion 64 at the University of California, San Francisco, and Siemens Sensation Cardiac 64 at Northwestern University) to assess pericardial fat volume and hepatic fat attenuation. Measurement methods and reading centers were similar to those used in MESA (20).

Classification of Cardiometabolic Abnormalities

We used National Cholesterol Education Program–Adult Treatment Panel III criteria to consider 4 cardiometabolic abnormalities (21). Decreased HDL-C was defined as a level lower than 1.03 mmol/L (<40 mg/dL) in men or 1.29 mmol/L (<50 mg/dL) in women, or any use of lipid-lowering medication (22). Elevated triglyceride was classified as a fasting triglyceride level of 1.7 mmol/L (150 mg/dL) or greater (22). Elevated glucose was classified as a fasting plasma glucose level of 5.6 mmol/L (100 mg/dL) or greater (23) or any use of glucose-lowering medication. High blood pressure was defined as 130/85 mm Hg or greater or any use of antihypertensive medication. The waist circumference criterion was not used because of collinearity with BMI (correlation coefficient, 0.85; $P < 0.0001$). On the basis of previous literature, cardiometabolic abnormality was defined as the presence of 2 or more of the aforementioned components (4, 24–28).

BMI Categories

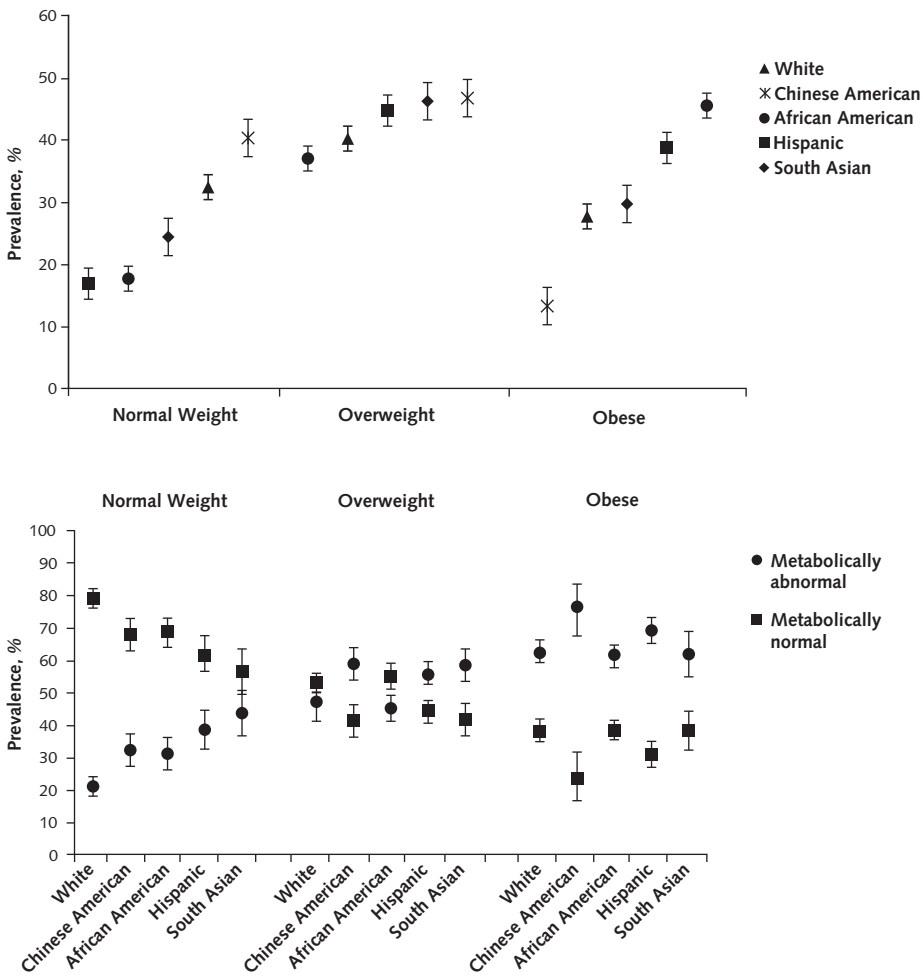
For white, African American, and Hispanic participants, BMI was classified according to World Health Organization (WHO) standard cut points for normal weight (BMI, 18.5 to 24.9 kg/m^2), overweight (BMI, 25.0 to 29.9 kg/m^2), and obesity (BMI, ≥30 kg/m^2) (27). For South Asian and Chinese American participants, BMI was classified according to WHO Asian cut points for normal weight (BMI, 18.5 to 22.9 kg/m^2), overweight (BMI, 23.0 to 27.4 kg/m^2), and obesity (BMI, ≥27.5 kg/m^2) (28). We also conducted sensitivity analyses by using the standard WHO BMI cut points for all racial/ethnic groups.

Body size phenotypes were defined on the basis of a combination of BMI category (normal weight) and cardiometabolic health. Combinations of BMI and cardiometabolic status yielded 2 distinct phenotypes (normal weight without cardiometabolic abnormalities and normal weight with cardiometabolic abnormalities [MAN]). We focused our analysis on the discordant MAN phenotype.

Statistical Analysis

Analyses were conducted by using pooled data from the 2 cohorts. Participant characteristics were described as means, geometric means, and percentages by race/ethnicity. Differences in these characteristics across race/ethnicity were assessed by using chi-square tests or analysis of variance as appropriate. The prevalence of metabolic abnormality was calculated by BMI strata. Prevalence ratios of MAN in Chinese, African American, Hispanic, and South Asian participants compared with whites were estimated by using Poisson models with robust SEs (29). Multivariate models were adjusted for age, sex, education, physical activity, daily caloric intake, alcohol use, smoking status, hepatic fat

Figure 1. Prevalence of BMI categories and metabolic status, by race/ethnicity.



Top. Prevalence of BMI category, by race/ethnicity. Error bars are 95% CIs. **Bottom.** Prevalence of metabolic normality, by BMI category and race/ethnicity. Metabolically abnormal was defined as the presence of ≥2 of the following components: decreased high-density lipoprotein cholesterol levels (<1.036 mmol/L [<40 mg/dL] in men or <1.295 mmol/L [<50 mg/dL] in women or use of lipid-lowering medication), elevated triglyceride levels (fasting triglyceride levels ≥1.7 mmol/L [≥150 mg/dL]), elevated glucose levels (fasting plasma glucose level ≥5.6 mmol/L [≥100 mg/dL] or use of glucose-lowering medication), and high blood pressure (≥130/85 mm Hg or use of antihypertensive medication). Error bars are 95% CIs. BMI = body mass index.

Table 1. Characteristics of Participants With MAN Phenotype, by Race/Ethnicity*

Characteristic	South Asian (*n* = 85)	White (*n* = 178)	*P* Value	Chinese American (*n* = 104)	*P* Value	African American (*n* = 104)	*P* Value	Hispanic (*n* = 97)	*P* Value
Prevalence, %	43.6	21.0	<0.001	32.2	0.008	31.1	0.004	38.5	0.04
Men, %	72.9	39.3	<0.001	47.1	<0.001	53.4	0.007	50.5	0.02
Mean age (SD), *y*	59.6 (8.9)	68.0 (9.6)	<0.001	66.8 (9.0)	<0.001	67.0 (9.6)	<0.001	64.6 (10.9)	0.001
Mean systolic blood pressure (SD), *mm Hg*	128.4 (15.9)	132.1 (21.7)	0.17	129.7 (24.3)	0.68	136.1 (19.6)	0.004	134.0 (24.9)	0.08
Mean diastolic blood pressure (SD), *mm Hg*	74.9 (8.8)	71.6 (10.0)	<0.001	71.6 (11.7)	0.04	75.4 (9.9)	0.67	72.8 (10.1)	0.15
Hypertension, %	67.1	78.1	0.57	65.4	0.81	92.3	0.002	69.1	0.09
Mean fasting glucose level (SD)			<0.001		0.46		0.36		0.33
mmol/L	6.3 (1.4)	5.3 (1.9)		6.1 (2.1)		6.0 (2.4)		6.7 (3.6)	
mg/dL	112.8 (24.6)	94.9 (34.9)		109.3 (37.6)		108.0 (43.7)		120.2 (65.4)	
Diabetes, %	38.8	7.9	<0.001	24.0	0.07	28.9	0.12	26.8	0.03
Mean total cholesterol level (SD)			<0.001		0.008		0.04		<0.001
mmol/L	5.00 (1.04)	5.11 (1.13)		5.00 (0.82)		4.91 (1.05)		5.21 (0.99)	
mg/dL	177.5 (40.0)	197.2 (43.5)		191.5 (31.7)		189.5 (40.6)		201.3 (38.3)	
Mean LDL-C level (SD)			0.005		0.02		0.02		<0.001
mmol/L	2.62 (0.84)	2.92 (0.79)		2.90 (0.68)		2.94 (0.97)		3.13 (0.92)	
mg/dL	101.2 (32.4)	112.8 (30.4)		111.6 (26.4)		113.7 (37.3)		120.8 (35.4)	
Mean HDL-C level (SD)			0.58		0.78		0.46		0.07
mmol/L	1.25 (0.34)	1.28 (0.40)		1.24 (0.32)		1.29 (0.41)		1.16 (0.36)	
mg/dL	48.3 (13.3)	49.4 (15.4)		47.8 (12.5)		49.9 (15.9)		44.7 (13.8)	
Geometric mean triglyceride level (SD)			0.03		0.07		0.16		<0.001
mmol/L									
mg/dL	123.5 (2.4)	143.8 (2.7)		141.9 (2.7)		110.8 (2.6)		161.5 (2.5)	
Mean calories (SD), *kcal/d*	1719 (477)	1446 (695)	0.002	1020 (620)	<0.001	1473 (710)	0.009	1598 (943)	0.30
Geometric mean HOMA-IR score (SD)	2.4 (0.5)	1.6 (0.2)	<0.001	1.9 (0.3)	0.002	2.0 (0.5)	0.12	1.9 (0.4)	0.02
Geometric mean HOMA-β score (SD)	70.5 (2.5)	99.7 (2.9)	<0.001	69.9 (2.8)	0.94	82.8 (4.0)	0.17	66.2 (3.8)	0.60
Geometric mean C-reactive protein level (SD), *nmol/L*	8.6 (9.5)	15.2 (5.7)	<0.001	8.6 (9.5)	0.88	18.1 (7.6)	<0.001	15.2 (5.7)	<0.001
Geometric mean adiponectin level (SD), *ng/mL*†	9.3 (1.3)	20.4 (1.6)	<0.001	14.3 (1.7)	0.008	19.8 (1.9)	<0.001	18.8 (1.3)	<0.001
Mean resistin level (SD), *ng/mL*†	22.2 (9.5)	15.8 (4.6)	<0.001	13.0 (4.6)	<0.001	21.6 (8.7)	0.99	16.7 (7.6)	0.01
Mean waist circumference (SD), *cm*	86.2 (6.0)	88.9 (7.1)	0.003	82.5 (5.7)	<0.001	87.6 (7.2)	0.15	88.1 (6.3)	0.03
Mean subcutaneous fat area (SD), cm^2†	155.2 (45.0)	168.4 (56.5)	0.16	144.8 (48.8)	0.38	182.7 (62.7)	0.02	177.7 (68.8)	0.04
Mean visceral fat area (SD), cm^2†	122.4 (44.4)	121.0 (48.7)	0.87	97.6 (33.6)	0.03	102.4 (47.4)	0.02	120.3 (47.4)	0.83
Mean hepatic fat attenuation (SD), *Hounsfield units*	55.9 (9.5)	64.0 (10.2)	<0.001	64.3 (10.7)	<0.001	63.4 (9.5)	<0.001	63.7 (12.1)	<0.001
Mean pericardial fat volume (SD), cm^3	51.0 (20.4)	66.4 (30.2)	<0.001	64.9 (19.4)	<0.001	53.3 (25.6)	0.49	64.3 (25.6)	<0.001
Mean intermuscular fat area (SD), cm^2†	17.4 (6.4)	22.9 (8.2)	<0.001	18.2 (4.7)	0.61	16.6 (6.9)	0.57	18.2 (6.0)	0.54
Mean physical activity (SD), *metabolic equivalent min/wk*	1057 (7.0)	1995 (8.0)	<0.001	1093 (7.0)	0.82	1791 (8.7)	0.002	1059 (8.0)	0.99
Never smoker, %	81.2	46.6	<0.001	73.1	0.19	39.4	<0.001	66.0	0.02
Alcohol use, %‡	41.1	61.0	0.003	19.4	0.001	63.5	0.002	41.2	0.99

HDL-C = high-density lipoprotein cholesterol; HOMA-β = homeostasis model assessment of β-cell function; HOMA-IR = homeostasis model assessment of insulin resistance; LDL-C = low-density lipoprotein cholesterol; MAN = metabolic abnormality but normal weight.
* *P* values compare characteristics with those of South Asians.
† Data are from a restricted sample that included only metabolically abnormal participants with measurements of adiponectin and resistin levels, subcutaneous and intermuscular fat area, and visceral fat area (396 South Asian, 281 white, 112 Chinese American, 145 African American, and 202 Hispanic participants).
‡ Defined as consumption of ≥1 drink weekly.

attenuation, and pericardial fat volume. Additional, restricted models including only the subset of participants who had measures of visceral fat, adiponectin, and resistin also were performed. To estimate the BMI values for South Asian, African American, Hispanic, and Chinese American participants that result in metabolic

outcomes equal to those in whites with a BMI of 25 kg/m^2 or 30 kg/m^2, we first fit a proportional odds model for the number of cardiometabolic abnormalities, with group-specific 4-knot restricted cubic splines in BMI, adjusting for sex and a 4-knot restricted cubic spline in age, then calculated the marginal expected number of abnormalities among whites, evaluated at a BMI of 25 kg/m^2 or 30 kg/m^2. We then used a search algorithm to find the BMI values for each of the other 4 groups that resulted in approximately the same marginal expected number of abnormalities. We also used this procedure to obtain BMI values for South Asian, African American, Hispanic, and Chinese American participants, resulting in an expected MAN prevalence approximately equal to that among whites with a BMI of 25 kg/m^2, based on a Poisson model for MAN, also adjusting for sex and a 4-knot spline in age. Confidence intervals for the BMI estimates were obtained by using bootstrap resampling. All analyses were performed with SAS, version 9.3 (SAS Institute).

The MESA study protocol was approved by the institutional review boards (IRBs) of the 6 field centers and the National Heart, Lung, and Blood Institute (NHLBI). The IRBs of Northwestern University and the University of California, San Francisco, approved the MASALA study protocol. The analysis was approved by the IRB at Emory University.

Role of the Funding Source

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RESULTS

The total sample of 7617 participants comprised 2622 whites, 803 Chinese Americans, 1893 African Americans, and 1496 Hispanic Americans from MESA and 803 South Asians from MASALA. The sample also was made up of 1950 (25.6%) normal-weight, 3163 (41.5%) overweight, and 2504 (32.9%) obese participants. Overall, the South Asian participants were significantly younger than members of all other racial/ethnic groups, and this group had a significantly higher proportion of men compared with all other racial/ethnic groups except for Chinese Americans (**Appendix Table 1**, available at Annals.org).

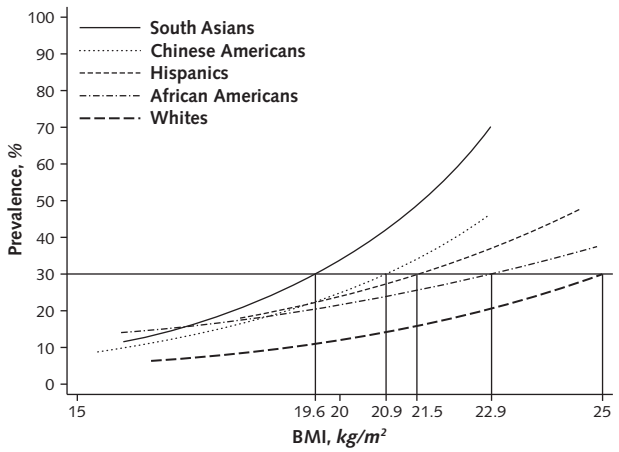
Prevalence of MAN

The overall prevalence of normal weight and obesity varied by race/ethnicity, with white and Chinese American participants having the highest prevalence of normal weight (32.3% and 40.2%, respectively) and African American and Hispanic participants having the highest prevalence of obesity (45.4% and 38.6%, respectively) (**Figure 1**, *top*). Overall, 29.1% of the participants with normal weight had the MAN phenotype, whereas 35.8% of those with obesity were metaboli-

Table 2. Unadjusted and Multivariable-Adjusted Prevalence Ratios of the Metabolically Abnormal Phenotype Among Normal-Weight Persons*

Covariate	Prevalence Ratio (95% CI)	
	Unadjusted	Multivariable-Adjusted†
Race/ethnicity		
White	1.00 (reference)	1.00 (reference)
South Asian	2.07 (1.69–2.55)	2.53 (1.99–3.22)
Chinese American	1.53 (1.25–1.88)	1.27 (1.02–1.59)
African American	1.48 (1.20–1.82)	1.66 (1.35–2.04)
Hispanic	1.83 (1.49–2.24)	1.56 (1.26–1.92)
Age		
44–54 y	1.00 (reference)	1.00 (reference)
55–64 y	1.71 (1.36–2.14)	1.37 (1.10–1.70)
65–74 y	2.26 (1.82–2.79)	1.80 (1.45–2.22)
75–84 y	2.52 (1.99–3.18)	1.94 (1.51–2.49)
Sex		
Male	1.00 (reference)	1.00 (reference)
Female	0.79 (0.69–0.90)	0.94 (0.81–1.10)
Highest education level		
High school or less	1.00 (reference)	1.00 (reference)
Less than a bachelor's degree	0.70 (0.58–0.83)	0.87 (0.73–1.05)
Bachelor's degree	0.56 (0.45–0.69)	0.70 (0.56–0.87)
Higher than a bachelor's degree	0.65 (0.54–0.78)	0.74 (0.60–0.92)
Alcohol use		
≥1 drink daily	1.00 (reference)	1.00 (reference)
<1 drink daily	1.15 (1.00–1.32)	1.00 (0.86–1.16)
Smoking status		
Never	1.00 (reference)	1.00 (reference)
Former	0.91 (0.78–1.06)	0.99 (0.84–1.17)
Current	0.84 (0.66–1.05)	0.90 (0.72–1.13)
Physical activity		
0–630 metabolic equivalent min/wk	1.00 (reference)	1.00 (reference)
631–1470 metabolic equivalent min/wk	1.00 (0.72–1.40)	1.15 (0.83–1.59)
1471–3000 metabolic equivalent min/wk	0.94 (0.68–1.30)	1.11 (0.80–1.53)
>3000 metabolic equivalent min/wk	0.78 (0.57–1.06)	1.04 (0.76–1.43)
Calories		
<1069 kcal/d	1.00 (reference)	1.00 (reference)
1069–1496 kcal/d	0.94 (0.79–1.12)	0.90 (0.76–1.07)
1497–2010 kcal/d	0.93 (0.77–1.12)	0.89 (0.74–1.07)
>2010 kcal/d	0.76 (0.61–0.94)	0.75 (0.60–0.93)
Pericardial fat volume		
<1.16 cm^3	1.00 (reference)	1.00 (reference)
1.16–1.67 cm^3	1.61 (1.35–1.90)	1.47 (1.23–1.75)
1.68–2.34 cm^3	2.21 (1.85–2.64)	1.93 (1.59–2.34)
>2.34 cm^3	2.76 (2.20–3.46)	2.40 (1.88–3.05)
Hepatic fat attenuation		
<4.40 Hounsfield units	1.00 (reference)	1.00 (reference)
4.40–5.00 Hounsfield units	0.73 (0.60–0.88)	0.73 (0.61–0.87)
5.01–5.47 Hounsfield units	0.54 (0.44–0.66)	0.59 (0.49–0.71)
>5.47 Hounsfield units	0.50 (0.41–0.61)	0.54 (0.45–

Figure 2. Race/ethnicity-specific BMI values associated with MAN compared with whites with a BMI of 25 kg/m^2.



MAN was defined as a BMI of 18.5 to 24.9 kg/m^2 for white, African American, and Hispanic participants or a BMI of 18.5 to 22.9 kg/m^2 for South Asian and Chinese American participants and ≥2 of the following components: decreased high-density lipoprotein cholesterol levels (<1.036 mmol/L [<40 mg/dL] in men or <1.295 mmol/L [<50 mg/dL] in women or use of lipid-lowering medication), elevated triglyceride levels (fasting triglyceride levels ≥1.7 mmol/L [≥150 mg/dL]), elevated glucose levels (fasting plasma glucose level ≥5.6 mmol/L [≥100 mg/dL] or use of glucose-lowering medication), and high blood pressure (≥130/85 mm Hg or use of antihypertensive medication). To obtain BMI values for South Asians, African Americans, Hispanics, and Chinese Americans that would result in an expected MAN prevalence approximately equal to that among whites with a BMI of 25 kg/m^2, based on a Poisson model for MAN, a proportional odds model was fit for the prevalence of MAN in white participants with a BMI of 25 kg/m^2, with group-specific 4-knot restricted cubic splines in BMI, adjusting for sex and a 4-knot restricted cubic spline in age. A search algorithm then was used to find the BMI values for each of the other 4 groups that resulted in approximately the same expected prevalence of MAN. BMI = body mass index; MAN = metabolic abnormality but normal weight.

cally normal. The prevalence of MAN varied significantly by race/ethnicity: 21.0% (95% CI, 18.4% to 23.9%) in whites, 32.2% (CI, 27.3% to 37.4%) in Chinese Americans, 31.1% (CI, 26.3% to 36.3%) in African Americans, 38.5% (CI, 32.6% to 44.6%) in Hispanics, and 43.6% (CI, 36.8% to 50.6%) in South Asians (**Figure 1**, *bottom*). These patterns were consistent by sex in all racial/ethnic groups except for South Asians, in whom the prevalence of MAN was greater in men (57.4%) than women (26.4%). In sensitivity analyses using the standard BMI criterion for the 2 Asian American subgroups, the prevalence of MAN was 40.4% in Chinese American and 47.9% in South Asian participants.

Among participants with 2 or more cardiometabolic abnormalities, the most common risk factor combination in whites was hypertension and a low HDL-C level (40.0%). In all other racial/ethnic groups, the risk factor combination of high glucose and low HDL-C levels was most common (48.7% in South Asians, 37.3% in Chinese Americans, 36.4% in African Americans, and 37.9% in Hispanics). **Appendix Table 2** (available at Annals.org) details the prevalence of risk factor combinations among all racial/ethnic groups.

Among participants with MAN, South Asians were significantly younger than members of all other racial/ethnic groups (**Table 1**). A significantly greater proportion of South Asians than whites or Hispanics had diabetes. Mean daily caloric intake was significantly higher in South Asians than members of any other racial/ethnic group except Hispanics. Levels of circulating adiponectin were significantly lower in South Asians than members of all other racial/ethnic groups. South Asians also had less hepatic fat attenuation (more fat in the liver) than all other racial/ethnic groups and less pericardial fat volume than all other groups except African Americans. **Appendix Table 3** (available at Annals.org) details the characteristics of participants who were normal weight regardless of metabolic phenotype.

Correlates of the MAN Phenotype

Compared with whites, the prevalence of MAN was approximately 100% greater in South Asians, 50% in Chinese and African Americans, and 80% in Hispanics (**Table 2**). It was also higher in older participants and those with greater pericardial fat volume and lower in those with higher educational status and greater hepatic fat attenuation (less fat in the liver). In a multivariable-adjusted model, South Asian, Chinese, African American, and Hispanic race/ethnicity remained independently associated with MAN, as did older age, pericardial fat volume, educational status, and hepatic fat attenuation. Adjustment for age, sex, education, smoking status, alcohol use, physical activity, daily caloric intake, hepatic fat attenuation, and pericardial fat volume did not explain the differences in MAN among the study groups.

In restricted models including only normal-weight persons with measured visceral fat mass, adiponectin, and resistin (**Appendix Table 4**, available at Annals.org), MAN was more prevalent in South Asians, Chinese Americans, African Americans, and Hispanics than whites. In multivariable-adjusted models, the prevalence of MAN remained greater in South Asians and Hispanics, but not in Chinese and African American participants, compared with whites.

Ethnic-Specific BMI Values

We estimated the BMI values at which the expected numbers of metabolic abnormalities among South Asians, Chinese Americans, African Americans, and Hispanics would equal those among whites with a BMI of 25.0 kg/m^2 or 30.0 kg/m^2. For the equivalent number of cardiometabolic abnormalities at a BMI of 25.0 kg/m^2 in white participants, the corresponding BMI values were 22.3 kg/m^2 (CI, 19.7% to 24.9%) in African Americans, 21.5 kg/m^2 (CI, 18.5% to 24.5%) in Hispanics, 20.5 kg/m^2 (CI, 19.6% to 21.4%) in Chinese Americans, and 18.9 kg/m^2 (CI, 16.7% to 21.1%) in South Asians. For the equivalent number at a BMI of 30.0 kg/m^2 in whites, the corresponding BMI values were 29.9 kg/m^2 (CI, 25.6% to 34.2%) in African Americans, 27.0 kg/m^2 (CI, 26.0% to 28.0%) in Hispanics, 24.5 kg/m^2 (CI, 23.6% to 25.5%) in Chinese Americans, and 23.3 kg/m^2 (CI, 22.3% to 24.3%) in South Asians. **Figure 2** displays the racial/ethnic BMI values associated with MAN prevalence after adjustment for age, sex, and race–BMI interaction. For the equivalent MAN

prevalence at a BMI of 25.0 kg/m^2 in whites, the corresponding BMI values were 22.9 kg/m^2 (CI, 19.5% to 26.3%) in African Americans, 21.5 kg/m^2 (CI, 18.5% to 24.5%) in Hispanics, 20.9 kg/m^2 (CI, 19.7% to 22.1%) in Chinese Americans, and 19.6 kg/m^2 (CI, 17.2% to 22.0%) in South Asians.

DISCUSSION

In this cross-sectional study of 2 large community-based cohorts including participants from several racial/ethnic groups in the United States, we found that nearly a third of those who were normal weight had cardiometabolic abnormalities. Furthermore, MAN prevalence varied by race/ethnicity, with a significantly higher proportion of South Asians and Hispanics, followed by Chinese and African Americans, having this phenotype compared with whites. Adjustment for demographic, behavioral, and ectopic fat variables did not explain these differences. For a MAN prevalence equivalent to that in whites with a BMI of 25 kg/m^2, the corresponding BMI values were lower in all racial/ethnic minority groups, suggesting that BMI alone is a poor indicator of cardiometabolic risk in most of these populations. A recent, nationally representative study assessing the prevalence and correlates of MAN in whites, African Americans, and Mexican Americans reported that 23.5% of all normal-weight adults had metabolic abnormalities (4). This percentage is lower than our finding of 29%, which partly may be a result of the younger mean age of the prior study's participants. Another difference is that our study included South Asian and Chinese American participants as well as measures of ectopic fat and adipokine levels; a previous study comparing the MESA and MASALA populations found significant differences in ectopic fat distribution and adipokine levels between South Asians and the 4 MESA racial/ethnic groups (30). Although these differences may partially account for the increased predisposition to insulin resistance and type 2 diabetes among South Asians, adjustment for ectopic fat measures and adipokine levels did not explain the difference in MAN among racial/ethnic groups in our study. Our findings also are consistent with those of a larger, longitudinal study, which found that a BMI cut point of 30 kg/m^2 in whites was equivalent to lower BMI cut points for South Asians, Chinese Americans, and African Americans in terms of diabetes incidence (13). Finally, our results build on those of a study that found elevated glucose and lipid levels at lower BMI values in non-European (South Asian, Chinese, and Aboriginal Canadian) versus European populations (12). Taken together, these findings suggest that established BMI cut points may be practical markers for detecting overweight but may not necessarily correlate with overall cardiometabolic health and that race/ethnicity alone may be a better predictor of cardiometabolic risk in racial/ethnic minority populations.

Our study has several strengths. We investigated cardiometabolic abnormalities in normal-weight persons from 5 U.S. racial/ethnic groups, including the relatively understudied South Asian and Chinese American populations, in whom previous studies showed cardiometabolic abnormalities developing at lower BMI levels than in other racial/ethnic groups (11–13). Furthermore, our study used harmonized data from 2 large cohorts that included several radiographic measures of body composition to assess ectopic fat and adipokine levels.

However, our results also should be interpreted within the context of several limitations. The difference in timing of data collection between studies (2000 to 2002 for MESA and 2010 to 2013 for MASALA) may have resulted in some differences in the prevalence of overweight and obesity between the 2 cohorts. Because the initial enrollment of the MESA cohort began a decade and a half ago, secular changes may have occurred in the adoption of healthier behaviors, such as a decreased prevalence of smoking (31). However, the prevalence of obesity and diabetes has not decreased substantially during the past 2 decades (32–34). Thus, we do not believe that the prevalence of metabolic abnormalities observed in the MESA participants would be much different from that observed in a current sample of middle- to older-aged adults. Furthermore, MESA and MASALA used different food-frequency questionnaires, limiting our ability to assess whether dietary patterns contribute to MAN prevalence. Of note, adjustment for daily caloric intake did not explain differences in MAN prevalence among racial/ethnic groups. Although the MASALA and MESA cohorts are community-based samples, neither is nationally representative; therefore, the results may not be generalizable to younger persons or South Asians and Chinese Americans born in the United States.

In conclusion, our findings suggest a high prevalence of cardiometabolic abnormality among normal-weight persons, particularly those in racial/ethnic minority populations. This disparity cannot be explained by differences in demographic, behavioral, or ectopic fat measures. Therefore, clinicians using overweight and obesity as the main criteria for cardiometabolic screening, as currently recommended by the U.S. Preventive Services Task Force for diabetes testing (35), may fail to identify cardiometabolic abnormalities in many patients from racial/ethnic minority groups. Although the Task Force recommends earlier screening in racial/ethnic minority populations, testing for cardiometabolic abnormalities in normal-weight and underweight members of these groups also may be an important consideration. Future research is needed to identify the prospective associations between MAN and incident diabetes and cardiovascular disease in various racial/ethnic groups.

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Reproducible Research Statement: *Study protocol:* MASALA protocol available from Dr. Kanaya (e-mail, alka.kanaya@ucsf.edu); MESA protocol available at www.mesa-nhlbi.org. *Statistical code:* Available from Dr. Gujral (e-mail, ugujral@emory.edu). *Data set:* Available with steering committee approval from both MESA and MASALA.

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Appendix Table 1. Characteristics of Study Participants, by Race/Ethnicity*

Characteristic	South Asian (*n* = 803)	White (*n* = 2622)	*P* Value	Chinese American (*n* = 803)	*P* Value	African American (*n* = 1893)	*P* Value	Hispanic (*n* = 1496)	*P* Value	Missing, *n*
Prevalence, %	10.5	34.4	<0.001	10.5	1.0	24.9	<0.001	19.6	<0.001	0
Men, %	52.8	48.0	0.02	48.6	0.09	44.5	<0.001	48.2	0.04	
Mean age (SD), *y*	56.9 (8.6)	62.6 (10.2)	<0.001	62.3 (10.3)	<0.001	62.1 (10.5)	<0.001	62.3 (10.3)	0.001	0
Mean systolic blood pressure (SD), *mm Hg*	125.6 (15.9)	123.5 (20.4)	0.01	124.6 (21.6)	<0.001	131.7 (21.6)	<0.001	126.7 (21.9)	0.02	3
Mean diastolic blood pressure (SD), *mm Hg*	73.3 (9.9)	70.2 (10.0)	<0.001	72.0 (10.3)	0.007	74.5 (10.2)	0.007	71.6 (10.1)	<0.001	3
Hypertension, %	52.8	47.4	0.007	48.1	0.06	68.3	<0.001	50.7	0.34	0
Mean fasting glucose level (SD), *mg/dL*	104.2 (25.4)	91.4 (21.5)	<0.001	99.0 (28.2)	<0.001	100.0 (32.0)	0.001	103.6 (39.1)	0.72	37
Diabetes, %	21.9	6.0	<0.001	13.1	<0.001	17.5	0.008	17.7	0.01	0
Mean total cholesterol level (SD), *mg/dL*	187.3 (36.7)	195.7 (35.1)	<0.001	192.6 (31.8)	0.002	189.6 (36.2)	0.12	197.9 (37.5)	<0.001	27
Mean LDL-C level (SD), *mg/dL*	110.6 (32.0)	117.0 (30.1)	<0.001	115.1 (29.0)	0.004	116.5 (33.0)	<0.001	119.5 (32.9)	<0.001	112
Mean HDL-C level (SD), *mg/dL*	50.3 (13.3)	52.2 (15.7)	<0.001	49.5 (12.7)	0.22	52.4 (15.3)	<0.001	47.6 (13.1)	<0.001	29
Geometric mean triglyceride level (SD), *mg/dL*	119.1 (2.1)	114.4 (2.5)	0.05	124.5 (2.5)	0.07	92.3 (2.2)	<0.001	136.7 (2.5)	<0.001	26
Mean calories, *kcal/d*	1675 (499)	1688 (761)	0.66	1152 (612)	<0.001	1683 (995)	0.85	1696 (930)	0.56	293
Mean geometric mean HOMA-IR score (SD)	2.6 (0.7)	1.8 (0.3)	<0.001	2.0 (0.4)	<0.001	2.2 (0.5)	<0.001	2.4 (0.6)	0.008	92
Geometric mean HOMA-β score (SD)	100.6 (2.9)	118.0 (2.6)	<0.001	96.8 (2.9)	0.22	108.9 (3.2)	0.01	109.9 (3.4)	0.004	92
Geometric mean C-reactive protein level (SD), *μg/mL*	1.3 (0.3)	1.8 (0.7)	<0.001	0.9 (0.1)	<0.001	1.1 (0.8)	<0.001	2.4 (0.9)	<0.001	64
Geometric mean adiponectin level (SD), *ng/mL*†	10.2 (1.5)	20.9 (1.7)	<0.001	14.1 (1.6)	<0.001	15.8 (1.6)	<0.001	17.3 (1.5)	<0.001	0
Mean resistin level (SD), *ng/mL*†	21.9 (12.1)	16.1 (5.3)	<0.001	15.3 (7.5)	<0.001	18.0 (13.7)	<0.001	16.1 (6.7)	<0.001	0
Mean waist circumference (SD), *cm*	92.7 (10.0)	98.0 (14.4)	<0.001	87.1 (9.9)	<0.001	101.2 (14.7)	<0.001	100.6 (13.1)	<0.001	1
Mean subcutaneous fat area (SD), cm^2	236.5 (95.2)	254.5 (115.4)	0.002	179.4 (70.9)	<0.001	298.5 (132.2)	<0.001	264.0 (108.5)	<0.001	0
Mean visceral fat area (SD), cm^2†	136.1 (57.0)	151.9 (74.9)	<0.001	113.9 (47.8)	<0.001	119.1 (55.9)	<0.001	151.6 (60.7)	<0.001	0
Mean hepatic fat attenuation (SD), *Hounsfield units*	55.1 (10.6)	61.4 (12.2)	<0.001	61.9 (12.0)	<0.001	63.0 (11.7)	<0.001	59.4 (14.2)	<0.001	80
Mean pericardial fat volume (SD), cm^3	59.5 (29.6)	85.2 (46.1)	<0.001	73.7 (31.4)	<0.001	67.5 (34.7)	0.49	88.3 (43.8)	<0.001	30
Mean intermuscular fat area (SD), cm^2	21.7 (8.8)	26.9 (12.0)	<0.001	18.7 (7.5)	<0.001	19.9 (12.3)	0.004	23.5 (9.9)	0.001	0
Mean physical activity (SD), *metabolic equivalent min/wk*	1048 (6.4)	1741 (7.7)	<0.001	1122 (7.6)	0.20	1574 (8.8)	<0.001	1205 (8.7)	0.009	19
Never smoker, %	82.9	44.1	<0.001	75.2	<0.001	44.9	<0.001	53.9	<0.001	22
Alcohol use, %‡	32.3	64.5	<0.001	21.4	<0.001	51.7	<0.001	46.8	<0.001	84

HDL-C = high-density lipoprotein cholesterol; HOMA-β = homeostasis model assessment of β-cell function; HOMA-IR = homeostasis model assessment of insulin resistance; LDL-C = low-density lipoprotein cholesterol.

* This sample includes all participants from the pooled MESA (Multi-Ethnic Study of Atherosclerosis) and MASALA (Mediators of Atherosclerosis in South Asians Living in America) cohorts regardless of weight and metabolic status. *P* values compare characteristics with those of South Asians. To convert glucose, cholesterol, or triglyceride values to mmol/L, multiply by 0.0555, 0.0259, or 0.0113, respectively.

† Data are from a restricted sample that included only participants with adiponectin, resistin, and visceral fat area measurements (708 South Asian, 645 white, 235 Chinese American, 337 African American, and 382 Hispanic participants).

‡ Defined as consumption of ≥1 drink weekly.

Appendix Table 2. Prevalence of Risk Factor Combinations Among Persons With ≥2 Cardiometabolic Risk Factors, by Race/Ethnicity*

Race/Ethnicity	Elevated Triglycerides/High Blood Pressure	Elevated Triglycerides/Elevated Glucose	Elevated Triglycerides/Low HDL-C	High Blood Pressure/Elevated Glucose	High Blood Pressure/Low HDL-C	Elevated Glucose/Low HDL-C
White	104 (9.25)	11 (0.98)	172 (15.3)	106 (9.43)	449 (39.95)	282 (25.09)
Chinese American	23 (5.68)	13 (3.21)	51 (12.59)	58 (11.85)	119 (29.38)	151 (37.28)
African American	38 (4.00)	7 (0.74)	24 (2.53)	211 (22.23)	324 (34.14)	345 (36.35)
Hispanic	57 (6.58)	19 (2.19)	137 (15.82)	112 (12.93)	213 (24.60)	328 (37.88)
South Asian	17 (3.79)	9 (2.01)	42 (9.38)	65 (14.51)	97 (21.65)	218 (48.66)

HDL-C = high-density lipoprotein cholesterol.
* Values are numbers (percentages).

Appendix Table 3. Characteristics of Normal-Weight Participants, by Race/Ethnicity*

Characteristic	South Asian (*n* = 195)	White (*n* = 846)	*P* Value	Chinese American (*n* = 323)	*P* Value	African American (*n* = 334)	*P* Value	Hispanic (*n* = 252)	*P* Value	Missing, *n*
Prevalence, %	24.3	32.3	<0.001	40.2	<0.001	17.6	<0.001	16.8	<0.001	0
Men, %	55.4	37.0	<0.001	45.5	0.03	52.7	0.55	48.4	0.14	0
Mean age (SD), *y*	57.8 (8.8)	62.7 (10.7)	<0.001	62.8 (10.1)	<0.001	63.5 (10.7)	<0.001	62.0 (11.2)	<0.001	0
Mean systolic blood pressure (SD), *mm Hg*	122.9 (16.1)	118.9 (21.9)	0.02	121.0 (22.8)	0.31	127.6 (21.5)	0.009	123.1 (24.1)	0.94	0
Mean diastolic blood pressure (SD), *mm Hg*	72.2 (9.4)	67.9 (10.1)	<0.001	70.3 (10.3)	0.03	74.3 (10.1)	0.02	69.4 (10.1)	0.004	0
Hypertension, %	42.6	36.3	0.01	37.8	0.28	59.3	<0.001	42.9	0.95	0
Mean fasting glucose level (SD), *mg/dL*	100.7 (20.3)	85.7 (18.2)	<0.001	95.3 (25.9)	0.01	91.5 (27.3)	<0.001	98.9 (44.4)	<0.001	
Diabetes, %	18.0	2.3	<0.001	8.7	0.002	9.6	0.005	10.7	0.03	0
Mean total cholesterol level (SD), *mg/dL*	185.3 (35.2)	196.5 (34.9)	<0.001	193.0 (31.3)	0.01	186.6 (36.5)	0.70	197.9 (36.3)	<0.001	5
Mean LDL-C level (SD), *mg/dL*	108.4 (30.3)	115.3 (29.6)	0.004	114.6 (27.5)	0.02	108.7 (33.7)	0.91	118.8 (33.0)	<0.001	20
Mean HDL-C level (SD), *mg/dL*	54.2 (14.8)	59.8 (17.7)	0.002	54.5 (13.3)	0.22	59.5 (18.9)	<0.001	52.8 (16.2)	<0.001	7
Geometric mean triglyceride level (SD), *mg/dL*	101.2 (2.1)	92.0 (2.2)	0.01	105.7 (2.3)	0.32	80.1 (2.2)	<0.001	115.3 (2.4)	0.006	5
Mean calories (SD), *kcal/d*	1648 (494)	1553 (726)	0.08	1150 (613)	<0.001	1617 (911)	0.66	1597 (995)	0.51	55
Geometric mean HOMA-IR score (SD)	1.7 (0.3)	1.2 (0.1)	<0.001	1.5 (0.2)	<0.001	1.3 (0.2)	<0.001	1.5 (0.2)	0.002	29
Geometric mean HOMA-β score (SD)	75.0 (2.3)	102.5 (2.4)	<0.001	83.1 (2.5)	0.05	94.3 (3.0)	<0.001	84.5 (3.2)	0.06	29
Geometric mean C-reactive protein level (SD), *µg/mL*	0.8 (0.2)	1.1 (0.1)	<0.001	0.7 (0.4)	0.12	1.4 (0.4)	<0.001	1.5 (0.5)	<0.001	15
Geometric mean adiponectin level (SD), *ng/mL*†	11.6 (1.5)	26.6 (1.8)	<0.001	17.2 (1.5)	<0.001	18.7 (1.9)	<0.001	20.0 (1.4)	<0.001	0
Mean resistin level (SD), *ng/mL*†	21.6 (9.0)	15.1 (4.3)	<0.001	14.0 (7.5)	0.008	17.9 (10.4)	<0.001	15.8 (6.9)	<0.001	0
Mean waist circumference (SD), *cm*	84.0 (6.3)	84.6 (8.8)	0.36	79.3 (7.0)	<0.001	84.5 (7.7)	0.43	86.2 (7.4)	<0.001	0
Mean subcutaneous fat area (SD), cm^2	162.5 (50.0)	183.4 (72.0)	0.001	137.2 (49.8)	<0.001	188.4 (78.2)	0.002	179.7 (67.2)	0.02	0
Mean visceral fat area (SD), cm^2†	99.2 (43.9)	97.3 (44.7)	0.67	82.2 (32.0)	0.003	81.0 (40.3)	0.003	107.9 (46.0)	0.14	0
Mean hepatic fat attenuation (SD), *Hounsfield units*	59.6 (9.1)	65.9 (8.7)	<0.001	65.5 (9.2)	<0.001	65.8 (9.0)	<0.001	65.5 (9.8)	<0.001	42
Mean pericardial fat volume (SD), cm^3	41.6 (18.9)	54.0 (24.6)	<0.001	57.1 (19.9)	<0.001	43.4 (21.7)	0.03	56.7 (25.2)	<0.001	8
Mean intermuscular fat area (SD), cm^2	17.2 (6.1)	22.1 (8.1)	<0.001	16.5 (5.3)	0.40	14.2 (6.0)	<0.001	18.5 (6.8)	0.15	0
Mean physical activity (SD), *metabolic equivalent min/wk*	1099 (6.7)	2039 (7.7)	<0.001	1072 (7.5)	0.80	1841 (8.8)	<0.001	1408 (8.7)	<0.001	5
Never smoker, %	86.2	44.6	<0.001	78.0	0.02	42.5	<0.001	58.7	<0.001	6
Alcohol use, %‡	35.4	66.3	<0.001	19.7	<0.001	57.7	<0.001	42.9	0.10	18

HDL-C = high-density lipoprotein cholesterol; HOMA-β = homeostasis model assessment of β-cell function; HOMA-IR = homeostasis model assessment of insulin resistance; LDL-C = low-density lipoprotein cholesterol.

* This sample includes both metabolically normal and abnormal participants. *P* values compare characteristics with those of South Asians. To convert glucose, cholesterol, or triglyceride values to mmol/L, multiply by 0.0555, 0.0259, or 0.0113, respectively.

† Data are from a restricted sample that included only participants with adiponectin, resistin, and visceral fat mass measurements (708 South Asian, 645 white, 235 Chinese American, 337 African American, and 382 Hispanic participants).

‡ Defined as consumption of ≥1 drink weekly.

Appendix Table 4. Unadjusted and Multivariable-Adjusted Prevalence Ratios of the Metabolically Abnormal Phenotype Among Normal-Weight Persons*

Covariate	Prevalence Ratio (95% CI)	
	Unadjusted	Multivariable-Adjusted†
Race/ethnicity		
White	1.00 (reference)	1.00 (reference)
South Asian	2.10 (1.55–2.84)	1.49 (1.10–2.04)
Chinese American	1.20 (0.75–1.91)	1.10 (0.79–1.53)
African American	1.57 (1.05–2.37)	1.37 (0.99–1.88)
Hispanic	1.97 (1.38–2.82)	1.30 (1.00–1.69)
Age		
44–54 y	1.00 (reference)	1.00 (reference)
55–64 y	1.25 (0.90–1.72)	1.02 (0.82–1.27)
65–74 y	1.65 (1.21–2.25)	1.16 (0.93–1.44)
75–84 y	2.00 (1.40–2.86)	1.29 (0.93–1.78)
Sex		
Men	1.00 (reference)	1.00 (reference)
Women	0.61 (0.49–0.77)	1.07 (0.88–1.29)
Education		
Less than a bachelor's degree	1.00 (reference)	1.00 (reference)
Bachelor's degree or higher	0.82 (0.67–1.03)	0.87 (0.74–1.03)
Alcohol use		
≥1 drink daily	1.00 (reference)	1.00 (reference)
<1 drink daily	1.05 (0.84–1.32)	0.97 (0.81–1.16)
Smoking status		
Never	1.00 (reference)	1.00 (reference)
Former	0.92 (0.71–1.19)	1.02 (0.84–1.24)
Current	0.82 (0.54–1.26)	1.08 (0.79–1.48)
Exercise		
0–750 metabolic equivalent min/wk	1.00 (reference)	1.00 (reference)
751–1575 metabolic equivalent min/wk	1.08 (0.84–1.56)	1.12 (0.90–1.39)
1576–3131 metabolic equivalent min/wk	0.94 (0.68–1.30)	1.14 (0.90–1.44)
>3131 metabolic equivalent min/wk	0.91 (0.67–1.30)	1.14 (0.91–1.43)
Calories		
<1033 kcal/d	1.00 (reference)	1.00 (reference)
1033–1394 kcal/d	1.20 (0.87–1.65)	1.05 (0.82–1.33)
1394–1912 kcal/d	1.18 (0.89–1.63)	0.98 (0.76–1.25)
>1912 kcal/d	1.13 (0.81–1.56)	0.91 (0.71–1.16)
Pericardial fat volume		
<0.84 cm^3	1.00 (reference)	1.00 (reference)
0.84–1.12 cm^3	1.51 (1.01–2.24)	1.13 (0.87–1.47)
1.13–1.48 cm^3	1.68 (1.14–2.47)	1.17 (0.88–1.55)
>1.48 cm^3	2.47 (1.73–3.52)	1.35 (0.99–1.82)
Hepatic fat attenuation		
<4.48 Hounsfield units	1.00 (reference)	1.00 (reference)
Resistin		
<12.73 ng/mL	1.00 (reference)	1.00 (reference)
12.73–16.32 ng/mL	1.73 (1.19–2.52)	1.07 (0.98–1.17)
16.32–21.08 ng/mL	1.58 (1.08–2.33)	1.04 (0.95–1.14)
>21.08 ng/mL	2.17 (1.52–3.11)	1.06 (0.98–1.17)
Visceral fat area		
<97.38 cm^2	1.00 (reference)	1.00 (reference)
97.38–134.78 cm^2	1.44 (0.89–2.35)	1.06 (0.80–1.15)
134.79–184.68 cm^2	2.90 (1.90–4.41)	1.29 (0.98–1.71)
>184.68 cm^2	3.67 (2.45–5.51)	1.35 (1.01–1.81)

* Metabolic abnormality was defined by the presence of ≥2 of the following components: decreased high-density lipoprotein cholesterol (<1.036 mmol/L [<40 mg/dL] in men or <1.295 mmol/L [<50 mg/dL] in women or use of lipid-lowering medication), elevated triglyceride levels (fasting triglyceride levels ≥1.7 mmol/L [≥150 mg/dL]), elevated glucose levels (fasting plasma glucose level ≥5.6 mmol/L [≥100 mg/dL] or use of glucose-lowering medication), and high blood pressure (≥130/85 mm Hg or use of antihypertensive medication). Data are from a restricted sample that included only metabolically abnormal participants with adiponectin, resistin, subcutaneous fat area, visceral fat area, and intermuscular fat area measurements (396 South Asian, 281 white, 112 Chinese American, 145 African American, and 202 Hispanic participants).
† Each factor was adjusted for every other factor in the table.