Obesity, Regional Body Fat Distribution, and the Metabolic Syndrome in Older Men and Women

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Background: The metabolic syndrome is a disorder that includes dyslipidemia, insulin resistance, and hypertension and is associated with an increased risk of diabetes and cardiovascular disease. We determined whether patterns of regional fat deposition are associated with metabolic syndrome in older adults.

Methods: A cross-sectional study was performed that included a random, population-based, volunteer sample of Medicare-eligible adults within the general communities of Pittsburgh, Pa, and Memphis, Tenn. The subjects consisted of 3035 men and women aged 70 to 79 years, of whom 41.7% were black. Metabolic syndrome was defined by Adult Treatment Panel III criteria, including serum triglyceride level, high-density lipoprotein cholesterol level, glucose level, blood pressure, and waist circumference. Visceral, subcutaneous abdominal, intermuscular, and subcutaneous thigh adipose tissue was measured by computed tomography.

Results: Visceral adipose tissue was associated with the

metabolic syndrome in men who were of normal weight (odds ratio, 95% confidence interval: 2.1, 1.6-2.9), overweight (1.8, 1.5-2.1), and obese (1.2, 1.0-1.5), and in women who were of normal weight (3.3, 2.4-4.6), overweight (2.4, 2.0-3.0), and obese (1.7, 1.4-2.1), adjusting for race. Subcutaneous abdominal adipose tissue was associated with the metabolic syndrome only in normal-weight men (1.3, 1.1-1.7). Intermuscular adipose tissue was associated with the metabolic syndrome in normal-weight (2.3, 1.6-3.5) and overweight (1.2, 1.1-1.4) men. In contrast, subcutaneous thigh adipose tissue was inversely associated with the metabolic syndrome in obese men (0.9, 0.8-1.0) and women (0.9, 0.9-1.0).

Conclusion: In addition to general obesity, the distribution of body fat is independently associated with the metabolic syndrome in older men and women, particularly among those of normal body weight.

Arch Intern Med. 2005;165:777-783

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Financial Disclosure: None.

T HE METABOLIC SYNDROME IS a complex disorder unifying dyslipidemia, insulin resistance, and hypertension. It is a primary risk factor for diabetes[1] and cardiovascular disease.[2] The overall prevalence of metabolic syndrome as defined by Adult Treatment Panel III guidelines[3] in US adults is high (22%), and even higher among older men and women (42%).[4] Physical inactivity, obesity, and diet composition all appear to be risk factors for the development of the metabolic syndrome.[5] However, little is known concerning risk factors of the metabolic syndrome specific to older adults, who have a higher incidence of type 2 diabetes[6,7] and cardiovascular disease[8] than younger adults.

The growing prevalence of overweight and obesity[9] are established risk factors for the metabolic syndrome. Patterns of fat distribution in middle-aged

adults may confer additional risk for metabolic syndrome.[10-12] Moreover, we have recently found in the Health, Aging, and Body Composition (Health ABC) Study that visceral abdominal adipose tissue (AT) and muscle-associated AT are related to insulin resistance in older subjects, particularly in those who are of normal weight, and that accumulation of these regional AT depots is characteristic of older people with type 2 diabetes and impaired glucose tolerance.[13] However, it is not known whether these regional AT depots are associated with the metabolic syndrome in older adults. Furthermore, although waist circumference is included in the definition for metabolic syndrome as a surrogate for total abdominal AT, waist circumference does not distinguish visceral from subcutaneous abdominal AT. Patterns of regional fat distribution may be a more critical feature in older adults who may experience health decline–related weight

loss composed of skeletal muscle and subcutaneous AT. Thus, normal-weight individuals may still be at risk for the metabolic syndrome and its consequences.

The Health ABC cohort includes approximately an equal proportion of older men and women and, importantly, an oversampling (41.7%) of blacks. We examined whether the specific criteria developed by the Adult Treatment Panel III to define the metabolic syndrome differ between older men and women and between blacks and whites. Using baseline data from this longitudinal study, we examined the primary hypothesis that visceral abdominal AT and AT infiltrating skeletal muscle are associated with the metabolic syndrome in older men and women, and also examined whether these associations differ by level of body weight or race.

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METHODS

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SUBJECTS

The study population consisted of men and women who participated in baseline evaluations in the Health ABC Study, a longitudinal investigation of 3075 nondisabled men and women aged 70 to 79 years, recruited primarily from a random sample of Medicare-eligible adults residing in designated ZIP code areas in Pittsburgh, Pa, and Memphis, Tenn, with an oversampling of blacks (41.7%). Detailed exclusion criteria for this cohort have been reported previously.[13] Briefly, subjects were ineligible if they reported difficulty getting around without assistive devices, reported difficulty in performing basic activities of daily living, reported difficulty walking one-quarter mile or climbing 10 steps without resting, reported life-threatening cancers, or were participating in any research study involving medications or modification of eating or exercise habits. This analysis included 3035 subjects of this cohort who had complete data on body composition as well as criteria defining the metabolic syndrome. The institutions' review boards approved the study, and written informed consent was obtained from each volunteer.

CRITERIA FOR METABOLIC SYNDROME

On the basis of recently defined criteria,[3] persons were characterized as having the metabolic syndrome if they had at least 3 of the following conditions: (1) waist circumference greater than 102 cm in men and 88 cm in women; (2) serum triglyceride level of 150 mg/dL (1.7 mmol/L) or greater; (3) high-density lipoprotein (HDL) cholesterol level less than 40 mg/dL (1.0 mmol/L) in men and 50 mg/dL (1.3 mmol/L) in women; (4) blood pressure of 130/85 mm Hg or greater; and (5) serum glucose level of 110 mg/dL (6.1 mmol/L) or more. In addition, individuals who reported currently using antihypertensive or antidiabetic medication were counted as meeting the high blood pressure or glucose criterion, respectively.

Age of participants was determined to the nearest year. Standing height and weight were measured in stocking feet and with light clothing, and body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters, to characterize men and women who were of normal weight (BMI, <25.0), overweight (BMI, 25.0-29.9), and obese (BMI, >29.9). Total body fat was determined by means of dual-energy x-ray absorptiometry (QDR 4500; Hologic Inc, Waltham, Mass). Waist circumference was determined to the nearest centimeter. Blood was drawn after an overnight fast and analyzed for serum triglycerides, HDL cholesterol, and glucose deter-

minations. Serum triglycerides and HDL cholesterol were measured on a chemistry analyzer (Vitros 950; Johnson & Johnson, Raritan, NJ). Plasma glucose was measured by means of an automated glucose oxidase reaction (YSI 2300 Glucose Analyzer; Yellow Springs Instruments, Yellow Springs, Ohio). A conventional mercury sphygmomanometer was used for the measurement of blood pressure. The participant rested quietly in a seated position with the back supported and feet flat on the ground for at least 5 minutes before the blood pressure measurement. Systolic and diastolic blood pressures were defined as the average of 2 measures.

COMPUTED TOMOGRAPHY OF ABDOMINAL AT

Computed tomographic (CT) images were acquired in Pittsburgh (9800 Advantage; General Electric Co, Milwaukee, Wis) and Memphis (Somatom Plus; Siemens, Iselin, NJ; or PQ 2000S; Picker, Cleveland, Ohio). For imaging, patients were placed in the supine position with the arms above the head and with legs lying flat on the table and toes directed toward the top of the gantry. To quantify abdominal AT, a single axial image at the L4-5 vertebral disk space was obtained as previously described.[13] Visceral AT was separated from subcutaneous AT by manually drawing a line around the interior of the abdominal muscles along the fascial plane, which separates the 2 AT compartments. The intrareader and interreader variability (coefficient of variation) in visceral AT (n=41) is less than 1%.

CT OF THE MIDTHIGH

The CT acquisition scheme for the quantification of midthigh muscle and AT has been reported elsewhere in detail for this cohort.[13] Briefly, a single, 10-mm-thick, axial image was obtained at the femoral midpoint, with the entire circumference of both thighs included in the field of view. Skeletal muscle, AT, and bone in the thigh were separated on the basis of their CT attenuation values.[14] Mean muscle attenuation values were determined by averaging the CT number (pixel intensity) values of the regions outlined on the images. Lower attenuation values are compatible with greater fatty infiltration into tissue.[15] Intermuscular AT was distinguished from the subcutaneous AT by manually drawing a line along the deep fascial plane surrounding the thigh muscles, ensuring that no bone density pixels were included in the muscle. The intrareader and interreader coefficient of variation in subcutaneous thigh AT (n=30) is less than 1% and 4.3%, respectively.

For all calculations, CT numbers were defined on a Hounsfield unit scale where 0 equals the Hounsfield units of water and −1000 equals the Hounsfield units of air. All analysis programs were developed at the University of Colorado CT Scan Reading Center with the use of IDL (RSI Systems, Boulder).

STATISTICAL ANALYSIS

Prevalence of metabolic syndrome, demographics, body composition, and regional AT variables were described, and the differences in continuous variables between those with and without metabolic syndrome were evaluated by either t tests or the Wilcoxon rank-sum test. Categorical differences between persons with and without the metabolic syndrome were evaluated with the χ^2 test. To assess sex-specific associations between regional AT distribution and metabolic syndrome, multiple logistic regression by maximum likelihood method was used to model the probability of metabolic syndrome as a function of each component of regional fat distribution separately after adjusting for race, smoking, and physical activity along with pertinent 2-factor interaction terms within each BMI stra-

| | Metabolic Syndrome* | | | | | |
| | Normal Weight | | Overweight | | Obese | |
Characteristic	Yes	No	Yes	No	Yes	No
	Men (n = 1473)					
No. (%)	53 (12)	398 (88)	254 (36)	440 (64)	205 (62)	123 (38)
BMI	23.7 (1.0)	22.7 (1.7)†	27.7 (1.4)	26.9 (1.3)†	32.8 (2.5)	32.4 (2.8)
Body fat, kg	17.0 (3.6)	14.5 (3.8)†	22.5 (4.0)	20.6 (3.6)†	30.2 (5.9)	29.6 (5.8)
Fat-free mass, kg	55.9 (4.1)	54.5 (5.5)	61.9 (5.6)	60.6 (5.9)†	69.0 (6.8)	67.3 (7.5)
% Body fat	25.9 (3.6)	23.7 (4.3)†	29.3 (3.8)	28.0 (3.5)†	32.8 (3.9)	32.8 (3.9)
	Women (n = 1562)					
No. (%)	116 (22)	406 (78)	269 (46)	310 (64)	280 (61)	181 (39)
BMI	22.6 (1.8)	22.0 (2.1)	27.6 (1.4)	27.2 (1.4)†	34.7 (3.8)	34.2 (3.9)
Body fat, kg	19.5 (4.1)	18.1 (4.3)†	27.1 (4.0)	26.5 (4.0)	37.4 (7.6)	37.3 (6.5)
Fat-free mass, kg	40.3 (4.1)	38.4 (4.1)†	44.1 (4.2)	43.3 (4.3)	51.2 (5.9)	48.7 (5.8)†
% Body fat	34.7 (4.6)	34.2 (5.0)	40.3 (3.6)	40.1 (3.7)	44.1 (4.1)	45.2 (3.4)†

Abbreviation: BMI, body mass index (weight in kilograms divided by the square of the height in meters).
*Values are presented as means (SDs) except for No. (%), which indicates number and percentage of subjects within BMI categories with and without the metabolic syndrome, so that the percentages equal 100% of subjects within each category.
†$P<.001$ between men and women with and without the metabolic syndrome.

| | Men (n = 1473) | | Women (n = 1562) | |
| | Black (n = 543) | White (n = 930) | Black (n = 718) | White (n = 844) |
Condition				
Waist circumference	217 (40.0)	428 (46.0)†‡	586 (81.6)	619 (73.3)†‡
Serum triglycerides	94 (17.3)	328 (35.3)†‡	149 (20.8)	359 (42.5)†
HDL cholesterol	108 (19.9)	342 (36.8)†‡	184 (25.6)	262 (31.0)†‡
Blood pressure	459 (84.5)	724 (77.8)†	624 (86.9)	633 (75.0)†
Blood glucose	181 (33.3)	235 (25.3)†‡	209 (29.1)	103 (12.2)†‡

Abbreviation: HDL, high-density lipoprotein.
*Prevalence is presented as total numbers and percentages of participants meeting specific criteria constituting the definition for metabolic syndrome.
†Significant race differences within sex ($P<.02$).
‡Significant sex differences within race groups ($P<.01$).

tum after stratifying by sex. Point estimates and the associated confidence interval for all the independent variables were obtained, multicollinearity was tested by variance inflation factor, and the model evaluation was done by Hosmer-Lemeshow statistic. Since the results were similar for BMI and total body fat strata, we present findings for only BMI strata. Current smoking status and physical activity were assessed by questionnaire.[16] All analyses were performed with SAS 6.12 for Windows (SAS Institute Inc, Cary, NC).

RESULTS

PREVALENCE AND CHARACTERISTICS OF METABOLIC SYNDROME

The overall prevalence of metabolic syndrome in this older cohort was 39%, with women having higher rates than men (Table 1). Prevalence of metabolic syndrome was higher ($P<.01$) in obese (63% and 61%) than overweight (37% and 46%) and normal-weight (12% and 22%) men and women, respectively. Within each BMI category, however, differences in the proportion of total body fat between those with and without the metabolic syn-

drome were modest in normal-weight and overweight men and not different at all in women (Table 1). In fact, obese women without metabolic syndrome had a significantly *higher* proportion of body fat than obese women with metabolic syndrome. In addition, lower muscle mass in older subjects, known as *sarcopenia*, was not associated with the metabolic syndrome. Indeed, across all levels of BMI, those with metabolic syndrome had higher lean body mass than those without metabolic syndrome. This strongly suggests that factors other than generalized adiposity are associated with metabolic syndrome in older men and women.

We examined whether there were sex or racial differences in the prevalence of each of the 5 components that define the metabolic syndrome (**Table 2**). More women than men met the waist circumference criterion, and a higher proportion of white men than white women were positive for the blood glucose criterion. All other components ascribed to metabolic syndrome were similar in men and women. Among men, a higher proportion of whites than blacks met waist circumference, serum triglyceride, and HDL cholesterol criteria, whereas black

Table 3. Regional Fat Distribution According to Metabolic Syndrome Status

| | Metabolic Syndrome* | | | |
| | Men (n = 1473) | | Women (n = 1562) | |
Variable	Yes	No	Yes	No
Waist circumference, cm	108.3 (11.6)†	97.1 (10.9)	103.7 (12.0)‡	94.2 (13.7)
Visceral AT, cm^2	195.4 (73.2)†	133.8 (61.2)	162.3 (61.5)‡	108.3 (49.5)
Intermuscular AT, cm^2	12.4 (9.1)†	8.7 (5.5)	11.8 (6.0)‡	9.5 (5.8)
Subcutaneous abdominal AT, cm^2	271.0 (89.5)†	210.4 (83.6)	370.9 (125.9)‡	312.0 (122.0)
Subcutaneous thigh AT, cm^2	51.9 (20.8)†	44.8 (19.6)	110.3 (48.3)‡	102.6 (44.7)
Muscle attenuation, HU	36.1 (6.5)†	38.2 (6.2)	33.2 (6.8)‡	34.8 (6.8)

Abbreviations: AT, adipose tissue; HU, Hounsfield units.
*Values are presented as means (SDs).
†P<.001 between men with and without the metabolic syndrome.
‡P<.001 between women with and without the metabolic syndrome.

Table 4. Abdominal AT in Men and Women With and Without Metabolic Syndrome According to a Revised Definition Omitting Waist Circumference

| | Metabolic Syndrome* | | | |
| | Men | | Women | |
Variable	Yes	No	Yes	No
No. (%)	311 (21.1)†	1161 (78.9)	324 (20.7)‡	1238 (79.3)
Visceral AT, cm^2	189.5 (75.9)†	145.9 (67.8)	169.4 (61.0)‡	121.2 (57.0)
Subcutaneous AT, cm^2	251.7 (88.4)†	226.0 (90.3)	346.1 (123.4)‡	334.3 (127.8)

Abbreviation: AT, adipose tissue.
*Values are presented as means (SDs) except for No. (%), which indicates number and percentage of men and women who had at least 3 defining criteria for metabolic syndrome omitting waist circumference criteria.
†P<.001 between men with and without the metabolic syndrome.
‡P<.001 between women with and without the metabolic syndrome.

men had higher rates of hypertension and abnormal blood glucose values (Table 2). Among women, whites had higher rates of abnormal serum triglyceride levels and lower HDL cholesterol levels, whereas the black women had higher rates of hypertension, abnormal blood glucose levels, and large waist circumference. Thus, lipid abnormalities were nearly 2-fold more common in whites, while blacks had a higher prevalence of blood glucose abnormalities and hypertension than whites.

REGIONAL FAT DISTRIBUTION IN THE METABOLIC SYNDROME

As shown in Table 1, although overweight and obesity were associated with a higher prevalence of the metabolic syndrome, differences in regional fat distribution were even more distinct (**Table 3**). Among those with metabolic syndrome, 77% of women and 44% of men met the waist circumference criterion. Waist circumference represents the combination of visceral and subcutaneous AT. When we examined whether these specific fat depots were associated with metabolic syndrome, we found in both men and women that differences in visceral AT were more prominent, being nearly 50% higher in both men and women with metabolic syndrome than in those without. Differences in subcutaneous AT were more modest, with men and women having 29% and 18%

more subcutaneous AT, respectively, than their counterparts without metabolic syndrome. Moreover, the proportion of abdominal AT as visceral AT remained higher in both men (42% vs 39%) and women (31% vs 26%), even when waist circumference was omitted from the defining criteria for metabolic syndrome (**Table 4**). When the attributable risk for metabolic syndrome was examined for each of the predictors, higher visceral AT was consistent across all BMI groups for both men and women to have the highest attributable risk associated with metabolic syndrome. Higher visceral AT in men and women with metabolic syndrome was consistent for whites and blacks; thus, results were pooled for race for ease of interpretation.

Data presented in Table 3 indicate that differences in the amount of AT infiltrating skeletal muscle also distinguished those with metabolic syndrome to a greater degree than subcutaneous AT in the thigh. Intermuscular AT was 44% higher in men and 27% higher in women with metabolic syndrome. This is in contrast to the smaller differences in subcutaneous thigh AT for men (16%) or women (9%) with metabolic syndrome. Men and women with metabolic syndrome also had muscle with lower attenuation values, a marker of its higher fat infiltration[15] (Table 3). Again, these results were similar for blacks and whites.
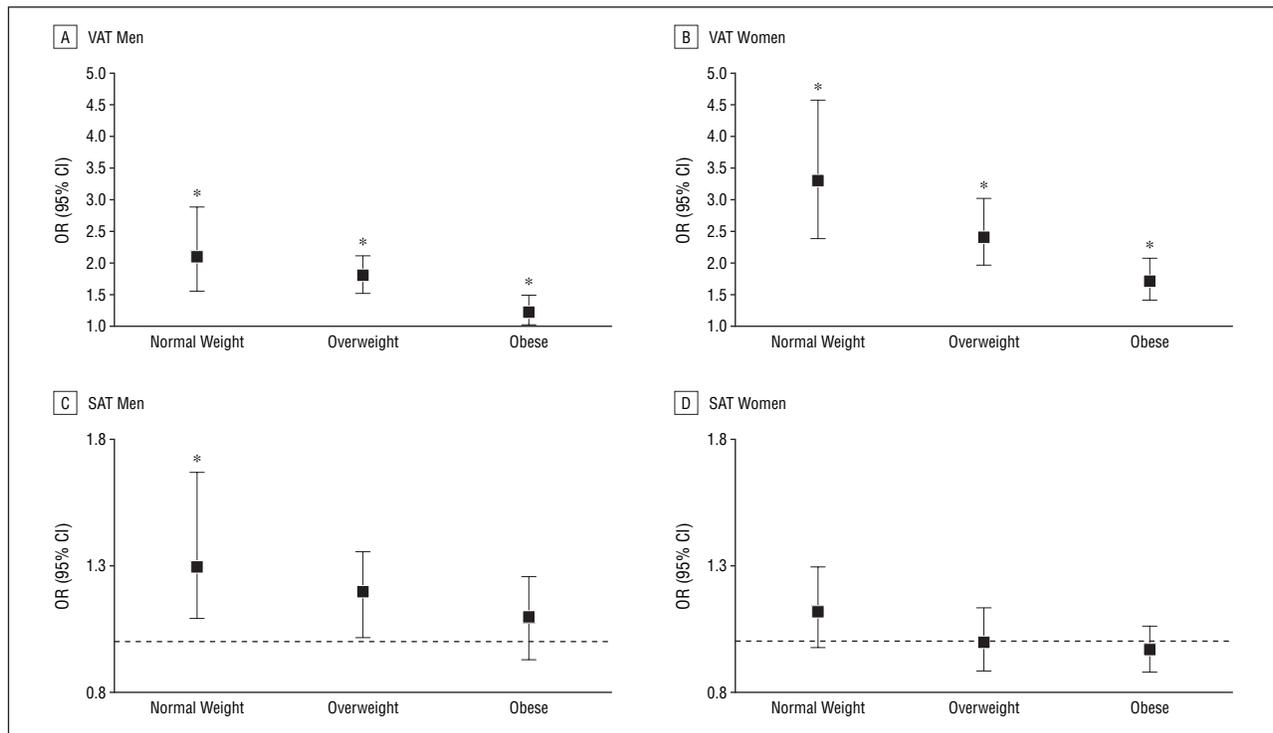
Figure 1. Odds ratios (ORs; adjusted for age and race) and 95% confidence intervals (CIs) of having metabolic syndrome with increasing visceral adipose tissue (VAT) and subcutaneous abdominal adipose tissue (SAT) by 50 cm^2 in normal-weight, overweight, and obese men and women. The dashed line represents an OR of 1. Asterisk denotes significant ($P<.05$) OR. Note the different scales for VAT and SAT.

METABOLIC SYNDROME IN NORMAL-WEIGHT, OVERWEIGHT, AND OBESE MEN AND WOMEN

Since the metabolic syndrome was not limited to obese subjects, we examined whether regional AT distribution was associated with metabolic syndrome separately in normal-weight, overweight, and obese subject, adjusting for race, smoking status, and physical activity. Higher visceral AT was associated with a significantly higher prevalence of metabolic syndrome, especially in normal-weight and overweight men and women but less so in the obese (**Figure 1**). The association between visceral AT and the metabolic syndrome was more evident at lower levels of total adiposity in both men and women independent of race ($P<.001$). Higher subcutaneous AT was significantly associated with metabolic syndrome in normal-weight and overweight but not in obese men. A positive interaction ($P=.03$) indicated that higher visceral AT and black race were both associated with the metabolic syndrome in obese women. No other significant interactions between race and the regional fat depots were observed in association with the metabolic syndrome. Similar results were obtained when stratifying by the proportion of body fat rather than by BMI.

Higher intermuscular AT was significantly associated with metabolic syndrome in normal-weight and overweight, but not in obese, men (**Figure 2**). There was an interaction ($P<.001$) between lower total body fat and higher intermuscular AT in predicting the metabolic syndrome in men independent of race. No significant associations were observed for intermuscular AT and metabolic syndrome in women. In contrast, having more subcutaneous thigh AT was associated with a lower preva-

lence of metabolic syndrome in obese men and in overweight and obese women.

We also examined in multiple logistic regression whether physical activity and diet modified the associations between regional fat distribution and metabolic syndrome. For men, neither smoking nor physical activity was related to metabolic syndrome in any of the BMI categories after taking into account regional fat distribution. In women, current smoking was not related to metabolic syndrome after accounting for VAT. Only in overweight women was physical inactivity associated with metabolic syndrome independent of all regional depots. Thus, adjusting results for smoking and physical activity did not appear to confound associations between regional fat depots and metabolic syndrome.

COMMENT

The overall prevalence of the metabolic syndrome in this older cohort was similar to that reported for older adults in the United States[4] and nearly double that reported for middle-aged adults.[4] This is, to our knowledge, the first large-scale investigation of predictors of the metabolic syndrome in older adults. With an oversampling of blacks, we were able to determine that, although the overall prevalence of metabolic syndrome was not different between blacks and whites, there were racial differences in the prevalence of specific criteria that define metabolic syndrome. Specifically, blacks had higher rates of hypertension and abnormal glucose metabolism, whereas whites had higher rates of dysregulated lipid metabolism. The
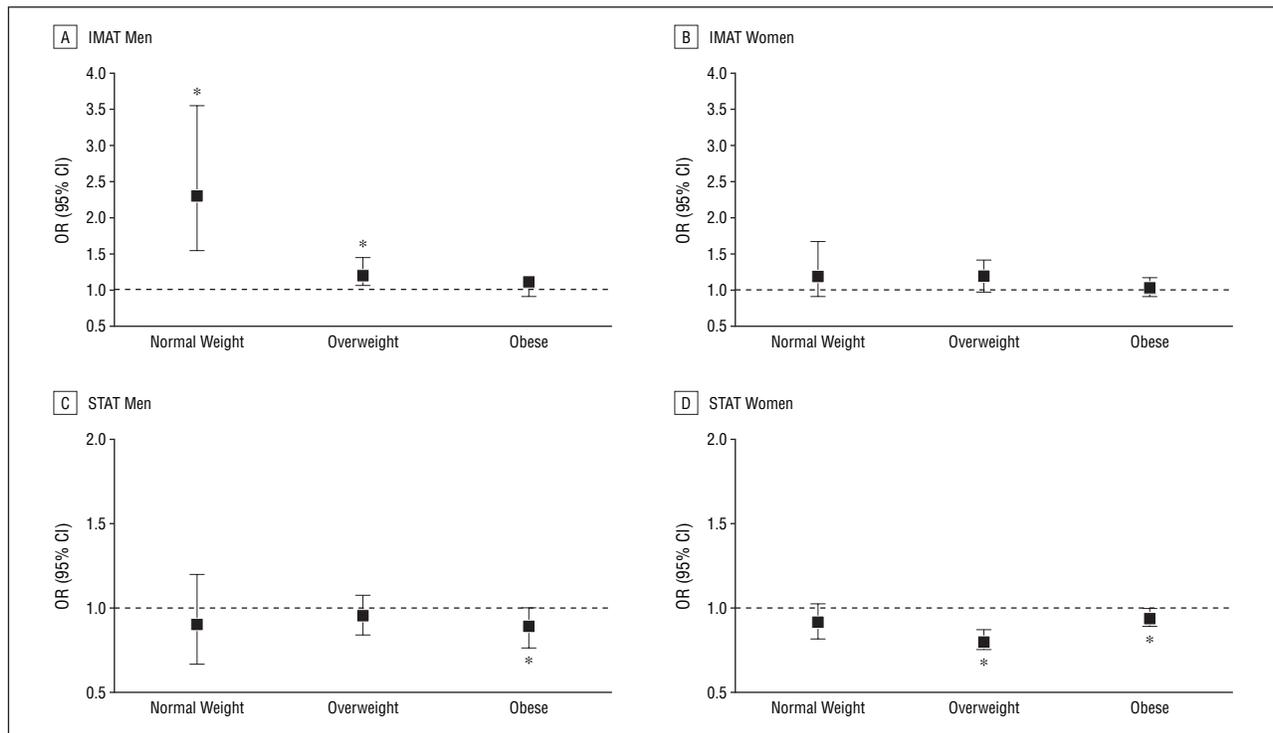
Figure 2. Odds ratio (ORs; adjusted for age and race) and 95% confidence intervals (CIs) of having metabolic syndrome with increasing intermuscular adipose tissue (IMAT) (4 cm²) and subcutaneous thigh adipose tissue (STAT) (10 cm²) in normal-weight, overweight, and obese men and women. The dashed line represents an OR of 1. Asterisk denotes significant (*P*<.05) OR. Note the different scales for IMAT and STAT.

development of metabolic syndrome involves an interaction of complex parameters including obesity, regional fat distribution, dietary habits, and physical inactivity,[5] so it is not yet entirely clear how to interpret these racial differences. Nevertheless, this suggests that the cause of metabolic syndrome is different in blacks and whites.

The prevalence of metabolic syndrome, not surprisingly, was much higher among the obese. However, differences in generalized obesity by BMI or total body fat criteria in those with metabolic syndrome were at best modest. Obese women with the metabolic syndrome actually had a *lower* proportion of body fat than obese women without metabolic syndrome. Regional fat distribution, particularly visceral abdominal AT and intermuscular AT, clearly discriminated those with the metabolic syndrome, particularly among the nonobese. This implies that older men and women can have normal body weight, and even have relatively lower total body fat, but still have metabolic syndrome, due to the amount of AT located intra-abdominally or interspersed within the musculature. What makes this observation more remarkable is that these associations were much less robust or even nonexistent for subcutaneous AT. More subcutaneous AT in the thighs of obese men and women was actually associated with a *lower* prevalence of metabolic syndrome. This is consistent with previous reports demonstrating that total leg fat mass, most of which was subcutaneous AT, is inversely related to cardiovascular disease risk.[17] The relationship between altered fat distribution and metabolic syndrome is further complicated by the observation in our study that whites had higher visceral AT, while blacks had higher intermus-

cular AT. Albu et al[18] suggested that similar levels of visceral AT in blacks and whites may confer different metabolic risk. Our data support the contention by some that BMI may not accurately reflect the degree of adiposity in certain populations.[19] Indeed, this suggests a complex and not fully understood relationship between metabolic syndrome, obesity, and abnormal fat distribution.

The current results parallel our previous observation in the Health ABC cohort that visceral and intermuscular AT strongly predict insulin resistance and type 2 diabetes.[13] These findings are consistent with the hypothesized links among insulin resistance, type 2 diabetes, dyslipidemia, abdominal fat accumulation, and hypertension (the metabolic syndrome). These associations between regional fat deposition and metabolic dysregulation are also consistent with other previous findings in both middle-aged and older adults.[20-25] The current data, however, are not without limitations. Although we included in the analysis physical activity as a potential confounder to our associations, it is possible that the self-reported estimates for physical activity were not sensitive enough to detect significant associations with metabolic syndrome demonstrated in previous studies.[26] It is also likely that diet composition is related to metabolic syndrome independent of obesity and physical activity.[5] This cross-sectional analysis also does not allow us to determine whether body composition prospectively predicts future development of the syndrome. However, predictors of the incidence of metabolic syndrome can be examined when data become available in this longitudinal study.

There are several possible explanations for the observed association between excess visceral fat accumula-

tion and the metabolic syndrome. Visceral fat is thought to release fatty acids into the portal circulation, where they may cause insulin resistance in the liver and subsequently in muscle.[27] Another emerging hypothesis is that the ability to store excess fat in AT is impaired, leading to the ectopic storage of fat into nonadipose tissue such as muscle and liver, and possibly the β cell.[28] This excess accumulation of fat into these cells is associated with insulin resistance[29-32] and metabolic syndrome.[33] Our novel observation of higher subcutaneous AT in the thigh associated with lower prevalence of the metabolic syndrome is in accord with lipodystrophic, insulin-resistant humans[34] and animals,[35] which have an abundance of visceral and muscle-associated fat and concomitantly less subcutaneous fat. A parallel hypothesis is that adipose tissue is an endocrine organ that secretes a variety of endocrine hormones such as leptin, interleukin 6, angiotensin II, adiponectin, and resistin, which may have potent effects on the metabolism of peripheral tissues. Production of these "adipokines" may be higher in visceral AT.[36] Further studies will be required to examine whether these secreted factors link either visceral or muscle AT to metabolic syndrome.

In conclusion, excess accumulation of either visceral abdominal or muscle AT is associated with a higher prevalence of metabolic syndrome in older adults, particularly in those who are of normal body weight. This suggests that practitioners should not discount the risk of metabolic syndrome in their older patients entirely on the basis of body weight or BMI. Indeed, generalized body composition, in terms of both BMI and the proportion of body fat, does not clearly distinguish older subjects with the metabolic syndrome. Moreover, racial differences in the various components of the metabolic syndrome provide strong evidence that the cause of the syndrome likely varies in blacks and whites. Thus, the development of a treatment for the metabolic syndrome as a unifying disorder is likely to be complex.

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