Minimum Waist and Visceral Fat Values for Identifying Japanese Americans at Risk for the Metabolic Syndrome

TOMOSHIGE HAYASHI, MD, PHD[1,2]
EDWARD J. BOYKO, MD, MPH[1,3]
MARGUERITE J. MCNEELY, MD[3]
DONNA L. LEONETTI, PHD, MPH[4]
STEVEN E. KAHN, MB, CHB[1,3]
WILFRED Y. FUJIMOTO, MD[3]

OBJECTIVE — Japanese American is an ethnic group with a high risk for type 2 diabetes, which is linked to the metabolic syndrome. Central adiposity is considered to play a key role in the metabolic syndrome. Not known are the optimal cut point values for central and visceral adiposity to identify Japanese Americans at risk for the metabolic syndrome.

RESEARCH DESIGN AND METHODS — Study subjects included 639 Japanese Americans. The nonadipose variables of the metabolic syndrome were defined using modified International Diabetes Federation criteria, and the accuracy of identifying at least two of these by intra-abdominal fat area (IAFA) as measured by computed tomography and waist circumference was cross-sectionally assessed using area under receiver operating characteristic (ROC) curves. The values for IAFA and waist circumference that resulted in maximizing the Youden index were defined as "optimal."

RESULTS — The area under the ROC curve for IAFA exceeded that for waist circumference (men 0.787 vs. 0.686; women 0.792 vs. 0.721). For women, the optimal cut points for IAFA and waist circumference were 51.5 cm^2 and 80.8 cm (age ≤56 years) and 86.3 cm^2 and 89.0 cm (age >56 years). For men, the optimal cut points for IAFA and waist circumference were 88.6 cm^2 and 90.0 cm (age ≤57 years) and 96.1 cm^2 and 87.1 cm (age >57 years).

CONCLUSIONS — These results argue that current Japanese waist circumference cut points for the metabolic syndrome need to be revised. Moreover, the waist circumference and IAFA cut points should be age specific, especially in women. Appropriate waist circumference cut points are from 80 to 90 cm in women and from 87 to 90 cm in men.

Diabetes Care 30:120–127, 2007

In 2001, the National Cholesterol Education Program Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III [ATP III]) suggested a clinical definition for the metabolic syndrome (1). Waist circumference ≥88 cm in women and ≥102 cm in men comprised one of the components of this syndrome but was not a prerequisite for its diagnosis. A new International Diabetes Federation (IDF) definition makes central adiposity a necessary component of the metabolic syndrome. Moreover, because accumulating evidence argues that ethnicity-specific waist circumference cut points should be used (2–5), the IDF incorporates different waist circumference cut points by sex and ethnicity (6).

The emphasis placed by the IDF on waist circumference arises from the important role of visceral adiposity in the development of each metabolic syndrome component compared with other measurements of regional or total adiposity (7–10). Although waist circumference reflects both visceral and subcutaneous abdominal fat, it is nevertheless used as an inexpensive and clinically feasible measurement compared with the direct imaging required for assessment of the visceral fat depot. Multiple reports have proposed optimal cut points for the strongest association of waist circumference or BMI with obesity-related cardiovascular disease risk factors (2–5), but little information exists on cut points of directly measured visceral fat area associated with these same risk factors. Therefore, we examined cross-sectionally in Japanese Americans which cut points of visceral adiposity directly measured by computed tomography (CT), waist circumference, and BMI result in the strongest associations between these measurements and nonadipose metabolic syndrome components by using receiver operating characteristic (ROC) curve analysis.

RESEARCH DESIGN AND METHODS

— The study population consisted of 639 second- and third-generation Japanese Americans of 100% Japanese ancestry between ages 34 and 76 years who had been enrolled into the Japanese American Community Diabetes Study (11,12). Details about selection and recruitment of the sample population for this study have been described previously (11,12). To recruit volunteers, we used a comprehensive mailing list and telephone directory that included nearly 95% of the Japanese-American population of King County, Washington. Recruited participants were shown to be representative of Japanese-American residents of King County, Washington, in age distribution, residential distribution, and immigration pattern of their parents. For the analyses described here, of the 658 participants in the original cohort, we excluded 19 participants because of incomplete data collection. The study population for analyses consisted of 639 men and women.

From the [1]Epidemiologic Research and Information Center, Veterans Affairs Puget Sound Health Care System, Seattle, Washington; the [2]Department of Preventive Medicine and Environmental Health, Osaka City University Graduate School of Medicine, Osaka, Japan; the [3]Department of Medicine, University of Washington, Seattle, Washington; and the [4]Department of Anthropology, University of Washington, Seattle, Washington.

Address correspondence and reprint requests to Edward J. Boyko, MD, MPH, 1100 Olive Way, Suite 1400, Seattle, WA 98101. E-mail: eboyko@u.washington.edu.

Received for publication 4 April 2006 and accepted in revised form 9 October 2006.

Abbreviations: ATP III, Adult Treatment Panel III; CT, computed tomography; IAFA, intra-abdominal fat area; IDF, International Diabetes Federation; ROC, receiver operating characteristic.

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

DOI: 10.2337/dc06-0739

Data collection

All evaluations were performed at the General Clinical Research Center, University of Washington. The protocol for this research was reviewed by the Human Subjects Review Committee at the University of Washington, and signed informed consent was obtained from all participants. After an overnight 10-h fast, blood samples were withdrawn to measure plasma levels of glucose, triglycerides, and HDL cholesterol. An average blood pressure value was calculated from the second and third of three consecutive measurements with a mercury sphygmomanometer read to the nearest 2 mmHg with the subjects in a recumbent position. Systolic blood pressure was determined by the first perception of sound and diastolic fifth-phase blood pressure by Korotkoff sound disappearance. A 75-g oral glucose tolerance test was used to classify all subjects as having normal glucose tolerance, impaired glucose tolerance, or type 2 diabetes on the basis of the American Diabetes Association 1997 criteria (13). The nonadipose components of the metabolic syndrome were defined using IDF criteria as the presence of two or more of the following components: *1*) HDL cholesterol <40 (men) or <50 mg/dl (women); *2*) triglycerides ≥150 mg/dl; *3*) systolic blood pressure ≥130 mmHg, diastolic blood pressure ≥85 mmHg, or subject taking antihypertensive medications; and *4*) fasting plasma glucose level ≥100 mg/dl, 2-h oral glucose tolerance test value ≥140 mg/dl, or receiving treatment for diabetes with oral hypoglycemic medication or insulin. Plasma glucose was assayed by an automated glucose oxidase method. Triglyceride and HDL cholesterol levels were measured by the Northwest Lipid Research Laboratory.

BMI was calculated as weight in kilograms divided by the square of height in meters. Single CT scans were obtained at the level of the umbilicus, and intra-abdominal fat area (IAFA) (in square centimeters) was measured as described previously (14). This measurement has been reported to have a high correlation with directly ascertained total visceral fat volume by CT scanning (15). Abdominal circumference was measured at the level of the umbilicus.

Statistical analysis

ROC curve analyses were performed to determine the appropriate cut points of IAFA, waist circumference, and BMI in identifying subjects with two or more nonadipose components of the metabolic syndrome. The optimal cut points were obtained from the Youden index [maximum (sensitivity + specificity − 1)], and the point on the ROC curve closest to (0,1) was calculated as the minimum value of the square root of $[(1 - \text{sensitivity})^2 + (1 - \text{specificity})^2]$ (16,17). Greater accuracy is reflected by a larger Youden index and a smaller distance to (0,1). All *P* values are two tailed. All statistical analyses were performed using STATA SE, version 8 for Windows (Stata, College Station, TX).

RESULTS — In 344 men, we found 212 (61.6%) with two or more nonadipose components of the metabolic syndrome with the IDF criteria and 196 (57.0%) with two or more nonadipose components of the metabolic syndrome using the ATP III criteria. In 295 women, we found 124 (42.0%) and 117 (39.7%), respectively. Both men and women with two or more nonadipose components of the metabolic syndrome had higher IAFA, waist circumference, and BMI than those without the metabolic syndrome (Table 1).

Table 2 presents the area under the ROC curves to identify subjects with two or more nonadipose components of the metabolic syndrome. IAFA showed the greatest areas by both sets of criteria in both men and women. In men, waist circumference and BMI had similar areas under the ROC curves. On the other hand, waist circumference had a greater area under the ROC curve than BMI in women.

Sensitivity, specificity, positive and negative predictive values, and the Youden index for IAFA, waist circumference, and BMI to detect subjects with two or more nonadipose components of the metabolic syndrome by the IDF criteria are presented in Table 3. In men, the optimal cut points were 96.1 cm^2 for IAFA, 90.0 cm for waist circumference, and 25.3 kg/m^2 for BMI (Table 3). After stratifying by the median value of age, the optimal cut point for IAFA for subjects aged ≤57 years was 88.6 cm^2 and for those aged >57 years was 96.1 cm^2. On the other hand, the optimal cut points for waist circumference and BMI for subjects aged ≤57 years were greater than those for subjects aged >57 years (Table 4).

In women, the optimal cut points to detect subjects with two or more nonadipose components for the metabolic syndrome of the IDF criteria were 74.9 cm^2 for IAFA, 84.5 cm for waist circumference, and 23.3 kg/m^2 for BMI (Table 3). After stratifying by the median value of age, the optimal cut points for IAFA and waist circumference but not for BMI for subjects aged ≤56 years were less than those for subjects aged >56 years. If the Japanese women cut points recommended by the IDF and the Japan Society for the Study of Obesity (8,16) of 100 cm^2 for IAFA or 90 cm for waist circumference were used, only 48.4 and 41.9%, respectively, of the subjects with two or more nonadipose components of the IDF criteria would be identified. These values were even lower for subjects aged ≤56 years (37.5 and 35.0%, respectively). On the other hand, if the optimal cut points of 74.9 cm^2 for IAFA or 84.5 cm for waist circumference that we identified were used, 74.2 and 68.6%, respectively, of subjects would be identified.

Two methods were used in this study to define optimal cut points: the minimum distance from (0,1) to the ROC curve and the Youden index. The optimal cut points for IAFA, waist circumference, and BMI obtained from both methods were very similar (Tables 3 and 4).

When we used fasting plasma glucose level ≥110 mg/dl instead of ≥100 mg/dl, the areas under the ROC curves for IAFA, waist circumference, and BMI in the detection of subjects with the two or more nonadipose components were not affected (data not shown). We repeated these analyses after excluding individuals taking oral hypoglycemic medication or insulin, antihypertensive medication, or lipid-lowering medication to determine the effect of these exclusions on the optimal cut points for IAFA, waist circumference, and BMI. In general, the optimal cut points did not change, except for a few exceptions (IAFA for women aged ≤56 years and waist circumference for men aged >57 years and women aged >56 years were slightly lower: 41.5 cm^2, 84.6 cm, and 84.5 cm, respectively [data not shown]).

CONCLUSIONS — These cross-sectional data demonstrated that IAFA was better than waist circumference and BMI in identifying both men and women with two or more nonadipose components of the metabolic syndrome. For all ages, the optimal cut points for men were 96 cm^2 for IAFA, 90 cm for waist circumference, and 25 kg/m^2 for BMI and for women were 75 cm^2, 84 cm, and 23 kg/m^2, respectively. However, women aged ≤56 years had much lower cut points of IAFA

Table 1—*Characteristics of study subjects according to metabolic syndrome status*

		Two or more nonadipose components of the IDF criteria other than waist circumference		Two or more nonadipose components of the ATP III criteria other than waist circumference	
	Total	Absent	Present	Absent	Present
Men					
n	344	132	212	148	196
Age (years)	54.2 ± 11.4	48.1 ± 11.5	58.1 ± 9.6	49.1 ± 11.7	58.1 ± 9.5
BMI (kg/m²)	25.5 ± 3.0	24.4 ± 2.5	26.2 ± 3.1	24.5 ± 2.5	26.3 ± 3.2
Waist circumference (cm)	88.8 ± 8.2	85.7 ± 7.2	90.8 ± 8.1	85.9 ± 6.9	91.0 ± 8.4
IAFA (cm²)	105.3 ± 55.3	73.1 ± 43.2	125.3 ± 52.5	75.6 ± 43.1	127.6 ± 52.9
Type 2 diabetes or fasting plasma glucose ≥110 mg/dl (%)	54.9	—	—	16.2	84.2
Type 2 diabetes or fasting plasma glucose ≥100 mg/dl (%)	63.7	24.2	88.2	—	—
Taking oral hypoglycemic medication or insulin (%)*	45.8	16.7	48.1	16.7	48.1
High blood pressure (%)†	61.6	21.2	86.8	27.7	87.2
Taking antihypertensive medications (%)‡	61.7	52.9	62.8	42.3	65.6
HDL cholesterol (mg/dl)	50.0 ± 13.2	56.1 ± 11.4	46.3 ± 12.9	55.7 ± 11.4	45.7 ± 12.9
Low HDL cholesterol (%)	19.5	1.5	30.7	1.4	33.2
Triglycerides (mg/dl)	174.5 ± 147.0	108.4 ± 44.0	215.7 ± 171.7	111.6 ± 46.3	222.0 ± 176.4
Hypertriglycemia (%)	40.1	12.9	57.1	13.5	60.2
Taking lipid-lowering medication (%)§	1.2	2.3	0.5	2.0	0.5
Women					
n	295	171	124	178	117
Age (years)	53.7 ± 12.3	49.8 ± 12.3	59.0 ± 10.3	50.1 ± 12.2	59.1 ± 10.4
BMI (kg/m²)	23.2 ± 3.3	22.5 ± 2.9	24.3 ± 3.4	22.6 ± 3.0	24.2 ± 3.4
Waist circumference (cm)	84.6 ± 9.1	81.7 ± 8.6	88.5 ± 8.2	82.1 ± 8.7	88.4 ± 8.2
IAFA (cm²)	74.3 ± 46.6	54.9 ± 35.9	101.2 ± 46.4	56.6 ± 37.8	101.4 ± 45.9
Type 2 diabetes or fasting plasma glucose ≥110 mg/dl (%)	50.8	—	—	25.8	88.9
Type 2 diabetes or fasting plasma glucose ≥100 mg/dl (%)	56.6	30.4	92.7	—	—
Taking oral hypoglycemic medication or insulin (%)*	44.9	22.2	50.0	22.2	50.0
High blood pressure (%)†	44.1	17.0	81.5	19.1	82.1
Taking antihypertensive medications (%)‡	50.0	52.6	49.4	58.3	47.4
HDL cholesterol (mg/dl)	64.9 ± 16.5	70.2 ± 15.6	57.6 ± 14.7	69.7 ± 15.8	57.5 ± 14.8
Low HDL cholesterol (%)	15.6	1.8	34.7	2.8	35.0
Triglycerides (mg/dl)	120.3 ± 87.7	88.7 ± 36.9	163.8 ± 114.9	89.0 ± 36.6	167.9 ± 116.9
Hypertriglycemia (%)	20.7	5.3	41.9	5.1	44.4
Taking lipid-lowering medication (%)§	1.0	0.0	2.4	0.0	2.6

Data are means ± SD or %. *Values are percentages of subjects who took oral hypoglycemic medication or insulin among subjects with type 2 diabetes. †High blood pressure was diagnosed if average systolic blood pressure was ≥130 mmHg, average diastolic blood pressure was ≥85 mmHg, or the subject was receiving antihypertensive medications. ‡Values are percentages of subjects who took antihypertensive medications among subjects with hypertension. §Values are percentages of subjects who took lipid-lowering medication among all subjects.

and waist circumference than those aged >56 years. We preferred to identify the optimal cut points as defined by the Youden index, as this measure appears to be superior to the minimum to (0,1) (17). Given our findings, the cut point values for waist circumference of 85 cm for Japanese men and 90 cm for Japanese women recommended by the new IDF criteria (6,18) should be reevaluated.

Ethnicity-specific cut points of waist circumference and BMI in relation to obesity-related cardiovascular risk factors have been reported in epidemiological studies (2–5). In these studies lower cut points of waist circumference than those recommended in the ATP III criteria were suitable to detect obesity-related cardiovascular risk factors in Caucasian, Mexican, Hong Kong Chinese, and Asian-Indian subjects. Despite the expected information gained from assessment of visceral fat, there exist only a few reports of cut points of visceral adiposity by directly measured by CT scanning to detect obesity-related cardiovascular risk factors (18–20). Williams et al. (19) reported in 220 Caucasian women that IAFA >110 cm² was associated with high total cholesterol, low HDL cholesterol, and ele-

Table 2—*Areas under the ROC curve of waist circumference, BMI, and IAFA to identify the presence of components of the metabolic syndrome*

	Men (n = 344)		Women (n = 295)	
	ROC curve area (95% CI)	*P* value compared with waist circumference*	ROC curve area (95% CI)	*P* value compared with waist circumference*
Two or more nonadipose components of the IDF criteria other than waist circumference				
IAFA	0.787 (0.738–0.836)	>0.001	0.792 (0.740–0.844)	0.005
Waist circumference	0.686 (0.629–0.743)		0.721 (0.663–0.779)	
BMI	0.677 (0.620–0.734)	0.819	0.661 (0.597–0.724)	0.014
Two or more nonadipose components of the ATP III criteria other than waist circumference				
IAFA	0.785 (0.736–0.833)	>0.001	0.786 (0.733–0.838)	0.002
Waist circumference	0.686 (0.630–0.742)		0.708 (0.649–0.767)	
BMI	0.677 (0.620–0.734)	0.842	0.651 (0.586–0.716)	0.025
Type 2 diabetes, impaired glucose tolerance, or fasting plasma glucose ≥100 mg/dl				
IAFA	0.734 (0.680–0.788)	0.001	0.739 (0.682–0.796)	0.005
BMI	0.642 (0.583–0.702)	0.976	0.617 (0.552–0.681)	0.030
Waist circumference	0.646 (0.586–0.705)		0.671 (0.609–0.733)	
Type 2 diabetes, impaired glucose tolerance, or fasting plasma glucose ≥110 mg/dl				
IAFA	0.736 (0.684–0.788)	0.001	0.711 (0.651–0.770)	0.017
Waist circumference	0.653 (0.595–0.710)		0.651 (0.589–0.714)	
BMI	0.649 (0.591–0.707)	0.968	0.604 (0.539–0.668)	0.067
High blood pressure				
IAFA	0.743 (0.690–0.796)	>0.001	0.746 (0.689–0.802)	0.018
Waist circumference	0.625 (0.565–0.685)		0.685 (0.624–0.746)	
BMI	0.616 (0.556–0.677)	0.851	0.621 (0.556–0.685)	0.008
Hypertriglycemia				
IAFA	0.689 (0.633–0.745)	0.849	0.693 (0.626–0.759)	0.290
Waist circumference	0.677 (0.619–0.734)		0.649 (0.578–0.721)	
BMI	0.654 (0.595–0.712)	0.294	0.623 (0.544–0.702)	0.604
Low HDL				
IAFA	0.710 (0.646–0.774)	0.904	0.785 (0.726–0.843)	0.069
Waist circumference	0.699 (0.630–0.767)		0.714 (0.647–0.780)	
BMI	0.665 (0.593–0.738)	0.257	0.738 (0.670–0.806)	0.669

*P value compared to waist circumference by the Sidak method. †High blood pressure was diagnosed if average systolic blood pressure was ≥130 mmHg, average diastolic blood pressure was ≥85 mmHg, or the subject was receiving antihypertensive medications.

vated blood pressure. In that study, the cut point was based on the highest likelihood ratio for a positive test result [(sensitivity)/(1 − specificity)], but sensitivity at 110 cm^2 of IAFA to detect these diseases was only 34%. Nicklas et al. (20) reported in Caucasian and African-American women that ≥106 cm^2 of IAFA (the 20th percentile) was associated with elevated cardiovascular disease risk for older obese women using statistical models. These proposed cut points may not be useful in individuals of a different sex, age, or ethnicity. Moreover, the criteria used for obesity-related cardiovascular risk factors were different from those currently recommended by the IDF.

Surprisingly the recommended cut point of waist circumference for the metabolic syndrome by the new IDF criteria for Japanese women was higher than in men. To the best of our knowledge, this is the only ethnic group in which the recommended waist circumference cut point for the definition of central obesity is higher in women (≥90 cm) than in men (≥85 cm). The Japan Society for the Study of Obesity has adopted the same waist circumference criteria for central obesity (18). These criteria appear to be based on a 2002 report from the Examination Committee of Criteria for 'Obesity Disease' in Japan, which stated that the optimal cutoff point of IAFA measured by CT scanning for identifying individuals at risk for obesity-related disease was 100 cm^2 in a study sample that combined both men and women. Thus, although it appears reasonable to assess sex-specific visceral adiposity cut points, this was not done. The waist circumference corresponding to 100 cm^2 of IAFA was then identified as 85 cm in men and 90 cm in women (18). Because this approach did not account for the possibility that the as-

Table 3—*Sensitivity and specificity of IAFA, waist circumference, and BMI to detect subjects with two or more nonadipose components of the IDF criteria other than waist circumference in Japanese-American men and women*

	Cut point	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	*J* value*	Distance to ROC curve†
Men (n = 344)							
IAFA (cm^2)							
Optimal cut point 1‡	96.1	70.3	76.5	82.3	61.3	0.47	0.38
Optimal cut point 2§	96.1	70.3	76.5	82.3	61.3	0.47	0.38
Japanese cut point by Japan Society for the Study of Obesity	100	65.6	78.0	82.7	58.5	0.44	0.41
Waist circumference (cm)							
Optimal cut point 1‡	90.0	55.2	75.8	78.5	51.3	0.31	0.51
Optimal cut point 2§	90.0	55.2	75.8	78.5	51.3	0.31	0.51
Japanese cut point by IDF and Japan Society for the Study of Obesity	85	77.8	45.5	69.6	56.1	0.23	0.59
IDF cut point for South Asians and Chinese	90	55.2	75.8	78.5	51.3	0.31	0.51
IDF cut point for Caucasians	94	30.2	88.6	81.1	44.2	0.19	0.71
ATP III cut point	102	7.1	97.7	83.3	39.6	0.05	0.93
BMI (kg/m^2)							
Optimal cut point 1‡	25.3	60.4	71.2	77.1	52.8	0.32	0.49
Optimal cut point 2§	25.3	60.4	71.2	77.1	52.8	0.32	0.49
Overweight	25.0	64.6	62.1	73.3	52.2	0.27	0.52
Obesity	30.0	11.3	97.0	85.7	40.5	0.08	0.89
Women (n = 295)							
IAFA (cm^2)							
Optimal cut point 1‡	74.9	74.2	75.4	68.7	80.1	0.50	0.35
Optimal cut point 2§	74.9	74.2	75.4	68.7	80.1	0.50	0.35
Japanese cut point by Japan Society for the Study of Obesity	100	48.4	87.7	74.1	70.1	0.36	0.53
Waist circumference (cm)							
Optimal cut point 1‡	84.5	68.6	67.3	60.3	74.7	0.36	0.45
Optimal cut point 2§	84.5	68.6	67.3	60.3	74.7	0.36	0.45
IDF cut point for Caucasians, South Asians, and Chinese	80	83.9	42.7	51.5	78.5	0.27	0.60
ATP III cut point	88	51.6	78.4	63.4	69.1	0.30	0.53
Japanese cut point by IDF and Japan Society for the Study of Obesity	90	41.9	84.2	65.8	66.7	0.26	0.60
BMI (kg/m^2)							
Optimal cut point 1‡	23.3	60.5	70.2	59.5	71.0	0.31	0.50
Optimal cut point 2§	23.3	60.5	70.2	59.5	71.0	0.31	0.50
Over weight	25.0	41.9	81.9	62.7	66.0	0.24	0.61
Obesity	30.0	5.7	98.2	70.0	58.9	0.04	0.94

*J = sensitivity + specificity − 1. †Distance defined as square root of $[(1 - \text{sensitivity})^2 + (1 - \text{specificity})^2]$. ‡The optimal cut point 1 was obtained from the Youden index as [maximum (J = sensitivity + specificity − 1)]. §The optimal cut point 2 was obtained from the point on the ROC curve closest to (0,1) calculated as the minimum value of square root $[(1 - \text{sensitivity})^2 + (1 - \text{specificity})^2]$. NPV, negative predictive value; PPV, positive predictive value.

sociations between IAFA or waist circumference and metabolic syndrome may vary by sex, in the present study we examined the cut points based on visceral fat area separately in men and women and found that the optimal IAFA cut points differed by sex. Hence, the waist circumference cut points are also different between men and women.

That the waist circumference cut point for women is higher than that in men at the same level of IAFA is not surprising. The ratio of waist circumference to IAFA is higher in women than in men, as can be seen from the following ratios of means from Table 1 (men 88.8/105.3 = 0.84 and women 84.6/74.3 = 1.14). Therefore, at any given value of IAFA, women will have, on average, a relatively higher waist circumference than men. This was also seen but ignored in the original publication from Japan (18), which means that the proportion of total abdominal fat in the subcutaneous depot is higher in women than in men at any value of waist circumference. Thus, fixing a single value of IAFA for both sexes as the cut point for central obesity is bound to lead to a correspondingly higher waist circumference cut point in women. Hence, the higher waist circumference cut point in women as recommended in the new IDF criteria for definition of metabolic syndrome is a consequence of the methodology used to derive the waist circumference cut point and is not due to any intrinsic ethnic difference.

The above example illustrates a fundamental problem in the determination of

Table 4—*Sensitivity, specificity, and Youden index of IAFA, waist circumference, and BMI to detect subjects with two or more nonadipose components of the IDF criteria other than waist circumference in Japanese-American men and women*

	Age ≤57 (n = 172)							Age >57 (n = 162)						
Men	Cut point	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	J value*	Distance to ROC curve†	Cut point	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	J value*	Distance to ROC curves†
IAFA (cm^2)														
Optimal cutoff 1‡	88.6	75.6	72.3	69.4	78.2	0.48	0.37	96.1	72.4	68.4	89.0	41.3	0.41	0.42
Optimal cutoff 2§	88.6	75.6	72.3	69.4	78.2	0.48	0.37	96.1	72.4	68.4	89.0	41.3	0.41	0.42
Japanese cutoff by Japan Society for the Study of Obesity	100	59.0	81.9	73.0	70.6	0.41	0.45	100	69.4	68.4	88.6	38.8	0.38	0.44
Waist circumference (cm)														
Optimal cutoff 1‡	90.0	66.7	75.5	69.3	73.2	0.42	0.41	87.1	64.9	65.8	87.0	34.7	0.31	0.49
Optimal cutoff 2§	90.0	66.7	75.5	69.3	73.2	0.42	0.41	87.1	64.9	65.8	87.0	34.7	0.31	0.49
Japanese cutoff by IFD and Japan Society for the Study of Obesity	85	82.1	43.6	54.7	74.5	0.26	0.59	85	75.4	50.0	84.2	36.5	0.25	0.56
IDF cutoff for South Asians and Chinese	90	66.7	75.5	69.3	73.2	0.42	0.41	90	48.5	76.3	87.8	29.6	0.25	0.57
IDF cutoff for Caucasians	94	42.3	88.3	75.0	64.8	0.31	0.59	94	23.1	89.5	88.6	24.8	0.13	0.78
ATP III cutoff	102	11.5	97.9	81.8	57.1	0.09	0.88	102	4.5	97.4	85.7	22.4	0.02	0.96
BMI (kg/m^2)														
Optimal cutoff 1‡	26.0	66.7	77.7	71.2	73.7	0.44	0.40	25.2	56.0	76.3	89.3	33.0	0.32	0.50
Optimal cutoff 2§	26.0	66.7	77.7	71.2	73.7	0.44	0.40	24.7	64.9	63.2	86.1	33.8	0.28	0.49
Overweight	25.0	73.1	58.5	59.4	72.4	0.32	0.49	25.0	59.7	71.1	87.9	33.3	0.31	0.50
Obesity	30.0	19.2	96.8	83.3	59.1	0.16	0.81	30.0	6.7	97.4	90.0	22.8	0.04	0.93

	Age ≤56 (n = 146)							Age >56 (n = 149)						
Women	Cut point	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	J value*	Distance to ROC curve†	Cut point	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	J value*	Distance to ROC curves†
IAFA (cm^2)														
Optimal cutoff 2‡	51.5	77.5	77.4	56.4	90.1	0.55	0.32	86.3	69.1	67.7	73.4	62.9	0.37	0.45
Optimal cutoff 3§	51.5	77.5	77.4	56.4	90.1	0.55	0.32	86.3	69.1	67.7	73.4	62.9	0.37	0.45
Japanese cutoff by Japan Society for the Study of Obesity	100	37.5	94.3	71.4	80.0	0.32	0.63	100	53.6	76.9	75.0	56.2	0.30	0.52
Waist circumference (cm)														
Optimal cutoff 1‡	80.8	82.5	63.2	45.8	90.5	0.46	0.41	89.0	54.8	70.8	70.8	54.8	0.26	0.54
Optimal cutoff 2§	83.2	70.0	74.5	50.9	86.8	0.45	0.39	89.0	54.8	70.8	70.8	54.8	0.26	0.54
IDF cutoff for Caucasians, South Asians, and Chinese	80.0	85.0	56.6	42.5	90.9	0.42	0.46	80	83.3	20.0	57.4	48.1	0.03	0.82
ATP III cutoff	88.0	45.0	86.8	56.3	80.7	0.32	0.57	88	54.8	64.6	66.7	52.5	0.19	0.57
Japanese cutoff by IFD and Japan Society for the Study of Obesity	90.0	35.0	89.6	56.0	78.5	0.25	0.66	90	45.2	75.4	70.4	51.6	0.21	0.60
BMI (kg/m^2)														
Optimal cutoff 1‡	23.3	75.0	73.6	51.7	88.6	0.49	0.36	21.8	75.0	47.7	64.9	59.6	0.23	0.58
Optimal cutoff 2§	23.3	75.0	73.6	51.7	88.6	0.49	0.36	23.2	54.8	64.6	66.7	52.5	0.19	0.57
Over weight	25.0	55.0	83.0	55.0	83.0	0.38	0.48	25.0	35.7	80.0	69.8	49.1	0.16	0.67
Obesity	30.0	12.5	97.2	62.5	74.6	0.10	0.88	30.0	2.4	100.0	100.0	44.2	0.02	0.98

*J = sensitivity + specificity − 1. †Distance defined as square root of $[(1 - \text{sensitivity})^2 + (1 - \text{specificity})^2]$. ‡The optimal cut point 1 was obtained from the Youden index as [maximum (J = sensitivity + specificity − 1)]. §The optimal cut point 2 was obtained from the point on the ROC curve closest to (0,1) calculated as the minimum value of square root $[(1 - \text{sensitivity})^2 + (1 - \text{specificity})^2]$. NPV, negative predictive value; PPV, positive predictive value.

excessive central adiposity based on the waist circumference measurement. The "gold standard" used to identify elevated waist circumference is inconsistent in the literature, with high BMI, elevated cardiovascular disease risk factors, and directly measured visceral fat depot used (2–5,18–21). This inconsistency must be considered in comparing recommended waist circumference cut points by ethnicity, because waist circumference cut point differences might arise because of different gold standard definitions.

In our study, the cut points of IAFA and waist circumference for the metabolic syndrome differed for women aged ≤56 years and those aged >56 years. In some cross-sectional studies visceral adiposity increases in the years after menopause were reported (22,23). Epidemiological studies have shown alterations in risk of cardiovascular disease in association with menopausal status (24). In the present study we had insufficient information to classify menopausal status, so further investigation will be needed to determine whether the age-related different cut points of waist circumference and IAFA in women can be explained by menopause.

In this study we did not directly address causal relationships between visceral fat and the metabolic syndrome. Several epidemiological studies have shown that visceral adiposity plays an important role in the metabolic syndrome or in each of its nonadipose components (7–10). Visceral adiposity is related to the metabolic syndrome independent of insulin resistance (7–10). Recently, the endocrine function of adipocytes has been recognized through their ability to synthesize and release a variety of peptide and nonpeptide compounds that act on other tissues and organs (25). Interestingly, some studies have indicated that visceral fat produced considerably more of these peptides than did subcutaneous fat (26,27). This differential adipokine release is a potential explanation for the nonuniform effects of body fat depots on metabolic disorders and risk of cardiovascular disease and diabetes. The role of visceral adiposity in the pathogenesis of the metabolic syndrome requires further investigation.

There are several potential limitations to this study. First, we cannot draw conclusions about cause and effect relationships because of the cross-sectional nature of our data. Visceral fat volume was also estimated with a single CT scan at the umbilicus, which corresponds to the intervertebral disk at the L4–L5 level. However, this measurement has been reported to have a high correlation with directly ascertained total visceral fat volume (15). Some studies have reported ethnic group differences in the amount of visceral fat volume (28). Because we studied Japanese Americans, our results may not be representative of the general population but should apply to native Japanese and possibly other Asian Americans. Research on other racial and ethnic groups is needed to identify cut points of visceral adiposity for the metabolic syndrome in those groups.

In summary, these results provide evidence that IAFA was better than waist circumference or BMI in identifying Japanese-American men and women at risk for the metabolic syndrome. The currently recommended cut points for waist circumference for the metabolic syndrome need to be reevaluated for Japanese ethnicity. In addition, in women, age-specific optimal cut points for waist circumference and IAFA should be considered for identifying women at risk for the metabolic syndrome.

Acknowledgments— This work was supported by National Institutes of Health Grants DK-02654, DK-31170, and HL-49293, the U.S. Department of Veterans Affairs, Diabetes and Endocrinology Research Center Grant DK-17047, Clinical Nutrition Research Unit Grant DK-35816, and General Clinical Research Center Grant RR-00037 at the University of Washington. T.H. was supported in part by a research grant (17390177) from the Japanese Ministry of Education, Science, Sports, and Culture.

We are grateful to the King County Japanese-American community for their support and cooperation.

References

1. Executive summary of the Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). *JAMA* 285:2486–2497, 2001
2. Ko GT, Chan JC, Cockram CS, Woo J: Prediction of hypertension, diabetes, dyslipidaemia or albuminuria using simple anthropometric indexes in Hong Kong Chinese. *Int J Obes Relat Metab Disord* 23:1136–1142, 1999
3. Berber A, Gomez-Santos R, Fanghanel G, Sanchez-Reyes L: Anthropometric indexes in the prediction of type 2 diabetes mellitus, hypertension and dyslipidaemia in a Mexican population. *Int J Obes Relat Metab Disord* 25:1794–1799, 2001
4. Zhu S, Wang Z, Heshka S, Heo M, Faith MS, Heymsfield SB: Waist circumference and obesity-associated risk factors among whites in the third National Health and Nutrition Examination Survey: clinical action thresholds. *Am J Clin Nutr* 76:743–749, 2002
5. Misra A, Vikram NK, Gupta R, Pandey RM, Wasir JS, Gupta VP: Waist circumference cutoff points and action levels for Asian Indians for identification of abdominal obesity. *Int J Obes* 30:106–111, 2006
6. Alberti KG, Zimmet P, Shaw J: Metabolic syndrome—a new world-wide definition: a consensus statement from the International Diabetes Federation. *Diabet Med* 23:469–480, 2006
7. Boyko EJ, Leonetti DL, Bergstrom RW, Newell-Morris L, Fujimoto WY: Visceral adiposity, fasting plasma insulin, and lipid and lipoprotein levels in Japanese Americans. *Int J Obes Relat Metab Disord* 20:801–808, 1996
8. Boyko EJ, Fujimoto WY, Leonetti DL, Newell-Morris L: Visceral adiposity and risk of type 2 diabetes: a prospective study among Japanese Americans. *Diabetes Care* 23:465–471, 2000
9. Hayashi T, Boyko EJ, Leonetti DL, McNeely MJ, Newell-Morris L, Kahn SE, Fujimoto WY: Visceral adiposity and the risk of impaired glucose tolerance: a prospective study among Japanese Americans. *Diabetes Care* 26:650–655, 2003
10. Hayashi T, Boyko EJ, Leonetti DL, McNeely MJ, Newell-Morris L, Kahn SE, Fujimoto WY: Visceral adiposity is an independent predictor of incident hypertension in Japanese Americans. *Ann Intern Med* 140:992–1000, 2004
11. Fujimoto WY, Leonetti DL, Kinyoun JL, Shuman WP, Stolov WC, Wahl PW: Prevalence of complications among second-generation Japanese-American men with diabetes, impaired glucose tolerance, or normal glucose tolerance. *Diabetes* 36:730–739, 1987
12. Fujimoto WY, Bergstrom RW, Leonetti DL, Newell-Morris LL, Shuman WP, Wahl PW: Metabolic and adipose risk factors for NIDDM and coronary disease in third-generation Japanese-American men and women with impaired glucose tolerance. *Diabetologia* 37:524–532, 1994
13. The Expert Committee on the Diagnosis and Classification of Diabetes Mellitus: Report of the Expert Committee on the Diagnosis and Classification of Diabetes Mellitus. *Diabetes Care* 20:1183–1197, 1997
14. Shuman WP, Morris LL, Leonetti DL, Wahl PW, Moceri VM, Moss AA, Fujimoto WY: Abnormal body fat distribution detected by computed tomography in diabetic men. *Invest Radiol* 21:483–487, 1986
15. Schoen RE, Thaete FL, Sankey SS, Weiss-

feld JL, Kuller LH: Sagittal diameter in comparison with single slice CT as a predictor of total visceral adipose tissue volume. *Int J Obes Relat Metab Disord* 22: 338–342, 1998
16. Youden WJ: An index for rating diagnostic tests. *Cancer* 3:32–35, 1950
17. Perkins NJ, Schisterman EF: The inconsistency of "optimal" cutpoints obtained using two criteria based on the receiver operating characteristic curve. *Am J Epidemiol* 163:670–675, 2006
18. Examination Committee of Criteria for 'Obesity Disease' in Japan, Japan Society for the Study of Obesity: New criteria for 'obesity disease' in Japan. *Circ J* 66:987–992, 2002
19. Williams MJ, Hunter GR, Kekes-Szabo T, Trueth MS, Snyder S, Berland L, Blaudeau T: Intra-abdominal adipose tissue cutpoints related to elevated cardiovascular risk in women. *Int J Obes Relat Metab Disord* 20:613–617, 1996
20. Nicklas BJ, Penninx BW, Ryan AS, Berman DM, Lynch NA, Dennis KE: Visceral adipose tissue cutoffs associated with metabolic risk factors for coronary heart disease in women. *Diabetes Care* 26: 1413–1420, 2003
21. Lean ME, Han TS, Morrison CE: Waist circumference as a measure for indicating need for weight management. *BMJ* 311: 158–161, 1995
22. Kotani K, Tokunaga K, Fujioka S, Kobatake T, Keno Y, Yoshida S, Shimomura I, Tarui S, Matsuzawa Y: Sexual dimorphism of age-related changes in whole-body fat distribution in the obese. *Int J Obes Relat Metab Disord* 18:207–202, 1994
23. Toth MJ, Tchernof A, Sites CK, Poehlman ET: Effect of menopausal status on body composition and abdominal fat distribution. *Int J Obes Relat Metab Disord* 24:226–231, 2000
24. Stampfer MJ, Colditz GA, Willett WC: Menopause and heart disease: a review. *Ann N Y Acad Sci* 592:193–203, 1990
25. Wajchenberg BL: Subcutaneous and visceral adipose tissue: their relation to the metabolic syndrome. *Endocr Rev* 21:697–738, 2000
26. Alessi MC, Peiretti F, Morange P, Henry M, Nalbone G, Juhan-Vague I: Production of plasminogen activator inhibitor 1 by human adipose tissue: possible link between visceral fat accumulation and vascular disease. *Diabetes* 46:860–867, 1997
27. Motoshima H, Wu X, Sinha MK, Hardy VE, Rosato EL, Barbot DJ, Rosato FE, Goldstein BJ: Differential regulation of adiponectin secretion from cultured human omental and subcutaneous adipocytes: effects of insulin and rosiglitazone. *J Clin Endocrinol Metab* 87:5662–5667, 2002
28. Park YW, Allison DB, Heymsfield SB, Gallagher D: Larger amounts of visceral adipose tissue in Asian Americans. *Obes Res* 9:381–387, 2001