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Is waist circumference an accurate index to evaluate obesity for the diagnosis of metabolic syndrome in the Japanese population?

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SUMMARY

The diagnosis of metabolic syndrome (MetS) is up-to-date, but still controversial. We investigated the relationship between several indices of obesity and other MetS components and discussed how to incorporate obesity into a MetS diagnosis.

We proposed this cross-sectional study, which 2, 333 Japanese men and women aged 40–79 years were recruited. Blood pressure and plasma concentrations of HDL-cholesterol, triglycerides, and glucose after overnight fasting were determined as MetS components. Waist circumference (WC), body mass index (BMI), and percent body fat were measured to evaluate obesity. For each obesity index, we calculated the relationship with other MetS compo-

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Footnote:

Abbreviation used: MetS, metabolic syndrome; WC, waist circumference; BMI, body mass index; PBF, percent body fat; HDLC, HDL-cholesterol; NCEP ATP III, National Cholesterol Education Program-Third Adult Treatment Panel; IDF, International Diabetes Federation; SD, standard deviations..

nents.

Obvious spikes in WC were observed at 75, 80, and 85cm. The standardized Cronbach alpha coefficients of WC and MetS components were 0. 449 among men and 0. 568 among women, which were not high enough for internal consistency. Areas under the WC ROC curve to two or more MetS components other than obesity were low (0. 641 for men and 0. 675 for women). Using the widely used cut-off point in Japan, i.e., WC ≥85cm for men and ≥90cm for women, sensitivity was only 0. 384 and 0. 205, respectively.

This result suggests that WC should not be considered a better index of obesity than BMI for MetS diagnosis in the Japanese population, partly because of the narrow range of obesity variation in the Japanese population and WC measurement error. We propose that obesity be incorporated as a risk factor for MetS, but not a prerequisite for diagnosis in the Japanese population.
(247 words)

Key words: waist circumference, metabolic syndrome, body mass index, central obesity, diagnostic accuracy

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INTRODUCTION

Metabolic syndrome (MetS) represents a constellation of metabolic derangements including centrally located obesity, glucose intolerance, hyperinsulinemia, low HDL-cholesterol (HDLC), high triglycerides, and hypertension (1). Since subjects with MetS are at an increased risk of cardiovascular disease (2, 3), a strategy to prevent a MetS epidemic should be an urgent need for health professionals. Several expert groups have attempted to develop a definition for MetS. The most widely accepted definitions were developed by the World Health Organization (4), National Cholesterol Education Program-Third Adult Treatment Panel (NCEP ATP III) (5), and International Diabetes Federation (IDF).(6) In Japan, the definition was established by the committee for diagnosis of metabolic syndrome in April 2005 (7). Although the main concept and components of MetS are in agreement, some clinical criteria and cut-off points are inconsistent. In particular, the definition of obesity varies by organization and target population (Table 1). In most obesity criteria, waist circumference (WC) is believed to represent central obesity and is used instead of body mass index (BMI), which has been widely used for overall obesity. The underlying assumption is that WC should highly correlate to MetS than BMI because MetS is etiologically connected more strongly to central obesity than general obesity.

The WC cut-off point for the Japanese population has not been consistent with other

Table 1. Criteria of obesity index for diagnosis of metabolic syndrome

Organization	Year	Country/ ethnic group	Index	Men	Women
WHO	1999	Not mentioned	Waist-hip ratio	>0. 9	>0. 85
			and/or BMI	>30 kg/m^2	
NCEP	2001	USA	Waist circumference	≥102 cm	≥88 cm
IDF	2005	Europids	Waist circumference	≥94 cm	≥80 cm
		Japanese	Waist circumference	≥85 cm	≥90 cm
		Chinese	Waist circumference	≥90 cm	≥80 cm
IDF	2007	Europids	Waist circumference	≥94 cm	≥80 cm
		Japanese	Waist circumference	≥90 cm	≥80 cm
		Chinese	Waist circumference	≥90 cm	≥80 cm

Abbreviations: BMI, body mass index (measured as weight in kilograms divided by the square of height in meters); WHO, World Health Organization; NCEP, National Cholesterol Education Program; IDF, International Diabetes Federation.

populations. The newest cut-off points for the Japanese population from the IDF (6) were changed to be consistent with others and, consequently, they seriously conflicted with the previous criteria. (8) In addition, the domestic cut-off points for Japanese were derived from a regression model of visceral fat area by CT scan (9, 10). Thus we need further studies for establishing the relationship between obesity and MetS from several viewpoints, including discussing accuracy of WC on MetS diagnosis and cut-off point of WC.

In this study, we focused on the relationship between WC, BMI, PBF, and components of MetS, other than obesity, to confirm whether WC has a stronger association with MetS components than BMI in the Japanese population. Furthermore, we discuss the cut-off point of the obesity index and how obesity should be incorporated into the MetS diagnosis.

MATERIALS AND METHODS

Subjects

The subjects consisted of 2, 428 (age, 40–79 years) participants from a screening program at Kasugai Health Center from April to July 2006. Ninety-five individuals were excluded due to drug therapy for hypertension, hyperlipidemia, and diabetes mellitus, and thus, 2, 333 subjects remained (1, 195 men and 1, 138 women). The present study was approved by the ethics review committee of Nagoya City University (No. 319).

Measurement of anthropometry and plasma

Weight, height, and PBF were measured automatically (Tanita BF–220, Japan) to the nearest 0. 1kg, 0. 1cm, and 0. 1%, respectively, and this was done bare foot and without heavy clothing. WC was measured by nurses to the nearest 1 cm at the level of the navel following a gentle expiration with the subjects standing and wearing only undergarments. If the navel was lowered because of obesity, WC was measured at the point midway between the lower rib margin and the iliac crest. BMI was calculated as weight divided by height squared (kg/m^2). Plasma concentrations of HDLC, triglycerides (TG), and glucose after overnight fasting were determined by the enzymatic chemistry method using an automated analyzer (7180, Hitachi, Japan). Blood pressure was measured using a standard mercury sphygmomanometer on the left arm by trained nurses after at least ten minutes of rest.

Data analysis

Data are presented as mean values and standard deviations (SDs). Spearman's correlation coefficients were computed for three among all the indices and MetS components. The correlation coefficient of the obesity index to the total and standardized Cronbach alpha coefficients (11) was also calculated to evaluate internal consistency of MetS components with a given obesity index. In the analysis, systolic blood pressure was used as an index of hypertension, and HDLC was added minus sign for consistent direction of the variables. In this study, subjects with two or more of the following four components of the NCEP ATP III criteria, other than obesity, were defined as having MetS: 1) TG ≥ 150mg/dl, 2) HDLC < 40mg/dl in men and < 50mg/dl in women, 3) systolic blood pressure ≥ 130mmHg and/or diastolic blood pressure ≥ 85mmHg, and 4) fasting plasma glucose ≥ 110mg/dl. Area under the curve (12) was calculated from the receiver operating characteristic (ROC) curve for each obesity index, excluding obesity, to evaluate their overall diagnostic accuracy. Sensitivity, specificity, and odds ratios of each WC cut-off point were calculated. All calculations were performed using SAS software (release 9. 0, SAS Institute, Cary, NC).

RESULTS

Table 2 shows the epidemiological characteristics of the subjects. The mean age was 63. 0 (8. 7) years for men and 61. 8 (8. 1) years for women. The mean WC among men was 80. 0 (7. 7) cm and was significantly higher than among women, 77. 6 (8. 6) cm. Although BMI was higher among men than women, PBF was higher among women. We observed a gender difference for the other MetS components, except for systolic blood pressure. Other than HDLC, men had higher average values. The prevalence of having two or more MetS components was also higher in men (15. 9%) than in women (10. 7%).

Figure 1 shows the distributions of the three obesity indices with normal distribution. All indices from men and women were symmetrically distributed around the mean. There were obvious spikes for the WC at 75, 80, and 85cm, which were not clearly observed in the

Table 2. Characteristics of the subjects

Characteristics	Men (n = 1, 195)		Women (n = 1, 138)		p
Age (years)	63. 0	(8. 7)	61. 8	(8. 1)	<0. 001
Average of obesity indices					
Waist Circumference (cm)	80. 0	(7. 7)	77. 6	(8. 6)	<0. 001
Body mass index (kg/m^2)	22. 9	(2. 8)	22. 0	(2. 9)	<0. 001
Percent body fat (%)	21. 0	(4. 8)	27. 6	(5. 6)	<0. 001
Average of the components of metabolic syndrome other than obesity					
Triglycerides	123. 0	(80. 8)	100. 6	(53. 7)	<0. 001
HDL-cholesterol	60. 4	(16. 3)	71. 5	(17. 1)	<0. 001
Fasting blood glucose	98. 2	(21. 5)	93. 0	(16. 5)	<0. 001
Systolic blood pressure	124. 0	(15. 4)	123. 0	(17. 2)	NS
Diastolic blood pressure	72. 8	(8. 9)	70. 9	(9. 4)	<0. 001
Prevalence of the components of metabolic syndrome other than obesity					
Triglycerides ≥150 mg/dl	24. 3%		13. 8%		<0. 001
HDL-cholesterol <40 mg/dl (men), 50 mg/dl (women)	7. 1%		8. 8%		NS
Fasting blood glucose ≥110 mg/dl	13. 9%		6. 7%		<0. 001
Blood pressure ≥130/85 mmHg	25. 6%		24. 6%		NS
Having two or more components	15. 9%		10. 7%		<0. 001

other indices.

The three obesity indices were highly correlated (Table 3), and the correlation coefficients were larger than 0. 75. The associations of each obesity index and the MetS components other than obesity were all significant among men and women. The strongest association was observed with HDLC (around—0. 30 among men and—0. 35 among women), while the weakest association was observed with systolic blood pressure among men and fasting plasma glucose among women. Standardized Cronbach alpha coefficients for WC and the four MetS components were 0. 449 among men and 0. 568 among women. The standardized Cronbach alpha coefficient was almost identical when the WC was replaced by BMI or PBF among men and women. Standardized Cronbach alpha coefficients for WC were much lower than the minimum requirement of internal consistency, 0. 7 (13).

Table 4 presents the diagnostic accuracy of WC for two or more MetS components by cut-off point. For an approximate 80% sensitivity, the cut-off point would be 78cm in men and 76cm in women, which is below average. The odds ratios, representing diagnostic accuracy, were 2. 84 and 3. 31 in men and women, respectively. They were maximized at 76cm in men and at 74cm in women, being 3. 71 and 3. 75, respectively. When we require at least 60% sensitivity, the cut-off point would be 81cm in men and 79cm in women, which is 1 cm longer than the average values. Using the widely used domestic cut-off point in Japan, i.e.,

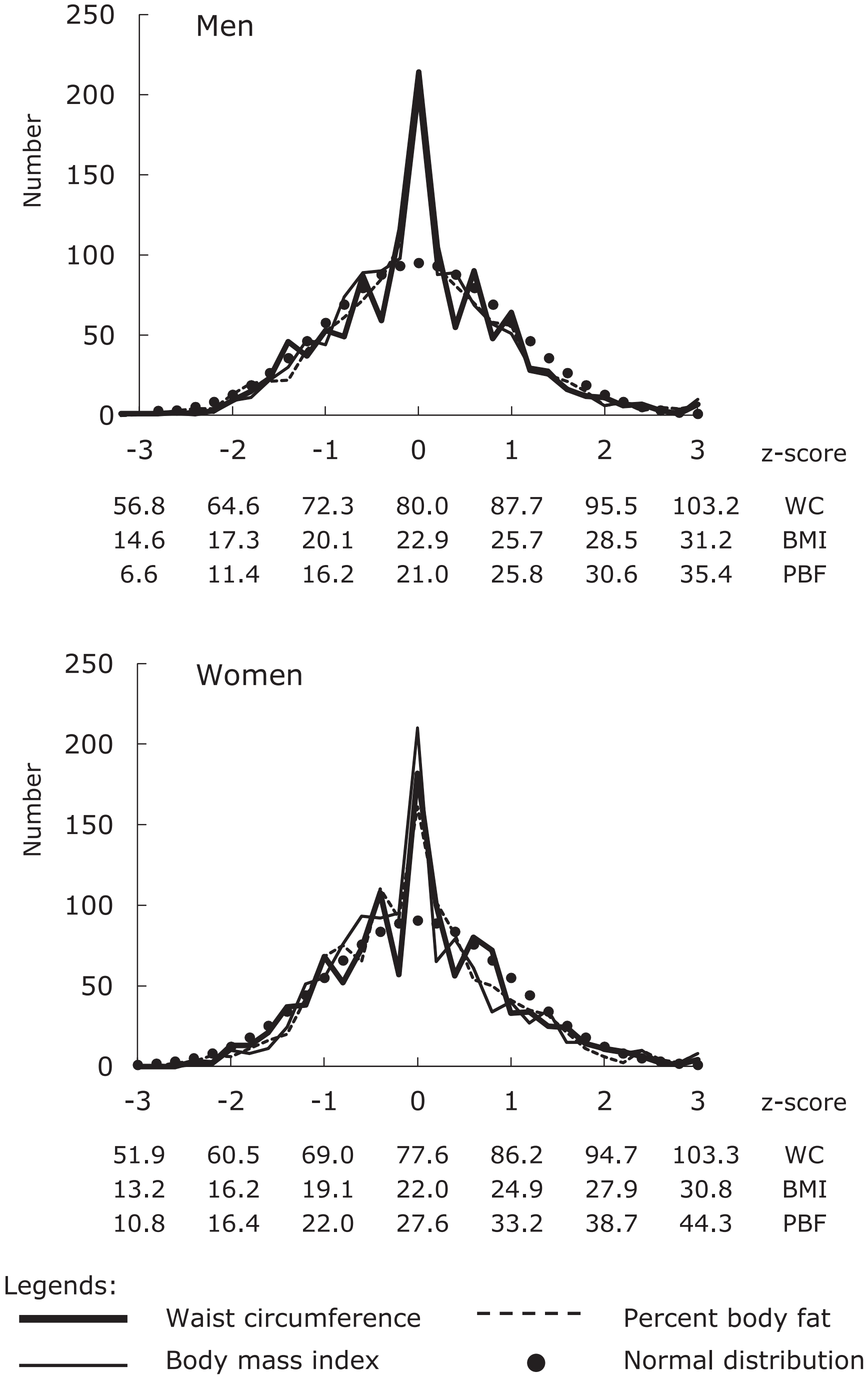

Figure 1

Comparison of distributions of WC, BMI and PBF. Obvious spikes are observed on 75, 80, and 85cm, compared to BMI and PBF that presents similar to normal distribution.

Abbreviations: WC, waist circumference; BMI, body mass index (measured as weight in kilograms divided by the square of height in meters); PBF, percent body fat.

Table 3. Spearman's Correlation coefficient of obesity index with other obesity indices and components of metabolic syndrome and internal agreement

	Men			Women		
	WC	BMI	PBF	WC	BMI	PBF
Obesity indices						
Body mass index	0. 810**	—	—	0. 761**	—	—
Percent body fat	0. 736**	0. 780**	—	0. 752**	0. 920**	—
Components of metabolic syndrome other than obesity						
Triglycerides	0. 314**	0. 332**	0. 391**	0. 305**	0. 306**	0. 331**
HDL-cholesterol	−0. 313**	−0. 313**	−0. 310**	−0. 347**	−0. 353**	−0. 354**
Fasting blood glucose	0. 217**	0179**	0. 189**	0. 186**	0. 184**	0. 177**
Systolic blood pressure	0. 090**	0. 070**	0. 050*	0. 241**	0. 235**	0. 216**
Internal agreement						
Standardized Cronbach's alpha	0. 449	0. 441	0. 448	0. 568	0. 564	0. 564
Correlation with total	0. 298	0. 302	0. 339	0. 356	0. 340	0. 349

*: 0.01≥ p<0.05, **: p<0.01

Abbreviations: WC, waist circumference; BMI, body mass index (measured as weight in kilograms divided by the square of height in meters); PBF, percent body fat.

Table 4. Accuracy of waist circumference for two or more metabolic syndrome components by cut-off point

Cut-off point	Men			Women		
	Sensitivity	Specificity	Odds ratio	Sensitivity	Specificity	Odds ratio
≥73 cm	0. 930	0. 189	3. 11	0. 878	0. 315	3. 29
≥74 cm	0. 909	0. 227	2. 92	0. 864	0. 371	3. 75
≥75 cm	0. 891	0. 277	3. 14	0. 837	0. 419	3. 69
≥76 cm	0. 887	0. 321	3. 71	0. 796	0. 459	3. 31
≥77 cm	0. 839	0. 362	2. 96	0. 748	0. 493	2. 90
≥78 cm	0. 800	0. 416	2. 84	0. 707	0. 529	2. 71
≥79 cm	0. 743	0. 475	2. 62	0. 633	0. 576	2. 34
≥80 cm	0. 683	0. 516	2. 29	0. 599	0. 627	2. 50
≥81 cm	0. 626	0. 584	2. 36	0. 551	0. 677	2. 57
≥82 cm	0. 565	0. 638	2. 29	0. 510	0. 711	2. 57
≥83 cm	0. 470	0. 679	1. 87	0. 463	0. 751	2. 59
≥84 cm	0. 435	0. 729	2. 06	0. 395	0. 793	2. 50
≥85 cm	0. 383	0. 761	1. 97	0. 354	0. 822	2. 53
≥86 cm	0. 330	0. 805	2. 04	0. 320	0. 859	2. 86
≥87 cm	0. 270	0. 841	1. 96	0. 286	0. 884	3. 05
≥88 cm	0. 230	0. 868	1. 98	0. 252	0. 906	3. 25
≥89 cm	0. 174	0. 898	1. 86	0. 224	0. 921	3. 39
≥90 cm	0. 152	0. 918	2. 01	0. 197	0. 932	3. 39

WC ≥85cm for men and ≥90cm for women, the sensitivity was only 0. 384 and 0. 205, respectively. This implies that 61. 6% of men and 79. 5% of women with multiple risk factors without obesity escape MetS diagnosis.

Figure 2 shows the ROC curves of the three obesity indices for predicting the presence of two or more MetS components other than obesity. The area under the WC, BMI, and PBF curves was 0. 640, 0. 623, and 0. 642 in men, and 0. 669, 0. 656, and 0. 658 in women, respectively. The area under the curve of the ROC curve was low among men and women, indicating the poor discrimination power of these indices for MetS.

DISCUSSION

In this study, we found that none of the obesity indices highly correlated to the MetS components in middle-aged Japanese adults based on analyses of internal consistency and ROC curves. WC was no more accurate for predicting the presence of two or more MetS components than BMI and PBF, suggesting that central obesity is no more correlated to MetS than BMI and that WC is not accurate enough to evaluate central obesity.

Several studies from Western countries have reported the superiority of WC compared with BMI for predicting coronary heart disease (14, 15), an association with cardiovascular risk factors (16), and diabetes (17, 18); however, these findings are inconsistent with reports regarding Aborigines (19) and Koreans. (20) A study from Turkey reported that the association between WC and visceral fat area was stronger than between BMI and visceral fat area. (21) However, in Japan, the correlation coefficients were relatively close to each other especially among women (10, 22). In the present study, WC and BMI correlation coefficients were high, which was consistent with a previous report on Asians (19, 23). A study from the US reported a lower correlation between WC and BMI. (24)

The higher the correlation coefficient, the more difficult it is to distinguish central obesity using WC from overall obesity by BMI. Studies from Asia with a high correlation between WC and BMI reported that both indices were similarly associated with cardiovascular outcome (19) or risk factors (25). These findings indicate that there is little variation in obesity in some populations and there would be little additional information if BMI was available.

Our results may be partly due to WC measurement error. We observed spikes in the histogram (Fig.1) every 5 cm of WC, and this accumulation towards zero would deteriorate the accuracy of WC. Previous studies reported that WC is insufficient for diagnosis of MetS due to measurement error (26, 27), but not all. (28) In the present study, we found that WC and BMI provided similar estimates of MetS; therefore, we have no practical reason to measure WC because BMI is widely measured.

One of the important differences in the definition of MetS is how obesity is incorporated.

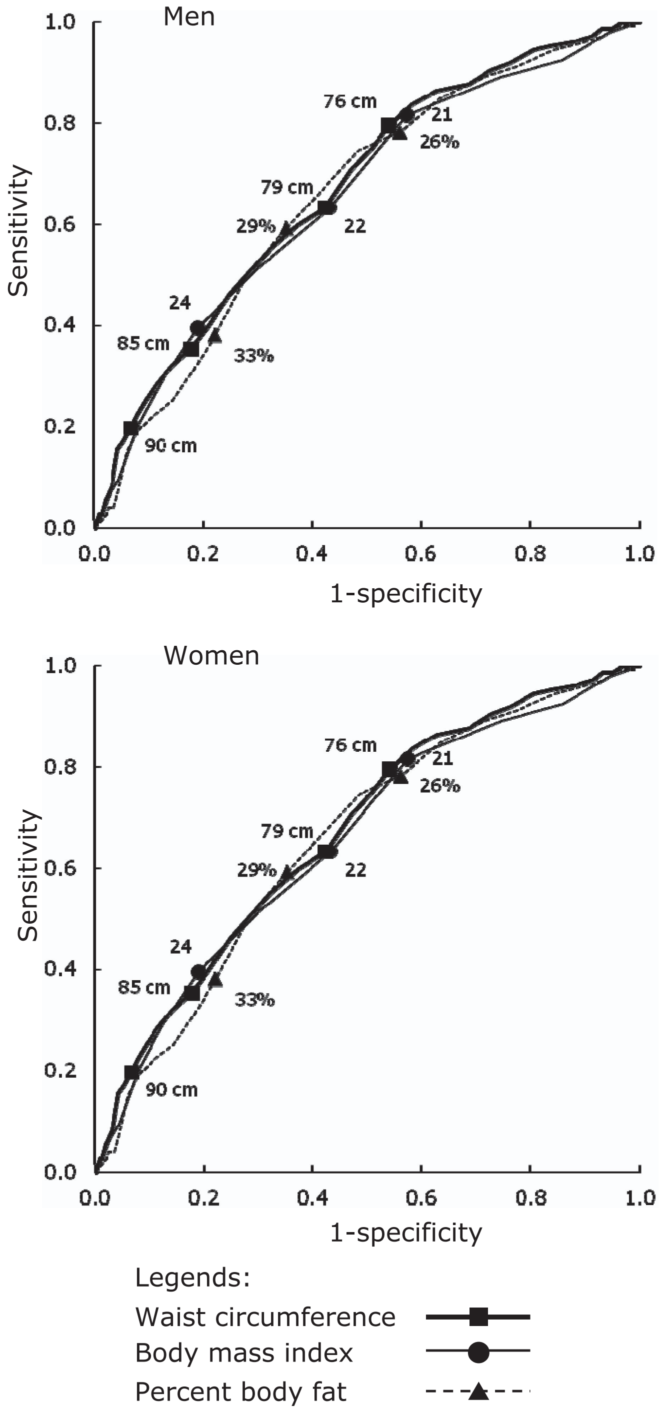

Figure 2
Comparison of ROC curves of WC, BMI and PBF for predicting the presence of two or more MetS components other than obesity. The area under each curve was 0.640, 0.623, and 0.642 in men, and 0.669, 0.656, and 0.658 in women, respectively.

For example, the IDF definition includes obesity as a prerequisite for diagnosis of MetS (6), and the NCEP ATP III definition includes obesity as one of the risk factors (5). Ideally, a prerequisite should be a strong positive effect modifier between the other MetS criteria (e.g., hypertension) and an endpoint (e.g., acute MI). Namely, those who have several risk factors for MetS without obesity should have similar risks of endpoints as people without risk factors. Otherwise, people with several MetS risks without obesity are ignored and not supplied medical follow-up despite their high risk. This problem would be minimized if there was a high degree of association between obesity and other MetS components; however, we found a relatively weak association between obesity and the MetS components, regardless of the index used (11, 13). A small area under the WC curve was also observed in previous studies. (29, 30) For example, the most commonly used cut-off point in Japan (WC ≥ 85cm for men and ≥ 90cm for women) drops to 62% in men and 80% in women with multiple risk factors. A report from Japan observed increased cardiovascular death risk according to the number of MetS factors, regardless of BMI strata. (31) In the US, NCEP ATP III reported that some male patients develop multiple metabolic risk factors when their WC is only marginally increased partly due to a strong genetic contribution to insulin resistance. (5) Thus, we propose that obesity would be incorporated as a risk factor, but not a prerequisite for MetS diagnosis, in the Japanese population.

The study is limited by its cross-sectional design and more follow-up studies of various diseases as MetS endpoints, including ischemic heart disease and diabetes mellitus, using large-scale cohorts by ethnic group are required. If the risk of obesity remains after adjusting other components, it should be listed as a risk factor for MetS. Otherwise, obesity need not be included in the MetS components as long as other components are measured. Moreover, insulin resistance, the other component of MetS, and its interaction between obesity indices should be investigated for further clarification of the etiology of MetS.

In summary, WC is not considered a better index of obesity than BMI for MetS diagnosis in the Japanese population, partly because of a narrow range in obesity in the Japanese population and WC measurement error. We propose that the obesity index be incorporated as a risk factor but not a prerequisite for MetS diagnosis in the Japanese population.

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