Original Article

BMI Specific Waist Circumference for Detecting Clusters of Cardiovascular Risk Factors in a Japanese Population

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Aim: The purpose of the study was to determine the sensitive cutoff values of waist circumference (WC) in relation to the body mass index (BMI) for detecting the clustering of cardiovascular risk factors (CCRF) in Japanese men and women.

Methods: The study population included 2,476 male and female residents who participated in a ward health examination in Tokyo, Japan. The CCRF were defined according to the Japanese Committee of the Criteria for Metabolic Syndrome. Receiver Operating Characteristics (ROC) analysis was conducted within each BMI category.

Results: The percentage of study participants in the normal BMI category was around 70% for both men and women. The sensitive cutoff values for the largest WC with at least 80% sensitivity were 81 cm for normal and 89 cm for overweight men. The corresponding values for women were 79 cm and 86 cm, respectively. The WC with maximized sensitivity plus specificity was 80 cm for normal and 89 cm for overweight men, and the sensitivity was 88.7% and 83.0%, respectively. The corresponding values for women were 78 and 94 cm, respectively, and the sensitivity was 91.5% and 57.6%, respectively.

Conclusions: For the early detection and management of clusters of cardiovascular risk factors, we concluded that a BMI-specific WC cutoff value of 80 cm for normal weight in both men and women and 89 cm for overweight men and 86 cm for overweight women should be discriminate cutoff values.

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Key words; Body mass index, Clustering of cardiovascular risk factors, Metabolic syndrome, Screening, Waist circumference

Introduction

The risk of the serious health consequences of type 2 diabetes, coronary heart disease (CHD) and various cancers has been shown to rise with an increase in body mass index (BMI) not only in Western populations but also in the Japanese¹⁻³. Further, the impor-

tance of waist circumference (WC) in predicting metabolic abnormalities and adverse outcomes (e.g., type 2 diabetes, CHD, and death rate) has been examined in large epidemiologic studies⁴⁻¹⁴.

The clustering of cardiovascular risk factors, such as raised blood pressure, dyslipidemia, and hyperglycemia, in the same individual appears to confer a substantial additional cardiovascular risk above the sum of the risk associated with each abnormality^{15, 16}. A multiple set of risk factors that commonly appear together in individuals with large WC is now known as metabolic syndrome¹⁷ and increases the morbidity and mortality of cardiovascular diseases¹⁸⁻²¹. The current Japanese Committee of the Criteria for Metabolic

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Syndrome (JCCMS) guidelines to diagnose metabolic syndrome recommend a gender-specific single WC cutoff value regardless of the BMI category²². The current criteria for WC are 85 cm for men and 90 cm for women²².

The clustering of cardiovascular risk factors is also prevalent in normal BMI individuals with WC values under the cutoffs and increases the risk of ischemic heart disease and stroke²³ and cardiovascular mortality²⁴ in the Japanese. Furthermore, the clustering of risk factors was positively and significantly correlated with carotid atherosclerosis²⁵ and the early stage of coronary atherosclerosis²⁶ in the Japanese. Around 70% of a Japanese representative sample of men and women were in the normal BMI category²⁷; therefore, sensitive WC cutoff values to detect clusters of risk factors for normal range BMI men and women are an important issue.

However, there is no evidence to suggest that the current recommended WC cutoff values are appropriate within a given BMI category. Indeed, these cutoffs may not adequately further discriminate health risks, because only a few normal weight people have a WC value above the recommended cutoffs, whereas almost all overweight and obese people have WC values exceeding these cutoff values^{28, 29}.

BMI and WC are different methods for assessing adiposity and may give additional and complementary information if combined; however, there is no evidence that dichotomizing JCCMS WC cutoff values can predict the clustering of cardiovascular risk factors in each BMI category in the Japanese. Given that the WC cutoff values currently recommended by the JCCMS were not designed to be used in combination with BMI categories, critical evaluation of the sensitivity of using WC cutoff values in combination with BMI categories is needed³⁰.

The purposes of this study were 1) to identify the sensitive WC cutoff values in relation to the BMI category for determining clusters of cardiovascular risk factors, and 2) to test the usefulness of these cutoff values compared with those proposed by the JCCMS (90 cm for women and 85 cm for men) for the first time in Japan using the general population residing in a community.

Research Design and Methods

The study population consisted of 1,269 men and 1,447 women (30 to 80 years old) who reside in Tokyo, Japan and participated in an annual health examination between 1999 and 2006 in a ward health center in Tokyo. An annual health examination was

conducted for residents and/or workers in the ward. Participants were recruited using a ward newsletter. The data from only the first visit of the health examination were used.

Blood samples were collected in the overnight fasting state, and the values of high-density lipoprotein cholesterol (HDL-C), triglycerides (TG) and fasting plasma glucose (FPG) were used. Resting systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured twice using a standard mercury sphygmomanometer after participants had rested for more than ten minutes. The latter blood pressure was considered as the resting SBP and DBP. Blood samples were taken and BP measured by public health nurses.

In a fasting state in the morning, WC, height, and body weight were measured. WC (cm) was measured at the umbilical level in a standing position to the nearest 0.1 cm by a technician. Body weight and height were measured to the nearest 0.1 kg and 0.1 cm respectively. BMI (body weight (kg) over height (m) squared) was calculated.

Information on the history of illnesses and current medications was confirmed after referring to each participant's medical records.

The clustering of cardiovascular risk factors was defined as two or more of the following three risk factors according to the JCCMS criteria²²: 1) SBP ≥ 130 mmHg and/or DBP ≥ 85 mmHg, 2) TG ≥ 150 mg/dL and/or HDL-C < 40 mg/dL, 3) FPG ≥ 110 mg/dL. Participants on medication for diabetes, raised TG or hypertension were included as having those risk factors.

This study was approved by the Ethics Review Committee of the University of Tokyo.

Statistical Analysis

Values are expressed as the mean $\pm$ SD and the difference between men and women was tested using Student's *t* test. Pearson's correlation between BMI and WC was tested. To test for linear trends, the Jonckheere-terpstra test for means and the Cochran-Armitage trend test for proportions were conducted. Using receiver operating characteristics (ROC) analysis, sensitive WC cutoff values to identify clusters of cardiovascular risk factors were analyzed within underweight (less than 18.5 kg/m²), normal weight (18.5 to 24.9 kg/m²), overweight (25 to 29.9 kg/m²), and obese (30 kg/m² and over) BMI categories. The sensitive cutoff value of WC was defined as the largest WC with at least 80% sensitivity. Also, the cutoff value of WC with maximized sensitivity plus specificity was tested. Further, the area under the ROC curve (AUC) and 95% confidence interval (95% CI) of the AUC

were calculated.

All analyses were performed using SAS Version 9.1 (SAS Institute Inc., Cary, NC, USA).

Table 1. Characteristics of study population

	Men	Women
numbers	1,146	1,330
Age (years)	53.2 ± 12.3	50.9 ± 12.0
Height (cm)	167.7 ± 6.5	155.5 ± 5.7
Weight (kg)	66.9 ± 10.2	53.8 ± 8.2
BMI ^a (kg/m ²)	23.8 ± 2.9	22.3 ± 3.3
WC ^b (cm)	84.6 ± 8.5	80.0 ± 9.6
SBP ^c (mmHg)	125.2 ± 15.9	117.0 ± 16.9
DBP ^d (mmHg)	77.4 ± 10.2	70.4 ± 10.5
TG ^e (mg/dL)	130.9 ± 111.2	91.5 ± 51.9
HDL-C ^f (mg/dL)	59.6 ± 16.5	69.8 ± 16.8
FPG ^g (mg/dL)	98.9 ± 18.9	91.4 ± 13.6

Values are the mean ± SD.

Differences between mean values for men and women were all statistically significant (Student's *t* test: $p < 0.0001$)

^aBody Mass Index. ^bWaist circumference. ^cSystolic blood pressure.

^dDiastolic blood pressure. ^eTriglycerides.

^fHigh density lipoprotein cholesterol. ^gFasting plasma glucose.

Results

A total of 234 individuals were excluded because 89 had a history of major illness, such as cardiovascular diseases or cancer, and/or 145 received postprandial blood testing. As a result, 1,146 men and 1,330 women were eligible for the study.

Table 1 shows the characteristics of the study participants. The mean age was 53.2 ± 12.3 years for men and 50.9 ± 12.0 years for women. All mean values except HDL-C were significantly higher in men than in women. HDL-C was significantly higher in women than in men.

Participants were divided according to their BMI categories and the mean WC, and the prevalence of those with risk factors in relation to BMI category are shown in **Table 2**. Around 70% of the population was in the normal BMI category for both men and women. From the underweight to obese BMI categories, the mean WC increased linearly and significantly for both men and women.

The most prevalent risk factor was raised SBP and/or DBP in both men and women. All risk factors and clusters of risk factors were more prevalent in men

Table 2. Waist circumference and prevalence of cardiovascular risk factors according to BMI classification

	Overall	BMI ^a classification			
		<18.5	18.5–24.9	25.0–29.9	≥ 30.0
Men					
Numbers (%)	1,146 (100.0)	21 (1.8)	783 (68.3)	309 (27.0)	33 (2.9)
Waist circumference (cm)	84.6 ± 8.5	67.4 ± 3.7	81.6 ± 6.0	91.5 ± 5.5	105.2 ± 9.8
High WC ^b (%)	47.6	0.0	29.9	90.3	100.0
High TG ^c and/or low HDL-C ^d (%)	30.5	4.8	25.0	42.1	66.7
High SBP ^e and/or DBP ^f (%)	45.4	33.3	41.0	57.6	42.4
High FPG ^g (%)	16.0	9.5	13.3	21.7	30.3
Clustering risk factors ^h (%)	23.0	9.5	19.2	32.4	33.3
Women					
Numbers (%)	1,330 (100.0)	111 (8.3)	1,000 (75.2)	181 (13.6)	38 (2.9)
Waist circumference (cm)	80.0 ± 9.6	67.7 ± 4.9	78.6 ± 7.2	90.6 ± 5.6	102.5 ± 8.3
High WC ^b (%)	15.4	0.0	6.8	55.8	94.7
High TG ^c and/or low HDL-C ^d (%)	12.1	3.6	9.8	25.4	34.2
High SBP ^e and/or DBP ^f (%)	26.6	10.8	24.6	39.8	63.2
High FPG ^g (%)	5.7	0.0	4.5	10.5	31.6
Clustering risk factors ^h (%)	8.1	0.0	5.9	18.2	39.5

Test for linear trends; Jonckheere-terpstra test for the mean and the Cochran-Armitage trend test for proportions were conducted: All these linear trends were statistically significant in relation to BMI categories: $p < 0.0001$

^aBody weight (kg)/height (m)². ^bWaist circumference ≥ 85 cm for men and ≥ 90 cm for women.

^cTriglycerides ≥ 150 mg/dL. ^dHigh density lipoprotein cholesterol < 40 mg/dL. ^eSystolic blood pressure ≥ 130 mmHg.

^fDiastolic blood pressure ≥ 85 mmHg. ^gFasting plasma glucose ≥ 110 mg/dL.

^hThe clustering of two or more risk factors among TG and/or HDL-C, SBP and/or DBP, FPG.

Subjects on medication for diabetes, high TG or hypertension were included as having high FPG, high TG or high SBP and/or DBP.

Table 3. Correlation between BMI and waist circumference

	Overall	BMI ^a classification			
		<18.5	18.5–24.9	25.0–29.9	≥30.0
Overall	0.85 ***	0.45 ***	0.70 ***	0.50 ***	0.71 ***
Men	0.86 ***	0.36	0.72 ***	0.55 ***	0.90 ***
Women	0.83 ***	0.46 ***	0.67 ***	0.44 ***	0.46 **

Pearson's correlation coefficients; ** $p < 0.01$, *** $p < 0.001$

^aBody weight (kg)/height (m)².

than in women. The prevalence of raised TG and/or reduced HDL-C, raised SBP and/or DBP, raised FPG, and the clustering of risk factors increased linearly and significantly in relation to the BMI category; however, the prevalence of raised SBP and/or DBP was highest in the overweight BMI category only in men.

Table 3 shows correlation coefficients between BMI and WC. Overall, the coefficients were more than 0.8 for men and women. The coefficients were significant in each BMI category except for men in the underweight category.

The proportion of study participants in the underweight and obese BMI categories was only 1.8% and 2.9% in men, respectively, and 8.3% and 2.9% in women, respectively. Further analysis of these BMI categories was not performed in this study because of the limited number of the population.

Table 4 shows the sensitivity and specificity of the WC cutoff values proposed by the JCCMS for detecting clusters of cardiovascular risk factors. When 85 cm was used for men, sensitivity within the normal BMI category was only 41.3%. Within the overweight BMI category, sensitivity was 97.0%; however, specificity was only 12.9%. In women, with 90 cm WC, sensitivity was only 28.8% in the normal BMI category and 72.7% in the overweight BMI category.

Table 5 shows the sensitive WC values in this study in relation to the BMI categories and the area under the ROC curve (AUC) and its 95% confidence interval. All AUC was statistically significant for both men and women. Sensitive cutoff values for the largest WC with at least 80% sensitivity were 81 cm in normal weight and 89 cm in overweight men, respectively. In women, sensitive cutoff values were 79 cm in normal weight and 86 cm in overweight groups, respectively. The cutoff values of WC with maximized sensitivity plus specificity were 80 cm and 89 cm in normal weight and overweight men, respectively. These values were quite similar to the sensitive WC cutoff values. In women, the cutoff values were 78 and 94 cm in the normal and overweight BMI categories,

Table 4. Sensitivity and specificity for detecting clusters of risk factors using the JCCMS^a criteria in relation to the BMI^b categories

BMI ^b classification	<18.5	18.5–24.9	25.0–29.9	≥30.0
Men				
WC ^c value (cm)	85	85	85	85
Sensitivity (%)	0.0	41.3	97.0	100.0
Specificity (%)	100.0	72.8	12.9	0.0
Women				
WC ^c value (cm)	90	90	90	90
Sensitivity (%)	–	28.8	72.7	100.0
Specificity (%)	–	94.6	47.9	8.7

^aJapanese Committee of the Criteria for Metabolic Syndrome

^bBody mass index: Body weight (kg)/height (m)²

^cWaist circumference proposed by the JCCMS

respectively.

The risk profiles in each category stratified by BMI and WC from the study results in **Table 5** were calculated (**Table 6**). For men in the normal BMI category, 133 (88.7%) of 150 individuals who had risk factor clustering could be screened with the 80 cm WC cutoff value. For women in the normal BMI category, 46 (78.0%) of 59 individuals who had risk factor clustering could be screened.

Discussion

The results of the present relatively large population-based study demonstrated that BMI-specific WC cutoff values would give additional and complementary information for detecting clusters of cardiovascular risk factors both for men and women.

For normal BMI category men, the largest WC with at least 80% sensitivity to identify clusters of cardiovascular risk factors was 81 cm, and the WC with maximized sensitivity plus specificity was 80 cm. These cutoff values of WC were lower than the JCCMS value of 85 cm. With an 85 cm cutoff value, sensitivity was only 41.3%. For overweight men, the largest WC with at least 80% sensitivity and WC with maximized sensitivity plus specificity was 89 cm. This value was higher than the JCCMS value and its sensitivity was 83.0%.

Currently, a 90 cm WC cutoff value for women is proposed by the JCCMS, regardless of their BMI. With this value, sensitivity was only 28.8% for normal weight but 72.7% for overweight women. The largest WC with at least 80% sensitivity was 79 cm for normal weight and 86 cm for overweight women with approximately 85% sensitivity. The cutoff value of

Table 5. Sensitive cutoff values of waist circumference in relation to the BMI^a categories

BMI ^a classification	<18.5	18.5–24.9	25.0–29.9	≥30.0
Men				
AUC (95% CI) ^b	–	0.67 (0.63–0.72)	0.60 (0.54–0.67)	–
Largest waist circumference with at least 80% sensitivity				
WC ^c value (cm)	72	81	89	104
Sensitivity (%)	100.0	81.3	83.0	81.8
Specificity (%)	89.5	47.4	37.3	59.1
Cutoff values with maximized sensitivity plus specificity				
WC ^c value (cm)	72	80	89	107
Sensitivity (%)	100.0	88.7	83.0	54.5
Specificity (%)	89.0	41.2	37.3	86.4
Women				
AUC (95% CI) ^b	–	0.77 (0.71–0.82)	0.64 (0.53–0.75)	–
Largest waist circumference with at least 80% sensitivity				
WC ^c value (cm)	–	79	86	100
Sensitivity (%)	–	84.7	84.8	80.0
Specificity (%)	–	54.4	19.6	56.5
Cutoff values with maximized sensitivity plus specificity				
WC ^c value (cm)	–	78	94	100
Sensitivity (%)	–	91.5	57.6	80.0
Specificity (%)	–	48.8	74.3	56.5

^aBody mass index: Body weight (kg)/height (m)²^bArea under the ROC curve (95% Confidence Intervals)^cWaist circumference**Table 6.** Risk profiles using proposed waist circumference from the current study

BMI ^a classification	18.5–29.9	18.5–24.9		25.0–29.9	
Men					
WC ^b value		<80 cm	≥80 cm	<89 cm	≥89 cm
Numbers (%)	1,092 (100.0) [100.0]	278 (100.0) [25.5]	505 (100.0) [46.2]	124 (100.0) [11.4]	185 (100.0) [16.9]
High TG ^c and/or low HDL-C ^d (%)	326 (29.9) [100.0]	34 (12.2) [10.4]	162 (32.1) [49.7]	25 (20.2) [7.7]	105 (56.8) [32.2]
High SBP ^e and/or DBP ^f (%)	499 (45.7) [100.0]	76 (27.3) [15.2]	245 (48.5) [49.1]	48 (38.7) [9.6]	130 (70.3) [26.1]
High FPG ^g (%)	171 (15.7) [100.0]	20 (7.2) [11.7]	84 (16.6) [49.1]	18 (14.5) [10.5]	49 (26.5) [28.7]
Clustering risk factors ^h (%)	250 (22.9) [100.0]	17 (6.1) [6.8]	133 (26.3) [53.2]	17 (13.7) [6.8]	83 (44.9) [33.2]
Women					
WC ^b cutoff values		<80 cm	≥80 cm	<86 cm	≥86 cm
Numbers (%)	1,181 (100.0) [100.0]	565 (100.0) [47.8]	435 (100.0) [36.8]	32 (100.0) [2.7]	149 (100.0) [12.6]
High TG ^c and/or low HDL-C ^d (%)	144 (12.2) [100.0]	35 (6.2) [24.3]	63 (14.5) [43.8]	9 (28.1) [6.3]	37 (24.8) [25.7]
High SBP ^e and/or DBP ^f (%)	318 (26.9) [100.0]	87 (15.4) [27.4]	159 (36.6) [50.0]	10 (31.3) [3.1]	62 (41.6) [19.5]
High FPG ^g (%)	64 (5.4) [100.0]	13 (2.3) [20.3]	32 (7.4) [50.0]	3 (9.4) [4.7]	16 (10.7) [25.0]
Clustering risk factors ^h (%)	92 (7.8) [100.0]	13 (2.3) [14.1]	46 (10.6) [50.0]	5 (15.6) [5.4]	28 (18.8) [30.4]

^aBody weight (kg)/height (m)². ^bWaist circumference.^cTriglycerides ≥150 mg/dL. ^dHigh density lipoprotein cholesterol <40 mg/dL.^eSystolic blood pressure ≥130 mmHg. ^fDiastolic blood pressure ≥85 mmHg.^gFasting plasma glucose ≥110 mg/dL. ^hThe clustering of two or more risk factors among TG and/or HDL-C, SBP and/or DBP, FPG.

Subjects on medication for diabetes, high TG or hypertension were included as those having high FPG, high TG or high SBP and/or DBP.

Figures in the left parentheses () represent % proportion of the vertical line and figures in the right parenthesis [] represent % proportion of the horizontal line.

WC with maximized sensitivity plus specificity was 78 cm for normal weight and 94 cm for overweight women with sensitivity of 91.5% and 57.6%, respectively. With 57.6% sensitivity, more than 40% of people with risk clustering will be dropped from primary screening of metabolic syndrome.

WC was included as a prerequisite condition of the initial assessment to diagnose metabolic syndrome according to the JCCMS. If the sensitivity of WC is low, most individuals with clusters of cardiovascular risk factors will not be included in the target population for the early detection and management of metabolic syndrome. The clustering of cardiovascular risk factors of metabolic syndrome is prevalent in normal weight people and increases the risk of ischemic heart disease and stroke²³⁾ and cardiovascular mortality²⁴⁾ in the Japanese. Therefore, determining the cutoff value of WC to detect clusters of risk factors with high sensitivity is needed. From the current study results, WC of 80 cm for the normal BMI category in both men and women and 89 cm for men and 86 cm for women in the overweight BMI category should be discriminate cutoff values.

The overall correlation coefficients between BMI and WC were relatively high in men and women. This means that WC cutoff values to discriminate clustering of risk factors have to be lower in the lower BMI category. These results support previous studies^{28, 29)}. Furthermore, almost 70% of people were classified into the normal BMI category, the same as the results of a Japanese representative sample²⁷⁾, and 56.8% of men and 54.6% of women with risk clustering were included in this BMI category.

The risk profiles in each category stratified by BMI and the proposed WC from this study were compared (**Table 6**). Among individuals with risk clustering in the normal BMI category, 88.7% men and 78.0% women were screened with the proposed WC cutoff values from this study. However, if JCCMS WC cutoff values were used, only 41.3% men and 28.8% women with risk clustering would be screened. Thus, for the early detection and management of risk clustering, the proposed BMI-specific WC cutoff values from this study should be discriminate cutoff values.

In our female study population, the number of people in the overweight BMI category was relatively small. These study results might be reconsidered in a larger population having a high prevalence of overweight participants; however, WC of 80 cm should be used in the risk assessment of those in the normal BMI category. In our study, the number of people in the underweight BMI or obese BMI categories was

too small to analyze. It would not be worthwhile to propose BMI-specific WC values for detecting clusters of cardiovascular risk factors for those with these BMI values.

The current study results showed that the proposed JCCMS WC values were too high for normal weight men and women to determine the risk for clusters of cardiovascular risk factors; however, the proposed current JCCMS WC values are relatively sensitive cutoff values for overweight men and women. Thus, the WC cutoff values for risk assessment should be combined with the individual's BMI.

Raised BP is well known as the most common component of metabolic syndrome^{27, 31)}, and the most attributable risk factor for all-cause mortality in the Japanese³²⁾. The mean values of BP were relatively low in our study participants because we measured BP twice after more than ten minutes rest and the latter BP was selected as the resting BP; however, raised BP showed the highest prevalence among the components of metabolic syndrome.

Self-measuring instead of laboratory examinations might reduce the time and cost of screening tests. Self-measured BP at home has a stronger predictive power for cardiovascular mortality and morbidity than measured BP at screenings in the Japanese³³⁻³⁶⁾. The values of self-measured BP are superior in identifying not only hypertension³⁷⁾ but also risk factor clustering³⁸⁾ and would provide a cost benefit to diagnosing and treating hypertension³⁷⁾.

Self-measured WC^{11, 13)} and body weight¹⁴⁾ also showed significant predictive power for mortality and/or morbidity of type 2 diabetes, cardiovascular diseases and cancer in large prospective studies. Self-measuring may also strengthen people's motivation for lifestyle modification.

Screening tests for the diagnosis of metabolic syndrome would be shortened if self-measured body weight, WC and BP were used. Further large-scale research is needed in regards to the predictive characteristics of self-measured body weight, WC and BP for metabolic syndrome, and its potential benefits on people's adherence to lifestyle modification.

The current study participants were community residents, and we carefully considered their medication status. The mean BMI, the percentages of those underweight, normal weight, overweight and obese, and the prevalence of cardiovascular risk factors of the nationwide representative sample of the Japanese Health and Nutrition Survey²⁷⁾ were similar to our study participants. Thus, the study population was not biased against the general Japanese population. The study analyses are based on cross-sectional data;

therefore, the cause and effect relationship between WC and cardiovascular risk factors within each BMI category can not be identified; however, we evaluated the clustering of cardiovascular risk factors using the JCCMS criteria and proposed sensitive cutoff values of WC for detecting clusters of cardiovascular risk factors in relation to BMI for the first time in Japan using the general population residing in a community.

Conclusion

This study proposed WC cutoff values combined with BMI for detecting clusters of cardiovascular risk factors in a Japanese population. For the early detection and management of clusters of cardiovascular risk factors in the primary screening setting, we concluded that a BMI-specific WC cutoff value of 80 cm for the normal weight men and women, and 89 cm for overweight men and 86 cm for overweight women should be discriminate cutoff values.

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