Criteria of Waist Circumference According to Computed Tomography-Measured Visceral Fat Area and the Clustering of Cardiovascular Risk Factors

Hidetoshi Kashiwara, PhD; Jung Su Lee, PhD*; Kiyoshi Kawakubo, MD**;
Masaki Tamura, MD; Akira Akabayashi, MD†

Background: The purpose of this study was to determine the discriminate gender-specific cutoff values of waist circumference (WC) for detecting the clustering of cardiovascular risk factors (CCRF), which reflects the intra-abdominal visceral fat area (VFA) using a large Japanese population.

Methods and Results: The study population consisted of 6,736 men and women who underwent a periodic health check-up and had a computed tomography scan for VFA measurement at the PL Tokyo Health Care Center in Tokyo, Japan. The CCRF was defined according to the Japanese Committee of the Criteria for Metabolic Syndrome. The discriminate values for detecting the CCRF were tested using receiver operating characteristics analysis. The discriminate values of VFA were 103.0 cm² with 68.7% sensitivity and 61.8% specificity for men and 69.0 cm² with 80.8% sensitivity and 70.0% specificity for women. The WC values corresponding to the VFA were 89.1 cm for men and 86.3 cm for women. The discriminate values of VFA and WC were not substantially different between people with or without raised blood pressure.

Conclusions: For the early detection and management of the CCRF and VFA in the primary screening setting, the discriminate and convenient gender-specific WC criteria would be 90 cm for men and 85 cm for women. (Circ J 2009; 73: 1881–1886)

Key Words: Cardiovascular risk factors; Intra-abdominal visceral fat area (VFA); Metabolic syndrome; Screening; Waist circumference

A nationwide prevention strategy for cardiovascular diseases, including a specific health check-up and health education for the metabolic syndrome, started with the fiscal year 2008 in Japan. The purpose of the strategy is to promote the early detection and management of the clustering of cardiovascular risk factors (CCRF); thus, the waist circumference (WC) measurement was introduced to health check-ups for the first time in Japan.

The CCRF that occurs in the same individual appears to confer a substantial additional cardiovascular risk over and above the sum of the risk associated with each abnormality.^{1,2} Multiple risk factors that commonly appear together are now known as the metabolic syndrome,³ which increases the morbidity and mortality of cardiovascular diseases.^{4–7} The metabolic syndrome has dramatically increased in developed countries, including Japan.^{8,9}

Intra-abdominal visceral fat accumulation is widely recognized as a cause of metabolic disorders.^{10–15} A simple and convenient indicator that reflects the visceral fat mass is needed in the primary screening setting. Measuring WC is a simple tool and WC is widely recognized as a measure of metabolic abnormalities.^{16–20} The Japanese Committee of the Criteria for Metabolic Syndrome (JCCMS)²¹ proposed

criteria for practical use in 2005, and WC was included as a primary crucial criterion.

The JCCMS current criteria for WC for men and women are 85 and 90 cm, respectively.²¹ The WC cutoff value was determined using the 100 cm² area of intra-abdominal visceral fat area (VFA),¹⁶ because the mean number of metabolic disorders (ie, hyperglycemia, dyslipidemia, and hypertension) increased with VFA, and the average number of metabolic disorders was more than 1.0 at 100 cm² of VFA.²² However, that study's population was relatively small and gender had not been considered when evaluating the VFA values to detect the CCRF.¹⁶

Only a few comparable Japanese studies have been conducted to simultaneously reassess appropriate VFA and WC cutoff values.^{22,23} These studies proposed much smaller cutoff values of VFA and WC for women than the current Japanese criteria.²¹ Therefore, it is necessary to reconfirm the gender-specific correlation between VFA and CCRF and to clarify the gender-specific cutoff values of WC corresponding to the new VFA values using a large, general Japanese population with a wide range of body mass.

Raised blood pressure (BP) is well known as the most common component of the metabolic syndrome,^{9,24} and the

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PL Tokyo Health Care Center, *Department of Health Promotion Sciences, Graduate School of Medicine, The University of Tokyo, **Department of Food Sciences & Nutrition, Kyoritsu Women's University and †Department of Biomedical Ethics, School of Public Health, Graduate School of Medicine, The University of Tokyo, Tokyo, Japan

Mailing address: Jung Su Lee, PhD, Department of Health Promotion Sciences, Graduate School of Medicine, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan. E-mail: jslee@m.u-tokyo.ac.jp

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Table 1. Characteristics of the Study Population

	Men		Women	
N	5,080		1,656	
Age (years)	49.2±10.1	30–74	51.4±10.2	30–74
Body mass index*	25.2±2.8	17.4–46.7	23.2±3.5	15.6–51.9
WC (cm)	88.3±7.1	62.5–136.0	81.7±9.4	58.5–124.0
Intra VFA (cm ²)	100.6±39.0	3.0–308.3	56.7±33.6	2.7–242.6
Patients with risk factors**	2,832	55.7%	409	24.7%
1 risk factor	1,969	38.8%	336	20.3%
2 risk factors	708	13.9%	66	4.0%
3 risk factors	155	3.1%	7	0.4%

Mean±SD or number of subjects and proportion of subjects (%).

*Body weight (kg)/height (m)².

**Risk factors: raised BP, raised triglycerides and/or reduced HDL-C, and raised fasting plasma glucose.

WC, waist circumference; VFA, visceral fat areas; BP, blood pressure; HDL-C, high-density lipoprotein-cholesterol.

most attributable risk factor for all-cause mortality in the Japanese.²⁵ However, it is still not clear whether the characteristic features differ between those who have raised BP and those who do not. Thus, it is imperative to compare the gender-specific discriminate cutoff values of VFA and WC for detecting CCRF between cases with or without raised BP.

The present study used a relatively large Japanese general population to: (1) determine gender-specific discriminate cutoff values of VFA for detecting the CCRF, (2) determine gender-specific cutoff values of WC reflecting the new VFA values, and (3) compare the discriminate gender-specific cutoff values of VFA and WC for detecting CCRF between cases with or without raised BP.

Methods

Study Population

The eligible study population consisted of 6,736 men and women (age range: 30–74 years old) who underwent an annual periodic health check-up and also had a computed tomography (CT) scan for VFA measurement from October 2005 to December 2008 at the PL Tokyo Health Care Center in Tokyo, Japan. People who were on medication for diabetes, hyperlipidemia, or hypertension were excluded from the study population. This center is a periodic health examination facility mainly for insured employees and their family members.

The present study was conducted in accordance with the ethical principles stated in the Declaration of Helsinki (by the World Medical Association). The autonomy of the participants was fully respected and security of personal information was provided to participants.

Measurements

The WC (cm) was measured at the navel in a standing position to the nearest 0.1 cm by a technician when the participants were in a morning fasting state.

Systolic and diastolic BP (SBP, DBP) were measured using an automatic BP monitor (UDEX Super type, ELK Corporation, Tokyo, Japan) after the participant had rested while seated for 30 min. Blood was taken from the anterior cubital vein in the fasting state, and triglycerides (TG), high-density lipoprotein-cholesterol (HDL-C), and fasting plasma glucose (FPG) were analyzed using enzymatic methods with an automatic analyzer (Hitachi 7450 Automatic Analyzer, Hitachi, Tokyo, Japan).

Quality control for blood testing was performed every

day using pooled standard blood samples. Coefficients of variation of TG, HDL-C, and FPG in this measurement system were less than 1.0%.

The CCRF of the metabolic syndrome was defined as 2 or more of the following 3 risk factors according to the JCCMS criteria²¹: (1) TG ≥150 mg/dl, and/or HDL-C <40 mg/dl, (2) SBP ≥130 mmHg and/or DBP ≥85 mmHg, and (3) FPG ≥110 mg/dl.

The VFA was measured from CT cross-sectional scans at the navel (ROBUSTO; Hitachi, Tokyo, Japan) according to the reported standard method.²⁶

Statistical Analysis

First, the gender-specific discriminate cutoff values of VFA or WC for detecting the CCRF were tested using receiver operating characteristics (ROC) analysis. The sensitivity and specificity were calculated for every 1 cm² of VFA or 1 cm of WC, and the discriminate point for the CCRF (the least distance from upper-left to VFA or WC ROC curve) was determined.

The calculation formula is $\sqrt{(1 - \text{Sensitivity})^2 + (1 - \text{Specificity})^2}$.

The area under the ROC curve (AUC) and 95% confidence interval (CI) were also calculated.

Next, the gender-specific WC cutoff value according to the VFA cutoff value was determined using simple regression analysis between VFA and WC.

Further, the gender-specific discriminate cutoff values of VFA or WC for detecting the CCRF were compared between those with raised BP (SBP ≥130 mmHg and/or DBP ≥85 mmHg) and those without raised BP using ROC analysis.

Results

Table 1 shows the characteristics of the study population. The mean age was 49.2 and 51.4 years for men and women, respectively. The mean body mass index (BMI) was 25.2 for men and 23.2 for women. The percentage of people who had 2 or more cardiovascular risk factors was 17.0% for men and 4.4% for women.

Figure 1 shows the gender-specific ROC curve of VFA for detecting the CCRF. AUC was 0.71 (95%CI 0.69–0.72) for men and 0.83 (95%CI 0.79–0.87) for women, and the AUC was statistically significant for both men and women. From the ROC curve, discriminate VFA values for detecting the CCRF were 103.0 cm² for men and 69.0 cm² for women. At these cutoff points, sensitivity and specificity were 68.7% and 61.8%, respectively, for men, and 80.8%

Figure 1. Gender-specific discriminate value of intra-abdominal visceral fat area (VFA) for clustering of cardiovascular risk factors using receiver operating characteristics (ROC) analysis. d, least distance from upper-left to intra abdominal VFA ROC.

Figure 2. Gender-specific discriminate value of waist circumference (WC) for clustering of cardiovascular risk factors using receiver operating characteristics (ROC) analysis. d, least distance from upper-left to WC ROC.

Figure 3. Gender-specific discriminate value of waist circumference (WC) reflecting the intra-abdominal visceral fat area (VFA).

Table 2. Comparison Between Patients With and Without Raised BP

	Men		Women	
	Without raised BP	With raised BP	Without raised BP	With raised BP
N	3,886	1,194	1,437	219
Age (years)	48.1±9.9	52.7±10.0	50.7±10.1	56.5±9.0
Body mass index*	24.9±2.7	26.0±3.0	22.9±3.3	25.2±4.1
Clustering risk factors**	232 (6.0)	631 (52.8)	17 (1.2)	56 (24.7)

Mean±SD or number of subjects (%).

*Body weight (kg)/height (m)².

**Patients who have 2 or more of the following risk factors: raised systolic BP and/or diastolic BP, raised triglycerides and/or reduced HDL-C, and raised fasting plasma glucose.

Abbreviations see in Table 1.

Table 3. Gender-Specific Discriminate Cutoff VFA and WC for Detecting Clustering of Cardiovascular Risk Factors Including Patients With and Without Raised BP

	Men		Women	
	Without raised BP	With raised BP	Without raised BP	With raised BP
VFA				
Value of least distance*	1,030.0	108.0	73.0	71.0
Sensitivity	0.690	0.631	0.765	0.786
Specificity	0.631	0.623	0.758	0.596
AUC	0.708	0.653	0.834	0.712
95%CI of AUC**	0.675–0.739	0.622–0.683	0.734–0.906	0.634–0.781
WC				
Value of least distance*	89.0	89.0	83.0	84.0
Sensitivity	0.647	0.607	0.882	0.732
Specificity	0.616	0.559	0.614	0.567
AUC	0.669	0.586	0.768	0.601
95%CI of AUC**	0.635–0.701	0.554–0.618	0.674–0.845	0.512–0.685

*Least distance from upper-left to ROC curve.

**95%CI of AUC.

CI, confidence interval; AUC, area under the receiver operating characteristics (ROC) curve. Other abbreviations see in Table 1.

and 70.0%, respectively for women. When 100 cm² of VFA was used for women, specificity was 91.4%, but sensitivity was only 38.4%.

Figure 2 shows the gender-specific ROC curve of WC for detecting the CCRF. AUC was 0.65 (95%CI 0.63–0.67) for men and 0.73 (95%CI 0.67–0.78) for women, and the AUC was statistically significant for both men and women. From the ROC curve, discriminate WC values for detecting the CCRF were 89.0 cm for men and 84.0 cm for women. At these cutoff points, sensitivity and specificity were 61.8% and 60.2%, respectively, for men, and 74.0% and 63.3%, respectively, for women. However, specificity was only 33.3% when 85 cm of JCCSM WC was used for men, and sensitivity was only 42.5% when 90 cm of JCCSM WC was used for women.

Gender-specific WC values corresponding to the discriminate VFA values were confirmed using a scattergram (**Figure 3**). Each WC cutoff point corresponding to a VFA of 103.0 cm² for men and 69.0 cm² for women was calculated using a simple regression formula. Results indicated that the WC cutoff points were 89.1 cm for men and 86.3 cm for women.

Table 2 compares the characteristic features of those with and without raised BP. The mean age and BMI were significantly higher in people with raised BP than those without in both men and women. A proportion of people who had CCRF was also significantly higher in people with raised BP than those without raised BP in both men and women.

Table 3 shows the comparison of discriminate VFA and

WC cutoff values for detecting the CCRF using ROC analysis between those with and without raised BP. The discriminate VFA cutoff value for men with raised BP was 108.0 cm², which was slightly higher than the 103.0 cm² for men without raised BP. The discriminate VFA cutoff value was 71.0 cm² and 73.0 cm² for women with and without raised BP, respectively. The discriminate WC cutoff value for men both with and without raised BP was 89.0 cm. The discriminate WC cutoff value was 84.0 cm and 83.0 cm for women with and without raised BP, respectively. The discriminate WC cutoff values did not differ between those with and without raised BP in both men and women.

Discussion

The purpose of the present study was to determine the gender-specific discriminate criteria of WC for detecting the CCRF of metabolic syndrome using a large number of Japanese men and women from the general population with a wide range of body mass. From the study results, the gender-specific cutoff values of VFA for detecting the CCRF is 103.0 cm² for men and 69.0 cm² for women, and the WC values corresponding to these VFA values are 89.1 cm for men and 86.3 cm for women. When WC for detecting the CCRF was evaluated using the ROC analysis, the discriminate WC cutoff values are 89.0 cm for men and 84.0 cm for women. These WC cutoff values are quite similar to the WC values corresponding to the VFA values detecting the CCRF. Therefore, for the early detection and management of the CCRF and VFA in the primary screen-

ing setting, the discriminate and convenient gender-specific WC criteria would be 90 cm for men and 85 cm for women.

The other study purpose was to compare the discriminate gender-specific cutoff values of VFA and WC for detecting CCRF between those with and without raised BP. The discriminate cutoff value of VFA was 5 cm² larger in men with raised BP than that in men without raised BP. However, the discriminate VFA value was 71 cm² for women with raised BP and 2 cm² smaller than the value for women without raised BP. These differences were too small to discuss any specific correlation between raised BP and VFA in men and women. Further study focusing on this issue is needed.

From the present study, we propose a WC of 90 cm for men and 85 cm for women, which are the discriminate and convenient gender-specific WC criteria. The cutoff value of 90 cm for men is larger than that of the JCCMS criteria^{16,21} and the cutoff value of 85 cm for women is smaller. The criteria of JCCMS were determined using the 100 cm² of VFA¹⁶ among a relatively small study population (775 men and 418 women). In that analysis, gender difference was not considered. WC was measured using gender-specific simple regression analysis between WC and VFA only for 554 men and 194 women.¹⁶ In the present study, specificity was only 33.3% for the 85 cm cutoff value of the JCCMS^{16,21} for men. In contrast, sensitivity for detecting the CCRF was only 42.5% for the 90 cm cutoff value of the JCCMS for women.

In Japan, a nationwide strategy including a specific health checkup and health education about the metabolic syndrome was initiated. In the specific health checkup, WC is a prerequisite condition of the initial assessment. To achieve the purpose of the strategy, a sensitive WC cutoff value is needed to differentiate among those people who have CCRF. The CCRF of the metabolic syndrome is prevalent even in non-obese people and increases the risk of ischemic heart disease and stroke²⁷ and cardiovascular mortality²⁸ in the Japanese. If the sensitivity of WC is too low, most of the people who have CCRF will not be included in the target population for the early detection and management of CCRF. Therefore, it is important to determine the discriminate cutoff value of WC with high sensitivity.

Previous limited Japanese studies^{29–31} also recommended much smaller WC values for women than the JCCMS criteria. However, they did not consider the WC value with the directly measured VFA using a CT scan. In the present study, VFA and WC were measured by trained technicians, and the measuring site was at the navel according to the JCCMS criteria.

A few comparable Japanese studies have been conducted to simultaneously reconfirm appropriate VFA and WC cutoff values.^{22,23} Miyawaki et al proposed WC cutoff values of 86 cm for men and 77 cm for women,²² whereas Oka et al proposed WC cutoff values 89.8 cm for men and 82.3 cm for women.²³ The cutoff values of WC for women were much smaller than the current Japanese criteria,²¹ as in the present study, and the results of these studies, especially those of Oka et al,²³ were quite similar to the results of the present study. Therefore, the cutoff values of 90 cm for men and 85 cm for women seem to be simple and convenient for gender-specific WC criteria for the Japanese population.

The present study population was a general population comprising insured people and their families living in or around the Tokyo metropolitan area. The mean BMI and the prevalence of cardiovascular risk factors of the nationwide representative sample used in the Japanese Health and

Nutrition Survey⁹ were quite similar to the present study. Thus, the study population was not biased against the general Japanese population. The study analyses are based on cross-sectional data; therefore, a cause and effect relationship between WC and cardiovascular diseases cannot be drawn. In order to more accurately define the cutoff values for WC in the Japanese population, we should compare WC cutoff values with the development of diabetes or cardiovascular disease. Further study using large representative samples in various communities in Japan with a prospective study design is needed. There is a growing body of evidence that adiponectin is strongly associated with metabolic disorders and visceral obesity and plays a crucial role in the pathogenesis of the metabolic syndrome and cardiovascular disease in the Japanese.^{32,33} However, we could not investigate the correlation between adiponectin and CCRF or the discriminate values of VFA and WC, because the present study population consisted of people who underwent an annual periodic health check-up without adiponectin examination. Further study focusing on this issue is needed.

Conclusion

For the early detection and management of CCRF in the primary screening setting, we concluded that the discriminate criteria of gender-specific WC with relatively high sensitivity and specificity are 90 cm for men and 85 cm for women.

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