Cut-Off Values for Visceral Fat Area Identifying Korean Adults at Risk for Metabolic Syndrome

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Background: Cut-off values for visceral fat area (VFA) measured by computed tomography (CT) for identifying individuals at risk of metabolic syndrome (MetS) have not been clearly established in Korean adults, particularly for large populations. We aimed to identify optimal VFA and waist circumference (WC) cut-off values and compare the ability of VFA and WC to predict the presence of ≥2 metabolic risk factors.

Methods: We included 36,783 subjects aged 19–79 years undergoing abdominal fat CT during regular health check-ups between January 2007 and February 2015 in Seoul. The risk factors for MetS except WC were based on the International Diabetes Federation criteria. Receiver operating characteristic curve analyses were used to determine the appropriate VFA and WC cut-off values for MetS.

Results: VFA was a more significant predictor of metabolic risk factors than WC and body mass index (BMI). The optimal cut-off values for VFA and WC were 134.6 cm² and 88 cm for men and 91.1 cm² and 81 cm for women, respectively. We estimated age-specific cut-off values for VFA, WC, and BMI. VFA cut-off values increased with age, particularly among women.

Conclusion: This large population study proposed the cut-off values for VFA and WC for identifying subjects at risk of MetS among Korean adults. For more accurate diagnosis, different age-specific cut-off values for VFA and WC may be considered.

Keywords: Metabolic Syndrome; Abdominal Obesity; Visceral Fat Area; Waist Circumference; ROC Curve
INTRODUCTION

Metabolic syndrome (MetS) is defined as a cluster of metabolic abnormalities characterized by central obesity, hypertension, high triglyceride (TG) levels, low high-density lipoprotein cholesterol (HDL-C) levels, and high fasting plasma glucose (FPG) levels. Individuals with MetS have been known to have a higher risk of type 2 diabetes mellitus and cardiovascular disease, and a subsequent increase in disease-related mortality or morbidity.1-4 Although the pathophysiology of MetS is not fully understood, central obesity is known to be a major cause of insulin resistance and is closely associated with the other four features of MetS by causing an imbalance between adipokines and insulin.5-7

In 2006, the International Diabetes Federation (IDF) announced a new definition for MetS that included central obesity as an essential element, proposing different waist circumference (WC) cut-offs according to sex and ethnicity, specifically, 90 cm for men and 80 cm for women of South Asian ethnicity.5

In Korea, the incidence of MetS has increased markedly over the past decades, as in some Western countries.8-10 Although visceral obesity is known to play an essential role in the development of MetS, the cut-off values for Korean-specific visceral fat area (VFA) and WC have not been clearly defined. In 2007, the Korean Society for the Study of Obesity (KOSSO) recommended ethnically appropriate WC cut-off values of 90 cm for men and 85 cm for women with regard to central obesity.11 These results were based on the Korea National Health and Nutritional Examination Survey (1998), which included 6,561 adults aged 20–80 years; the employed criteria were consistent with the IDF Asia-Pacific region criteria. However, the KOSSO did not provide the cut-off values for VFA.

WC is widely used to diagnose abdominal obesity because of its ease of measurement. However, it has been reported that insulin resistance is more strongly associated with VFA directly measured by computed tomography (CT) than with WC or body mass index (BMI).12,13 Accumulation of visceral fat is recommended to be measured by magnetic resonance imaging or CT, which can distinguish fat from other tissues and allow the measurement of visceral and subcutaneous abdominal fat mass independently with high reproducibility.14 Furthermore, with aging, fat mass increases progressively and distributes more centrally; accordingly, a number of studies suggest that different VFA cut-offs should be determined according to age.15,16

In this study, we investigated the appropriate sex- and age-specific cut-off values for VFA as reference values for predicting metabolic risk factors in Korean adults.

METHODS

1. Study Population

This cross-sectional study involved 39,181 subjects (23,728 men and 15,453 women) aged between 19 and 79 years who underwent health check-up tests, including abdominal fat CT, between January 2007 and February 2015 at Seoul National University Hospital Gangnam Center, Seoul, Republic of Korea. For participants undertaking health examinations on more than two occasions, we included only the result of the first examination. Our study excluded participants with a past medical history of any cancer (n=1,429), stroke (n=267), and cardiovascular event or stent insertion (n=702). Finally, 36,783 participants (22,365 men and 14,418 women) were enrolled in this study. Lifestyle factors, such as smoking, alcohol consumption, degree of exercise, marital status, and degree of education, were assessed using a self-report questionnaire. Alcohol consumption was calculated as the amount of drinking per week. Exercise was classified as regular exercise where subjects exercised ≥3 times per week. This study protocol was approved by the Institutional Review Board of Seoul National University Hospital (IRB approval no., H-1608-018-781).

2. Anthropometric Measurements and Blood Tests

Anthropometric measurements of individuals were performed by well-trained nurses. Height and weight were determined using a fixed wall-scale measuring device that measured to the nearest 0.1 cm or 0.1 kg, respectively, using an electronic scale that was calibrated before each measurement. BMI was calculated by dividing weight (kg) by squared height (m²). WC was measured at the end of normal expiration, measuring the minimum circumference at the level of the umbilicus to the nearest 0.5 cm. All subjects had their blood pressure (BP) checked twice after at least 5 minutes of rest in sitting position and were asked to answer questionnaires under the supervision of a well-trained interviewer. Blood samples were collected in the morning after an overnight fast. FPG, total cholesterol, low-density lipoprotein cholesterol, HDL-C, and TG levels were measured enzymatically using the Hitachi 747 chemical analyzer (Hitachi, Tokyo, Japan).

3. Measurement of Abdominal Adipose Tissue Areas Using Computed Tomography Scans

The adipose tissue areas were measured at the level of the umbilicus using a 16-detector row CT scanner (Somatom Sensation 16; Siemens Medical Solutions, Forchheim, Germany) with the subjects in a supine position. A 5-mm-thick umbilical-level abdominal section was obtained using a 16-detector row CT scanner. The cross-sectional area (cm²) of abdominal fat was calculated using Rapidia 2.8 CT software (INFINITT, Seoul, Korea) with attenuation values for the region of interest within a range of −250 to −50 Hounsfield units. The technique used for adipose tissue area measurements with CT cross-sectional images has been previously standardized and validated. The visceral adipose tissue area was defined as intra-peritoneal fat bound by parietal peritoneum or transversalis fascia, and the subcutaneous adipose tissue area was defined as the fat area external to the abdomen and back muscles.17-19

4. Definition of Metabolic Risk Factors

In this study, we used the following criteria for the definition of MetS proposed by the IDF, excluding WC as a risk factor:20 systolic BP of ≥130 mm Hg or diastolic BP of ≥85 mm Hg or treatment of previously diag-
nosed hypertension; FPG level of ≥100 mg/dL or treatment of previously diagnosed type 2 diabetes; TG level of ≥150 mg/dL; HDL-C level of <40 mg/dL for men and <50 mg/dL for women; and a combination of two or more of these metabolic risk factors.

5. Statistical Analysis

Statistical analyses were performed separately for men and women because of known differences in abdominal fat distribution between sexes. Continuous variables were expressed as means and standard deviation, and discrete variables were expressed as proportions. Differences between sexes were determined by the Student t-test. A receiver operating characteristic (ROC) curve analysis was used to develop a cut-off for each anthropometric value associated with the presence of two or more risk factors of MetS, except WC, and to compare the predictive value of VFA, WC, and BMI. We performed subgroup analysis to obtain the age-specific cut-off values. The cut-off values for VFA, WC, and BMI that maximized the Youden index (sensitivity + specificity - 1) were defined as optimal. The Youden index is an integrative indicator of sensitivity and specificity.20 The statistical significance level was set at a probability value of <0.05, and the statistical analyses were performed using STATA ver. 14.0 (Stata Corp., College Station, TX, USA).

RESULTS

1. Subject Characteristics

A total of 36,783 participants (22,365 men and 14,418 women) were included in the analysis. The characteristics of our study population are presented in Table 1. The mean age was approximately 50.8 years in men and 51.7 years in women. The mean VFA, WC, and BMI values were 136.0 cm², 88.0 cm, and 24.6 kg/m² for men and 83.0 cm², 80.6 cm, and 22.3 kg/m² for women, respectively. The proportion of current smoking and alcohol consumption was significantly higher for men. We found that 8,868 (39.7%) of 22,365 men and 3,090 (21.4%) of 14,418 women had two or more risk factors for MetS according to the IDF criteria, excluding the WC risk factor.

2. Receiver Operating Characteristic Curve Analysis

Figure 1 presents the age-adjusted ROC curves of VFA, WC, and BMI in men (Figure 1A) and in women (Figure 1B), which were used to identify the presence of ≥2 metabolic risk factors except WC. The area under the ROC curve (AUC) values of VFA, WC, and BMI are presented in Table 2. Among both men and women, the AUC for VFA (men, 0.7004; women, 0.7881) was associated with higher values than that for WC (men, 0.6732; women, 0.7336) or BMI (men, 0.6654; women, 0.7323), suggesting that VFA was a better parameter than WC and BMI.

Table 1. Baseline characteristics of the study population

| Characteristic                                                                 | Total (n=36,783) | Men (n=22,365) | Women (n=14,418) |
|-------------------------------------------------------------------------------|-----------------|----------------|------------------|
| Age (y)                                                                       | 50.8±9.5        | 51.7±9.5       |                  |
| Body mass index (kg/m²)                                                       | 24.6±2.8        | 22.3±2.9       |                  |
| WC (cm)                                                                       | 88.0±8.0        | 80.6±8.0       |                  |
| Total fat area (cm²)                                                          | 277.2±94.7      | 259.9±97.3     |                  |
| Visceral fat area (cm²)                                                       | 136.0±53.1      | 83.0±42.7      |                  |
| Systolic BP (mm Hg)                                                           | 119.5±13.1      | 113.4±14.9     |                  |
| Diastolic BP (mm Hg)                                                          | 78.6±10.3       | 71.3±10.7      |                  |
| Total cholesterol (mg/dL)                                                     | 195.4±34.6      | 198.5±35.3     |                  |
| TG (mg/dL)                                                                    | 129.5±89.9      | 87.4±54.7      |                  |
| HDL-C (mg/dL)                                                                 | 49.3±13.0       | 58.4±13.0      |                  |
| Fasting glucose (mg/dL)                                                       | 100.3±21.2      | 91.8±15.8      |                  |
| Alcohol consumption (g/wk)* (26.3% in men, 7.7% in women)                     | 222.0±190.1     | 127.2±151.1    |                  |
| Current smoker (%)                                                           | 36.1            | 4.4            |                  |
| Regular exercise (>3 times/wk)*                                               | 28.5            | 27.1           |                  |
| Married (%)                                                                  | 93.7            | 87.0           |                  |
| Educational status*                                                          | 4.0             | 9.6            |                  |
| Middle school or less (%)                                                     | 16.6            | 24.5           |                  |
| College or more (%)                                                          | 83.5            | 65.9           |                  |
| Features of metabolic syndrome except WC                                       |                  |                |                  |
| BP ≥130/85 mm Hg or Med                                                       | 9,462 (42.3)    | 3,661 (25.4)   |                  |
| Fasting blood sugar ≥100 mg/dL or Med                                         | 8,641 (38.6)    | 2,727 (19.9)   |                  |
| TG ≥150 mg/dL                                                                | 6,210 (27.8)    | 1,321 (9.2)    |                  |
| Low HDL-C (<40 for men, <50 for women)                                       | 4,560 (20.4)    | 4,211 (29.2)   |                  |
| ≥2 metabolic risk factors of the IDF criteria, except WC                     | 8,868 (39.7)    | 3,090 (21.4)   |                  |

Values are presented as mean±standard deviation, %, or number (%). Gender differences in all variables were statistically significant (P<0.001). WC, waist circumference; BP, blood pressure; TG, triglyceride; HDL-C, high-density lipoprotein cholesterol; Med, medication; IDF, International Diabetes Federation. *Missing values are included in this data.
for determination of the subjects at risk of developing MetS. The AUC values were greater in women than in men for all metabolic risk factors.

3. Cut-Off Values for Visceral Fat Area, Waist Circumference, and Body Mass Index

The optimal cut-off values for VFA, WC, and BMI to identify ≥2 risk factors for MetS, except WC, were 134.6 cm², 88.4 cm, and 24.7 kg/m² and for men and 91.1 cm², 81.0 cm, and 22.4 kg/m² for women, respectively (Table 3). We estimated the age-specific cut-off values for VFA, WC, and BMI by dividing subjects into the following three groups based on their age: 19–39 years, 40–59 years, and 60–79 years. The VFA cut-off values increased with age, particularly among female subjects (Table 4).

**DISCUSSION**

Our results demonstrated that the optimal VFA cut-off values (134.6 cm² for men and 91.1 cm² for women) yielded maximum sensitivity and specificity. Considering our findings, the WC cut-off values were comparable to the IDF criteria for subjects of South Asian ethnicity. The BMI cut-off value was comparable to the World Health Organization (WHO) criteria for men but was lower than the WHO criteria for women (Table 3).

To date, few studies have reported Korean-specific VFA cut-off values. Han et al. performed a cross-sectional, hospital-based study in 276 men and 540 women, who had undergone regular health check-ups at general hospitals in Seoul, Republic of Korea. The authors proposed optimal VFA cut-off values of 100 cm² for men and 70 cm² for women, which are lower than those calculated in our study groups. The different characteristics of the study population may have contributed to this difference; their study population was younger and the mean VFA was relatively lower than that in our population (Table 5).

However, the prevalence of metabolic abnormalities in their study was higher than that in ours. The prevalence of ≥2 metabolic risk factors in the study by Han et al. was 61.6% for men (high BP, 52.9%; high FPG, 57.2%; hyperTG, 53.3%; and low HDL-C, 24.3%) and 33.0% for women (high BP, 34.1%; high FPG, 28.9%; hyperTG, 21.1%; and low HDL-C, 36.5%). This number is higher than the actual prevalence of MetS observed in Korean adults: 30.8% for men (high BP, 39.7%; high FPG, 37.0%; hyperTG, 37.8%; and low HDL-C, 38.7%) and 26.3% for women (high BP, 26.7%; high FPG, 24.6%; hyperTG, 45.8%; and low HDL-C, 52.6%). Therefore, the cut-off values reported by Han et al. may be
excessively low. In contrast, the prevalence of metabolic abnormalities in the present study was similar to the actual prevalence of MetS in Korean adults; consequently, our cut-off values would be more appropriate.

Kim et al.23) investigated 280 subjects aged 30–80 years, and their VFA and WC cut-off values were comparable to those reported in our study: VFA=136 cm$^2$ and WC=89 cm for men and VFA=95 cm$^2$ and WC=82 cm for women. Consistent with our study, the mean VFA and the cut-off values were higher than those reported by Han et al.21) The prevalence of MetS in that study was 28.4% for men and 19.5% for women.

Table 3. Comparison of the cut-off values for VFA, WC and BMI for identifying metabolic risk factors in the present and previous studies

| Variable | Cut-off | Sensitivity (%) | Specificity (%) | PPV (%) | NPV (%) |
|----------|---------|----------------|----------------|---------|---------|
| Men      |         |                |                |         |         |
| VFA (cm$^2$) | Cut-off in present study* (n=22,365) | 134.6 | 67.3 | 62.3 | 63.5 | 66.1 |
|          | Han et al.22) 2007 (n=276) | 100.0 | 67.1 | 51.9 | 80.3 | 35.0 |
|          | Kim et al.24) 2014 (n=195) | 136.0 | 74.3 | 78.3 | 72.3 | 80.0 |
|          | Seo et al.23) 2009 (≥63 y, n=308) | 92.6 | 70.4 | 70.5 | 79.7 | 59.1 |
|          | Lim S et al.24) 2011 (≥65 y, n=294) | 140.0 | 49.1 | 74.1 | 46.6 | 76.0 |
|          | JIM25) (for Japanese, n=775) | 100.0 | 83.4 | 34.8 | 78.9 | 41.7 |
|          | Oka et al.26) 2008 (for Japanese, n=1,061) | 132.6 | 63.3 | 64.3 | 50.0 | 75.6 |
| WC (cm)  | Cut-off in present study* (n=22,365) | 88.4 | 61.3 | 64.7 | 59.7 | 66.2 |
|          | KOSSO’s cut value11) | 90.0 | 54.2 | 81.9 | 62.0 | 76.6 |
|          | IDF criteria for South Asians8) | 90.0 | 44.6 | 76.1 | 50.4 | 71.6 |
| BMI (kg/m$^2$) | Cut-off in present study* (n=22,365) | 24.7 | 60.8 | 62.9 | 57.3 | 66.2 |
|          | WHO Asia Pacific criteria for obesity21) | 25.0 | 45.8 | 84.8 | 67.4 | 69.5 |
| Women    |         |                |                |         |         |
| VFA (cm$^2$) | Cut-off in present study* (n=14,418) | 91.1 | 71.4 | 72.2 | 60.2 | 81.1 |
|          | Han et al.22) 2007 (n=540) | 70.0 | 80.3 | 55.2 | 69.2 | 69.1 |
|          | Kim et al.24) 2014 (n=185) | 95.0 | 79.1 | 77.4 | 64.5 | 87.7 |
|          | Seo et al.23) 2009 (≥63 y, n=381) | 88.9 | 72.5 | 59.4 | 53.3 | 77.3 |
|          | Lim S et al.24) 2011 (≥65 y, n=313) | 100.0 | 65.2 | 56.5 | 39.7 | 78.7 |
|          | JIM25) (for Japanese, n=775) | 100.0 | 519.0 | 81.4 | 55.1 | 79.4 |
|          | Oka et al.26) 2008 (for Japanese, n=1,061) | 91.5 | 67.0 | 74.4 | 60.4 | 79.4 |
| WC (cm)  | Cut-off in present study* (n=14,418) | 81.0 | 74.1 | 61.1 | 59.6 | 75.3 |
|          | KOSSO’s cut value11) | 85.0 | 76.4 | 51.5 | 35.2 | 86.4 |
|          | IDF criteria for South Asians8) | 80.0 | 82.1 | 42.5 | 57.2 | 71.7 |
| BMI (kg/m$^2$) | Cut-off in present study* (n=14,418) | 22.4 | 71.4 | 63.3 | 59.2 | 74.8 |
|          | WHO Asia Pacific criteria for obesity21) | 25.0 | 54.6 | 64.4 | 34.6 | 80.5 |

Table 4. Age-specific cut-off values of VFA, WC, and BMI for predicting two or more risk factors for metabolic syndrome

| Age (y) | VFA (cm$^2$) | AUC | WC (cm) | AUC | BMI (kg/m$^2$) | AUC |
|---------|-------------|-----|---------|-----|---------------|-----|
| Men     |             |     |         |     |               |     |
| 19–39 (n=2,652) | 120.5 | 0.760 | 89.3 | 0.751 | 24.7 | 0.742 |
| 40–59 (n=15,645) | 134.4 | 0.699 | 88.5 | 0.673 | 25.0 | 0.671 |
| 60–79 (n=4,068) | 131.7 | 0.656 | 87.8 | 0.633 | 24.3 | 0.627 |
| Women   |             |     |         |     |               |     |
| 19–39 (n=1,428) | 62.6 | 0.838 | 77.2 | 0.816 | 22.4 | 0.821 |
| 40–59 (n=10,093) | 85.9 | 0.775 | 80.8 | 0.717 | 23.1 | 0.729 |
| 60–79 (n=2,897) | 115.6 | 0.679 | 82.5 | 0.630 | 24.0 | 0.635 |

VFA, visceral abdominal fat area; WC, waist circumference; BMI, body mass index; AUC, area under the receiver operating characteristic curve.
Comparable results have also been reported in Japan, another Northeast Asian country. Since the Japan Society for the study of Obesity proposed a VFA cut-off value of 100 cm² in 2002, it has been used as the gold standard for the definition of central obesity among Japanese adults. This standard has been widely used, but a number of follow-up studies have been conducted to re-evaluate its efficiency. Oka et al. suggested that the optimal VFA cut-off value for identifying subjects with ≥2 risk factors for MetS is 132.6 cm² for men and 91.5 cm² for women. Comparable results have also been reported in Japan, another Northeast Asian country. Since the Japan Society for the study of Obesity proposed a VFA cut-off value of 100 cm² in 2002, it has been used as the gold standard for the definition of central obesity among Japanese adults. This standard has been widely used, but a number of follow-up studies have been conducted to re-evaluate its efficiency. 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tionnaire.

To the best of our knowledge, this is the largest study to propose VFA cut-off values for the Korean population. We suggest that VFA values higher than the cut-off value of 134.6 cm² for men and 91.1 cm² for women are risk factors for predicting MetS that could result in cardiovascular disease or type 2 diabetes mellitus. Future prospective studies are needed to validate the association between the optimal WC/VFA cut-off values and the incidence of or mortality resulting from cardiovascular diseases.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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