Sagittal Abdominal Diameter Is a Strong Anthropometric Measure of Visceral Adipose Tissue in the Asian General Population

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OBJECTIVE — Finding the anthropometric measure of visceral obesity is essential to clinical practice, because it predicts cardiovascular and metabolic risks. Sagittal abdominal diameter (SAD) has been proposed as an estimate of visceral adipose tissue (VAT). The aim of the present study was to evaluate the usefulness of SAD in predicting visceral obesity by comparing SAD to other anthropometric measures.

RESEARCH DESIGN AND METHODS — Estimation of subcutaneous and visceral adipose tissue and measurement of SAD and transverse abdominal diameter using computed tomography at the umbilical level were obtained in 5,257 men and women who were enrolled in a health checkup program in Korea. To compare SAD to other anthropometric measures, linear regression analyses were used to determine correlations between anthropometrics and visceral obesity.

RESULTS — SAD showed a stronger correlation to VAT than waist circumference, BMI, and transverse abdominal diameter in the both sexes (men: r = 0.804, women: r = 0.724). Waist circumference showed generally stronger associations to subcutaneous adipose tissue (SAT) than to VAT (men: r = 0.789 vs. 0.705, women: r = 0.820 vs. 0.636). Even after subdividing according to age or BMI in both sexes and analyzing multiple regressions, SAD showed the strongest correlation to VAT.

CONCLUSIONS — SAD showed the strongest correlation to VAT irrespective of age, sex, and the degree of obesity compared with other anthropometric measures, whereas waist circumference may have a stronger correlation to SAT than to VAT. The clinical use of SAD has advantages over other anthropometric measures in predicting VAT.

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Although abdominal obesity has been considered a risk factor compromising health in only Western countries, where its presence has been relatively high, the prevalence of abdominal obesity has recently increased in Asian countries because of sedentary lifestyles and westernized diet. Abdominal obesity frequently leads to diabetes or metabolic disorders and can induce cardiovascular diseases with a risk of early death (1,2). Several studies have suggested that, compared with subcutaneous adipose tissue (SAT), visceral adipose tissue (VAT) has a stronger correlation to these obesity-related disorders (3,4). Thus, accurate measurement of VAT is required to predict the risk of obtaining such diseases. Computed tomography (CT) or magnetic resonance imaging is the most accurate method for estimating VAT (5). However, since the high costs of these tests make them clinically impractical, much effort has been made to find inexpensive, easily obtainable anthropometric measures to clinically evaluate the relationship between VAT and metabolic diseases.

Waist circumference (WC) has been widely used to measure abdominal obesity (6), and it serves as one of the criteria for the diagnosis of metabolic syndrome (7,8). However, WC does not distinguish visceral from subcutaneous abdominal adipose tissue (9–11). Pou et al. (11) revealed that WC may misclassify individuals in terms of VAT. Their result implies that other anthropometric measures to correlate with VAT are needed.

Sagittal abdominal diameter (SAD), which measures the anteroposterior diameter of the abdomen, reflects VAT based on the fact that subcutaneous fat is displaced inferiorly by gravity (12). Since SAD was introduced as a means of estimating visceral obesity (12), a few studies have been conducted on the usefulness of SAD in the evaluation of visceral obesity (13–15) as well as cardiovascular and metabolic risks (16,17) in comparison to other anthropometric measures. However, there were still insufficient evidences to draw any conclusions whether SAD more accurately represents visceral obesity due to the small number of subjects and selection process in the previous studies. Larger population-based studies are still needed to determine it. Moreover, the previous studies on SAD have been carried out in Western countries; there have been little data in the Asian population.

Transverse abdominal diameter (TAD) was the largest spanned width, whereas SAD was the largest spanned height of the abdomen (12). TAD has been presented on correlation to SAT (12,13,15). However, TAD has never previously been investigated in terms of its correlation to the amount of adipose tissue in the Asian population.

Therefore, the present study was conducted to compare SAD to other anthropometric measures in predicting the

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amount of CT-measured adipose tissue in a large, apparently healthy population.

RESEARCH DESIGN AND METHODS

— The study population consisted of 5,257 men and women who were enrolled retrospectively in a health checkup program from March 2007 to December 2008 at the Seoul National University Hospital Healthcare System Gangnam Center. They were mostly free of symptoms and voluntarily underwent an abdominal CT scan with the blood samplings for laboratory determinants including serum lipid profiles, fasting glucose, and A1C as part of their exam. All subjects had their blood pressure checked twice and were asked to answer questionnaires under the supervision of a well-trained interviewer. Current smoker was defined as smoking at least one cigarette per day in the previous year. Alcohol consumption was dichotomized on the basis of >140 g/week. Women were considered menopausal if periods had stopped over 1 year. The questionnaire included questions regarding the medical and surgical histories. The subjects who had experienced prolonged bed rest in the previous year or recent weight changes and who had undergone abdominal surgery in the past were excluded. The subjects with malignancy or chronic liver disease with ascites were also excluded. A total of 5,100 subjects were finally enrolled in this study. The subjects were classified by age within each sex (<50 or ≥50 years). This study protocol conformed to the ethical guidelines of the 1975 Declaration of Helsinki and was approved by the Institutional Board of Seoul National University Hospital.

Anthropometric measurements

Anthropometric measurements were performed on subjects wearing light hospital gowns without shoes. Body weight was measured to the nearest 0.1 kg, and height was assessed to the nearest 0.1 cm by using a wall-mounted stadiometer. BMI was calculated by dividing weight (kg) by the square of height (m^2) categorized as follows: normal to overweight group (BMI <25 kg/m^2) and obese group (BMI ≥25 kg/m^2). With the subject in a standing position, the WC was taken at the midline between the lower border of the rib cage and iliac crest to the nearest 0.1 cm after a normal expiration.

Measurement of adipose tissue areas and SAD by CT

Measurement of abdominal adipose tissue areas. The technique used for adipose tissue area measurements in CT cross-sectional images has been previously described (18). Briefly, the subjects were examined with a 16-detector row CT scanner (Somatom Sensation 16; Siemens Medical Solutions, Forchheim, Germany) in a supine position. The area was measured with commercially available CT software (Rapidia 2.8; INFINITT, Seoul, Korea), which electronically determined the adipose tissue area by setting the attenuation values for a region of interest within a range of −250 to −50 Housefield units.

Measurement of SAD and TAD. SAD was determined via an electronic measurement using the umbilical CT image, with the cursor extending from skin to skin through the center of the abdomen in the anterior-posterior direction. TAD was defined as the largest spanned width from skin to skin through the center of the abdomen in both lateral directions in the same image. These measurements were determined to the nearest 0.1 cm.

Statistical analyses

Statistical analyses were conducted separately for men and women because of known differences in adiposity. Data are presented as means and SDs. To compare differences between sex groups, the Student *t* test and Mann-Whitney *U* test were performed. Age-adjusted correlation coefficients between the abdominal adipose tissue compartments (SAT and VAT) and the anthropometric measures (SAD, TAD, BMI, and WC) were calculated for each group. The independent relationship between anthropometric measures and abdominal adipose tissue compartment was examined by multiple regression analysis and determination of the standardized correlation coefficients. In the multiple regression models, we included additional variables with a known or probable association with abdominal obesity, such as age, smoking, alcohol, diabetes, hyperlipidemia, medication history, and menopausal status. Analyses were performed using the Statistical Package for the Social Sciences (version 12.0; SPSS, Chicago, IL). A two-tailed *P* value of <0.05 was considered statistically significant.

RESULTS

— Clinical characteristics of the enrolled population are presented in Table 1. The mean age of this population was 51.1 ± 9.6 years and 63.9% were men. Table 2 gives correlations adjusted for age and additional variables between anthropometric measures and adipose tissue compartments in each sex. All anthropometric measures were statistically correlated to VAT and SAT in both sex groups. Compared with other variables, SAD was more strongly correlated to VAT in both sexes (men: $r = 0.804$, women: $r = 0.724$). In contrast, WC showed stronger correlations to SAT than to VAT in all groups. Particularly in women, TAD showed a statistically stronger correlation to SAT than the correlation of WC to SAT.

We divided the total population into younger and older age-groups using a 50-year-old cutoff point, and anthropometric and adipose tissue characteristics of the subject are presented in Table 3. All variables were statistically significantly higher in the older women than in the younger women. In contrast, the older men had statistically significantly more VAT but less SAT than the younger men, and only TAD and BMI were significantly lower in the older men, like SAT. Table 4 shows the correlations between anthropometric measures and adipose tissue compartments according to age in both sex groups. SAD was presented the highest correlation coefficients for VAT in both sexes and in both age-groups, whereas WC showed stronger correlations with SAT than with VAT. The correlations of anthropometric measures to adipose tissue after subdividing into two groups on the basis of BMI within both sexes are shown in Table 5. SAD showed the strongest correlation to VAT in both normal/overweight and obese groups within both sexes. In addition, WC was more highly correlated to SAT than to VAT in all the subgroups. TAD showed a stronger correlation to SAT than the correlation of WC to SAT in all subgroups of women.

CONCLUSIONS

— The aim of the present study was to evaluate the usefulness of SAD in predicting visceral obesity by comparing SAD to WC, BMI, and TAD. The results showed that SAD strongly correlated to VAT irrespective of age, sex, the degree of obesity, and other metabolic risks compared with other anthropometric measures.

SAD reflected VAT most accurately in all subjects and both sex groups. Van der Kooy et al. (13) reported that SAD more strongly correlated with VAT in men,

Table 1—*Clinical characteristics of the study population*

	Total	Men	Women
n	5,100	3,259	1,841
Age (years)	51.1 ± 9.6 (26–84)	51.0 ± 9.6 (26–84)	51.3 ± 9.6 (26–80)
Diabetes (%)	7.5	9.6	3.9*
Diabetes medication (%)	6.0	7.7	3.1*
Hypertension (%)	20.8	23.5	16.2*
Hypertension medication (%)	17.5	19.7	13.5*
Smoking (%)			
Current	30.7	45.4	4.7*
Former	22.2	32.5	3.8*
Never	47.1	22.1	91.5*
Alcohol consumption (%)	19.9	29.9	2.2*
Postmenopausal (%)			51.1
Hormone replacement therapy (%)			11.8
BMI (kg/m^2)	23.97 ± 3.00 (14.3–42.0)	24.81 ± 2.70 (15.5–42.0)	22.49 ± 2.92 (14.3–36.9)*
Waist circumference (cm)	85.79 ± 8.14 (61.0–129.0)	88.18 ± 7.21 (61.0–129.0)	81.57 ± 7.97 (61.0–118.0)*
Systolic blood pressure (mmHg)	117.5 ± 14.3 (74–186)	119.5 ± 13.4 (83–186)	113.7 ± 15.2 (74–163)*
Diastolic blood pressure (mmHg)	75.9 ± 11.4 (36–120)	78.5 ± 10.7 (46–120)	71.3 ± 11.1 (36–113)*
Total cholesterol (mg/dl)	193.0 ± 34.0 (88–393)	192.1 ± 33.8 (88–321)	194.7 ± 34.2 (98–393)*
Triglycerides (mg/dl)	119.7 ± 76.9 (32–1,222)	134.9 ± 84.4 (32–1,222)	92.7 ± 51.6 (32–863)*
HDL cholesterol (mg/dl)	53.1 ± 13.7 (18–128)	49.4 ± 12.1 (18–128)	59.6 ± 14.1 (26–126)*
Lipid-lowering medication (%)	7.7	8.4	6.5†
Fasting glucose (mg/dl)	97.1 ± 20.2 (56–330)	100.5 ± 21.8 (61–330)	91.1 ± 15.2 (56–260)*
A1C (%)	6.00 ± 0.72 (4.1–13.4)	6.03 ± 0.80 (4.1–13.4)	5.94 ± 0.56 (4.6–12.6)*
VAT (cm^2)	118.0 ± 55.2 (6.03–445.59)	137.7 ± 51.9 (6.03–445.59)	83.2 ± 42.2 (10.40–269.31)*
SAT (cm^2)	152.5 ± 61.6 (7.30–617.79)	139.4 ± 54.6 (7.30–617.79)	175.8 ± 66.1 (17.43–483.97)*
SAD (cm)	21.5 ± 3.0 (12.61–34.12)	22.6 ± 2.4 (14.53–34.12)	19.3 ± 2.4 (12.61–29.95)*
TAD (cm)	30.7 ± 2.8 (21.71–45.28)	31.4 ± 2.5 (21.94–45.28)	29.6 ± 3.1 (21.71–41.48)*

Data are means ± SD (range) unless otherwise indicated. *$P < 0.001$ men vs. women; †$P < 0.05$ men vs. women.

whereas WC more strongly correlated with VAT in women. However, other previous studies have demonstrated that SAD has a stronger correlation with VAT in women (14,15). It is well known that visceral adiposity increases with age (9). We confirmed that the older men and women had significantly more VAT than the younger group. In the present study, the highest correlations among the four anthropometric measures in both women ≥50 years and <50 years were found between SAD and VAT. SAD was also superior to other measures in predicting visceral obesity in men ≥50 years as well as men <50 years. In other words, SAD was well correlated with VAT in both the younger and older groups, as demonstrated in previous studies (15). When the subjects were divided according to the degree of obesity, SAD showed a consistently stronger correlation with visceral obesity compared with other measures in both the normal/overweight and obese groups; this result was similar to previous studies, which found that SAD predicted VAT in subjects with a wider range of BMIs (12).

Table 2—*Sex-specific age-adjusted and multivariable-adjusted standardized correlation coefficients between anthropometric measures and adipose tissue compartments*

	Men (n = 3,259)		Women (n = 1,841)	
	VAT	SAT	VAT	SAT
SAD				
Age-adjusted	0.804	0.687	0.724	0.724
Multivariable-adjusted	0.798	0.691	0.716	0.732
TAD				
Age-adjusted	0.693	0.742	0.613	0.857
Multivariable-adjusted	0.687	0.744	0.602	0.861
BMI				
Age-adjusted	0.639	0.734	0.617	0.742
Multivariable-adjusted	0.630	0.738	0.606	0.753
WC				
Age-adjusted	0.705	0.789	0.636	0.820
Multivariable-adjusted	0.698	0.796	0.626	0.830

All correlations were statistically significant ($P < 0.001$). Data were multivariable adjusted for age, smoking, alcohol consumption, diabetes, hyperlipidemia, treatment for diabetes, treatment for hyperlipidemia, menopausal status (women only), and hormone replacement therapy (women only).

WC, on the other hand, showed a stronger correlation with SAT than with VAT in both sexes, which was similar to previous studies (3,15,19). We also showed the same results even after subdividing according to age or BMI. Although WC is an easily obtainable index of abdominal obesity, it has not shown any superiority to SAD in the correlation with VAT. Since Kvist et al. (12) proposed the usefulness of SAD in the evaluation of visceral obesity, there have been a few stud-

Table 3—*Anthropometric and adipose tissue characteristics of younger and older age-groups*

	Men		Women	
	Age <50 years	Age ≥50 years	Age <50 years	Age ≥50 years
n	1,455	1,804	804	1,037
VAT (cm^2)	133.8 ± 51.5	140.9 ± 52.0*	64.3 ± 33.9	97.9 ± 42.2*
SAT (cm^2)	148.3 ± 61.6	132.3 ± 47.1*	154.6 ± 59.0	192.2 ± 66.7*
SAD (cm)	22.7 ± 2.5	22.6 ± 2.3	18.5 ± 2.3	20.0 ± 2.4*
TAD (cm)	31.7 ± 2.6	31.2 ± 2.4*	28.5 ± 2.7	30.4 ± 3.1*
BMI (cm)	25.05 ± 2.93	24.62 ± 2.48*	21.58 ± 2.81	23.19 ± 2.81*
WC (cm)	88.24 ± 7.69	88.13 ± 6.81	78.49 ± 7.28	83.96 ± 7.65*

Data are means ± SD. *$P < 0.001$, age <50 years group vs. age ≥50 years group.

ies comparing SAD with WC in predicting VAT measured by CT or MRI (13–15). However, besides the small number of study subjects, these studies were limited in that the subjects were not of the general population, because they had enrolled for weight loss treatment (13) or volunteered to participate in other studies (15). The present large-scale, population-based study evaluated SAD by comparing it with WC as a measure of VAT, and we suggest that SAD is a more reliable index of VAT.

According to the anthropometric characteristics of the younger and older age-group in our study, the older men had less SAT and the older women had more SAT. SAT has been reported to decrease with age in men (11), but age-related changes of SAT in women are unclear because some studies have reported the same results with ours (20), whereas others have not (21). Our data demonstrate that WC and TAD reflect SAT in men and women, respectively.

BMI did not reflect regional body fat distribution (22). We were also not able to find any stronger correlations between BMI and VAT or SAT than other anthropometric measures. Regional body fat distribution differs according to ethnicity (10). Although Asians show lower BMI values than Westerners, they have been shown to have a higher percentage of body fat (23). Furthermore, it has been documented that, in subjects with the same WC, Asians have more VAT than Western people (10). For these reasons, the World Health Organization Asia-Pacific Region recommended to modify WC criteria to apply to the Asian population (8). Consequently, each country measured WC and decided its cutoff value for VAT, but the values were too variable to draw an acceptable conclusion, even in the same country (23–25). The reason for this result may be that WC is inappropriate for evaluating VAT in Asians, whose regional body fat distribution is different from that of individuals of the Western population.

Strengths of our study include our sample size, which is large, even after subdividing to explore differences among age and BMI. Also, the data collected were measurements obtained by trained personnel with a systematic protocol, not self-reported measurements. Importantly, based on a screening policy, the subjects in this study are generally regarded to be representative of the general population.

The results of our study are subject to limitation. SAD and TAD were not measured directly; instead, SAD and TAD were measured by CT scans. However, previous studies have shown that SAD measured by anthropometry is an excellent predictor of SAD measured by a CT image (13,14). Also, because there have been few studies within the Asian population, our study has some clinical implications that may introduce the usefulness of SAD as an index of VAT in Asians.

In conclusion, the results of the present study showed that SAD has a stronger correlation to VAT than BMI, WC, and TAD, irrespective of age, sex, and the degree of obesity, whereas WC may have a stronger correlation to SAT than to VAT. From a public health perspective, the clinical use of SAD has ad-

Table 4—*Sex-specific age-adjusted and multivariable-adjusted standardized correlation coefficients between anthropometric measures and adipose tissue compartments according to age in both sexes*

	Men				Women			
	Age <50 years (*n* = 1,455)		Age ≥50 years (*n* = 1,804)		Age <50 years (*n* = 804)		Age ≥50 years (*n* = 1,037)	
	VAT	SAT	VAT	SAT	VAT	SAT	VAT	SAT
SAD								
Age-adjusted	0.807	0.732	0.805	0.661	0.785	0.732	0.741	0.715
Multivariable-adjusted	0.801	0.736	0.799	0.664	0.779	0.737	0.732	0.726
TAD								
Age-adjusted	0.696	0.792	0.693	0.696	0.689	0.848	0.603	0.850
Multivariable-adjusted	0.692	0.793	0.685	0.698	0.685	0.851	0.589	0.855
BMI								
Age-adjusted	0.643	0.768	0.637	0.712	0.712	0.764	0.621	0.738
Multivariable-adjusted	0.637	0.771	0.628	0.715	0.703	0.767	0.607	0.753
WC								
Age-adjusted	0.708	0.829	0.713	0.757	0.706	0.813	0.622	0.797
Multivariable-adjusted	0.702	0.834	0.706	0.764	0.703	0.818	0.609	0.810

All correlations were statistically significant ($P < 0.001$). Data were multivariable adjusted for age, smoking, alcohol consumption, diabetes, hyperlipidemia, treatment for diabetes, treatment for hyperlipidemia, menopausal status (women only), and hormone replacement therapy (women only).

Table 5—*Sex-specific age-adjusted and multivariable-adjusted standardized correlation coefficients between anthropometric measures and adipose tissue compartments according to obesity*

	Men				Women			
	BMI <25 kg/m^2 (n = 1,761)		BMI ≥25 kg/m^2 (n = 1,498)		BMI <25 kg/m^2 (n = 1,513)		BMI ≥25 kg/m^2 (n = 328)	
	VAT	SAT	VAT	SAT	VAT	SAT	VAT	SAT
SAD								
Age-adjusted	0.762	0.576	0.690	0.520	0.652	0.633	0.642	0.525
Multivariable-adjusted	0.758	0.577	0.687	0.527	0.648	0.637	0.632	0.537
TAD								
Age-adjusted	0.587	0.628	0.540	0.622	0.534	0.799	0.372	0.770
Multivariable-adjusted	0.584	0.629	0.542	0.624	0.530	0.800	0.369	0.769
BMI								
Age-adjusted	0.520	0.564	0.404	0.609	0.516	0.657	0.399	0.505
Multivariable-adjusted	0.517	0.563	0.402	0.612	0.512	0.660	0.373	0.521
WC								
Age-adjusted	0.647	0.711	0.515	0.684	0.544	0.743	0.399	0.667
Multivariable-adjusted	0.643	0.715	0.513	0.689	0.542	0.747	0.382	0.697

All correlations were statistically significant ($P < 0.001$). Data were multivariable adjusted for age, smoking, alcohol consumption, diabetes, hyperlipidemia, treatment for diabetes, treatment for hyperlipidemia, menopausal status (women only), and hormone replacement therapy (women only).

vantages over other anthropometric measures in predicting VAT.

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