Original Article

Relationship between Visceral Fat and Cardiovascular Disease Risk Factors: The Tanno and Sobetsu Study

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We assessed the amount of visceral fat using ultrasonography (US) and studied its relationship to cardiovascular disease risk factors, particularly blood pressure. The subjects in the first study were 45 male and 61 female outpatients. We measured the visceral fat area (VFA) of each subject using abdominal CT and waist circumference (WC), and visceral fat distance (VFD) using US. The subjects in the second study were 353 male and 457 female inhabitants of a rural community, for whom VFD and WC were measured. We divided subjects into tertiles based on VFD and WC, and studied the relationship between each group and individual risk factors. In an analysis of outpatient subjects, the correlation coefficient between VFA and VFD was satisfactory: $r=0.660$ for men and $r=0.643$ for women. In the analysis of the rural subjects, the high VFD group had a significantly higher odds ratio than the low VFD group in high blood pressure (HBP) and hypertriglyceridemia (HTG) for men and in HBP, HTG and low high-density lipoprotein cholesterolemia (LHDL) for women. Moreover, adjusting VFD for body mass index revealed that, in comparison to WC, VFD was significantly related to risk factors. VFD was used as an independent variable in multiple regression analysis with blood pressure level as a dependent variable; no significant association between WC and blood pressure was obtained. Visceral fat assessment by US may be useful for epidemiological study and for clinics with no abdominal CT equipment for identifying high-risk individuals, such as those with metabolic syndrome. (*Hypertens Res* 2007; 30: 229–236)

***Key Words*: ultrasonography, visceral obesity, cardiovascular disease risk factors, waist circumference, hypertension**

Introduction

Obesity is often complicated by arteriosclerotic diseases such as hypertension, ischemic heart disease and cerebrovascular disease as well as by their risk factors (*1*, *2*). Since the late 1980s, these complications have been explained by the concept of a multiple risk factor syndrome such as syndrome X (*3*), the deadly quartet (*4*), and visceral fat syndrome (*5*). More recently, the term metabolic syndrome (MS) has been adopted by the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATPIII) (*6*). Visceral obesity, in which fat markedly accumulates in the peritoneal mesentery and around the greater omentum, is thought to be a fundamental pathology for MS in particular. The incidence of cardiovascular disease is high even in non-obese individuals with a body mass index (BMI) within the normal range who have an accumulation of visceral fat (*7*), and accurate assessment of both body fat distribution and visceral fat accumulation is critical for assessing the risk of arteriosclerotic disease.

Previous studies have shown that waist-to-hip ratio, waist-to-height ratio, waist circumference (WC), and visceral fat

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assessed by abdominal CT are relatively good indicators of the risk of cardiovascular disease (*8–13*). Abdominal CT enables quantification of the visceral fat area (VFA) and therefore serves as the gold standard for visceral fat assessment. On the other hand, WC measurement is recommended as a simpler and easier screening method (*14*). However, abdominal CT has drawbacks, including exposure to radiation, lack of ease and simplicity, and high cost. WC includes subcutaneous fat, and WC measurement therefore has drawbacks such as an inability to account for an individual's height and a low level of reproducibility in the case of marked obesity.

Simple methods for assessing visceral fat accumulation using ultrasonography (US) have been studied in recent years (*15–20*). In addition, previous studies have indicated a relationship between hypertension and visceral fat assessed by abdominal CT and WC, but US was not used in any of those studies (*21–24*). Thus, in the present study, we assessed the usefulness of visceral fat assessment by US in outpatients. Then, based on the results of a cross-sectional study, we assessed the relationships between abdominal obesity determined by US and cardiovascular disease risk factors, particularly blood pressure levels.

Methods

Study 1

The subjects were 45 men and 61 women outpatients (mean ages: 55.4±19.4 years for men and 67.5±10.8 years for women). Individuals with cardiovascular disease, renal disease or a severe debilitating disease were excluded from participation. Height, body weight, WC, VFA and total fat area (TFA) were determined by abdominal CT, and visceral fat distance (VFD) was determined by US. The subcutaneous fat area (SFA) was calculated by subtracting VFA from TFA.

Informed consent was obtained from each outpatient, who completed a form consenting to testing. Height, body weight and visceral fat levels were measured on the same day, and BMI was calculated. Correlations between VFA, SFA, VFD, BMI and WC were investigated.

Measurement of Visceral Fat Levels

CT equipment from Toshiba Medical Systems (Tokyo, Japan) was used for abdominal CT. Imaging was done at the end of expiration at the umbilical level. Tracing in cross-sectional images was done using a trackball; the total cross-sectional area was determined by automatic calculation of portions with a CT number of −200 to 1,000 Hounsfield units (HU) using the method of Grauer *et al*. (*25*). In addition, portions with a CT number of −200 to −10 HU were separated as adipose tissue and their areas were automatically calculated.

WC was measured with non-stretchable measuring tape while subjects bared the circumference of the abdomen. The umbilical circumference was measured in increments of 0.1 cm during expiration while standing (*14*).

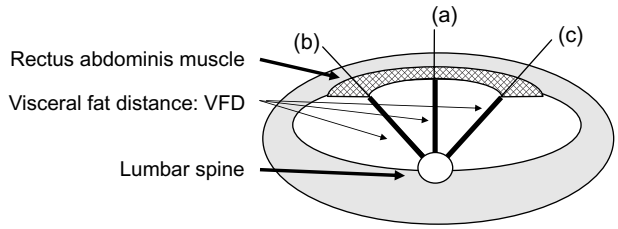

Fig. 1. *VFD was measured between the peritoneum and the lumbar spine, and which was taken as the average value. VFD = (*a + b + c*)/3. Each subject assumed a supine position, and at the end of expiration the distance from the peritoneum to the front of the vertebral body was measured perpendicularly three times with a 3.5 MHz linear probe while making the slightest contact possible, and the average value was used as the VFD.*

VFD was measured using VF-750XT portable ultrasonography equipment (Fukuda Electrical, Tokyo, Japan) by the method of Stolk *et al*. (*18*, *19*). That is, each subject assumed a supine position, and at the end of expiration the distance from the peritoneum to the front of the vertebral body was measured perpendicularly three times with a 3.5 MHz linear probe while making the least possible amount of contact, and the average value was used as the VFD (Fig. 1). All measurements were performed by the same investigator.

Study 2

The subjects were 353 men and 457 women (mean ages: 62.8±12.2 years for men and 57.8±12.6 years for women) out of 1,455 individuals who underwent screening for local residents of a rural community; individuals being treated for hypertension, diabetes or hyperlipidemia were excluded. The study was approved by the Ethics Committee of Sapporo Medical University, and written informed consent was obtained from each subject.

For all subjects, height and body weight were measured after fasting for 8 h or longer since their last meal, blood pressure levels were measured and blood samples were taken. The blood samples were used to measure high-density lipoprotein (HDL)–cholesterol levels (HDL-c), triglyceride levels (TG), fasting plasma glucose levels (FPG) and serum insulin levels. Afterwards, WC and VFD were measured. Height and body weight were measured at intervals of 0.1 cm and 0.1 kg, respectively, with subjects lightly dressed and shoes removed. Blood pressure was measured twice consecutively on the upper arm using an automated sphygmomanometer (HEM-907, Omron Instruments, Tokyo, Japan) with subjects in a seated resting position, and the average was used for systolic blood pressure (SBP) and diastolic blood pressure (DBP).

Table 1. Characteristics of the Subjects for Study 1

	Men (n=45)	Women (n=61)	p-value
Age (years)	55.4±19.4	67.5±10.8	<0.001
Body weight (kg)	67.1±11.8	56.4±8.8	<0.001
BMI (kg/m^2)	24.2±3.2	24.7±3.9	0.462
Lean: BMI<22	11/45 (24%)	14/61 (23%)	
Overweight: 22≤BMI<25	17/45 (38%)	23/61 (38%)	
Obese: 25≤BMI	17/45 (38%)	24/61 (39%)	
WC (cm)	84.9±8.8	85.6±10.1	0.787
VFD (cm)	5.2±1.2	4.9±1.43	0.459
SFA (cm^2)	147.0±63.8	221.2±132.4	<0.001
VFA (cm^2)	137.0±62.6	128.9±51.8	0.606

All values are mean±SD. BMI, body mass index; WC, waist circumference; VFD, visceral fat distance; SFA, subcutaneous fat area; VFA, visceral fat area.

Table 2. Correlation between Adipose Tissue Measured by CT and Other Anthropometric Parameters

	Adipose tissue measured by CT	
	SFA	VFA
Men (n=45)		
BMI	0.763*	0.565*
WC	0.861*	0.646*
VFD	0.237	0.660*
Women (n=61)		
BMI	0.591*	0.571*
WC	0.595*	0.499*
VFD	0.289**	0.643*

Values are Pearson's correlation coefficients. *p<0.001, **p<0.05. SFA, subcutaneous fat area; VFA, visceral fat area; BMI, body mass index; WC, waist circumference; VFD, visceral fat distance.

Measurement Methods

HDL-c was measured by the enzymatic method (homogenous), TG was measured by the enzymatic colorimetric method (free glycerol elimination), FPG was measured by the GOD immobilized oxygen electrode maximum reaction acceleration method, and serum insulin level was measured by the enzyme immunoassay method. In addition, homeostasis model assessment index (HOMA-IR) was calculated on the basis of FPG and serum insulin levels (*26*).

Diagnostic Criteria for Cardiovascular Disease Risk Factors

Diagnostic criteria for cardiovascular disease risk factors followed the NCEP ATPIII criteria for MS (*6*). High blood pressure (HBP) was defined as SBP ≥130 mmHg and/or DBP ≥85 mmHg or higher, hypertriglyceridemia (HTG) was defined as TG ≥150 mg/dl, low HDL cholesterolemia (LHDL) was defined as HDL-c <40 mg/dl for men and <50 mg/dl for women, and high fasting plasma glucose (HFPG) was defined as FPG ≥110 mg/dl.

Statistical Analysis

Statistical analysis was done using Windows SPSS version 11.5J. Numerical values are shown as means (mean)±SD. The correlation between two variables was evaluated using Pearson's correlation coefficient. Comparison between two groups was done with an unpaired t-test. For logistic regression analysis, subjects were divided into tertiles based on VFD and WC, adjusted for age (model 1) and then adjusted for age and BMI (model 2); with the low VFD and low WC groups as a reference, odds ratios (OR) and individual cardiovascular disease risk factors were examined. Comparison of three groups was done by multiple comparisons after one-way ANOVA. For multiple regression analysis, blood pressure level served as a dependent variable, and the relationships between cardiovascular disease risk factors with VFD and WC were studied. In all instances, the level of significance was p<0.05.

Results

Study 1

Table 1 shows characteristics of the 45 male and 61 female outpatient subjects whose visceral fat levels were measured by abdominal CT. No significant difference between the male and female subjects was found in BMI, WC, VFD or VFA. SFA was significantly larger for women than for men.

The correlations between SFA and VFA determined by abdominal CT and BMI, VFD and WC are shown in Table 2. The correlation coefficients between VFA and VFD were r=0.660 (p<0.001) for men and r=0.643 (p<0.001) for women. In addition, VFA had a stronger correlation to VFD than to BMI or WC. Moreover, BMI and WC had stronger

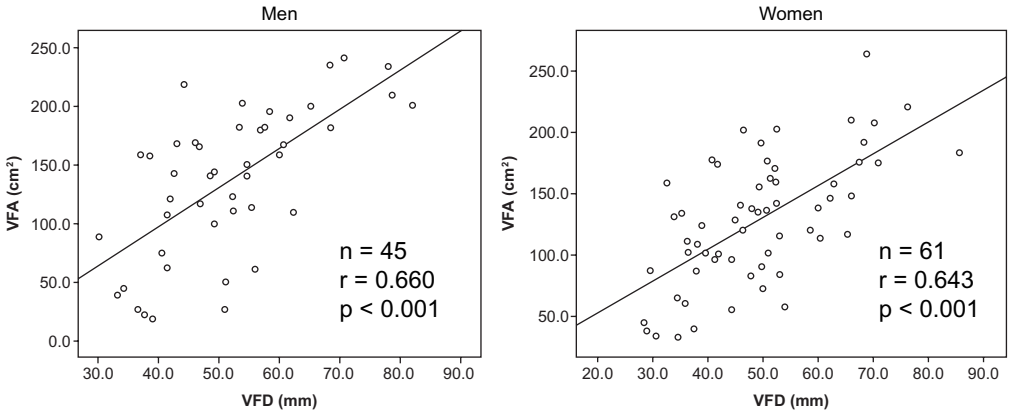

Fig. 2. *Scattergrams of relationship between VFD and VFA for men and women. VFD, visceral fat distance assessed by ultrasonography; VFA, visceral fat area assessed by CT. There were significant positive correlations between VFD and VFA in both men and women.*

Table 3. Characteristics of the Study Subjects of Residents of a Rural Community

	Men (n=353)	Women (n=457)	p-value
Age (years)	62.8±12.2	57.8±12.6	<0.001
Body weight (kg)	63.9±10.1	53.7±7.6	<0.001
BMI (kg/m^2)	23.7±3.2	23.0±3.2	0.002
Lean: BMI<22	107/353 (30%)	177/457 (39%)	
Overweight: 22≤BMI<25	143/353 (41%)	171/457 (37%)	
Obese: 25≤BMI	103/353 (29%)	109/457 (24%)	
WC (cm)	84.7±9.1	82.6±9.9	0.002
VFD (cm)	5.5±1.7	4.7±1.3	<0.001
SBP (mmHg)	131.9±20.1	127.0±21.2	0.001
DBP (mmHg)	75.5±11.6	71.9±10.6	<0.001
HDL-c (mg/dl)	51.3±11.7	59.3±14.5	<0.001
TG (mg/dl)	115.1±75.2	88.3±49.2	<0.001
FPG (mg/dl)	96.8±15.7	94.4±17.7	0.041
Serum insulin levels (μU/ml)	4.5±4.7	4.4±2.9	n.s.
HOMA-IR	1.13±1.38	1.04±0.72	n.s.

All values are mean±SD. BMI, body mass index; WC, waist circumference; VFD, visceral fat distance; SBP, systolic blood pressure; DBP, diastolic blood pressure; HDL-c, high-density lipoprotein-cholesterol; TG, triglyceride; FPG, fasting plasma glucose; HOMA-IR, homeostasis model assessment index; n.s., not significant.

correlations to SFA than to VFA (Table 2).

Figure 2 shows scattergrams of the relationships between VFD and VFA for men and women. There were significant positive correlations between VFD and VFA in both sexes.

Study 2

Table 3 shows the characteristics of the subjects in Study 2. Average VFDs were 5.5±1.7 cm for men and 4.7±1.3 cm for women, and average WCs were 84.7±9.1 cm for men and 82.6±9.9 cm for women.

The subjects were divided into tertiles based on VFD and WC; OR for cardiovascular disease risk factors with individual low-tertile groups as a reference are shown in Table 4. Adjusted only for age (model 1), OR increased significantly for the male VFD group in comparison to that for the low VFD group in HBP (OR: 3.45 [95% CI: 1.83–5.77]; p<0.001) and HTG (OR: 3.74 [1.72–8.12]; p<0.05), and it increased significantly for the female group in HBP (OR: 2.31 [1.37–3.92]; p<0.05), HTG (OR: 13.3 [3.02–58.5]; p<0.05) and LHDL (OR: 4.62 [2.47–8.62]; p<0.001). Similarly, OR increased significantly for the male WC group in comparison to that for the low WC group in HBP (OR: 2.00 [1.15–3.45]; p<0.05), HTG (OR: 3.09 [1.41–6.75]; p<0.05) and LHDL (OR: 8.82 [1.98–39.3]; p<0.05), and it increased significantly for the female group in HBP (OR: 1.95 [1.18–3.23];

Table 4. Odds Ratios and 95% CIs of CAD Risk Factors by Tertile of VFD and WC

	HBP	HTG	HFPG	LHDL
Men (n=353)				
Model 1				
VFD				
Lower tertile	1.00	1.00	1.00	1.00
Middle tertile	1.79 (1.04–3.09)*	2.31 (1.04–5.16)*	1.04 (0.4–2.44)	1.95 (0.83–4.59)
Upper tertile	3.45 (1.83–5.77)†	3.74 (1.72–8.12)*	0.80 (0.32–2.00)	2.02 (0.85–4.77)
WC				
Lower tertile	1.00	1.00	1.00	1.00
Middle tertile	2.10 (1.22–3.59)*	3.41 (1.56–7.44)*	0.79 (0.32–1.99)	16.4 (3.79–71.1)†
Upper tertile	2.00 (1.15–3.45)*	3.09 (1.41–6.75)*	1.26 (0.54–2.96)	8.82 (1.98–39.3)*
Model 2				
VFD				
Lower tertile	1.00	1.00	1.00	1.00
Middle tertile	1.67 (0.95–2.95)	2.21 (0.97–5.04)	0.88 (0.36–2.13)	1.71 (0.71–4.14)
Upper tertile	2.75 (1.37–5.50)*	3.35 (1.35–8.32)*	0.52 (0.17–1.62)	1.44 (0.52–4.04)
WC				
Lower tertile	1.00	1.00	1.00	1.00
Middle tertile	1.60 (0.86–2.96)	3.09 (1.31–7.31)*	0.71 (0.25–1.96)	17.6 (3.77–82.2)†
Upper tertile	1.15 (0.51–2.59)	2.54 (0.87–7.41)	1.00 (0.29–3.46)	10.1 (1.75–58.1)*
Women (n=457)				
Model 1				
VFD				
Lower tertile	1.00	1.00	1.00	1.00
Middle tertile	1.76 (1.04–2.98)*	6.28 (1.38–28.6)*	0.52 (0.16–1.72)	2.32 (1.23–4.38)*
Upper tertile	2.31 (1.37–3.92)*	13.3 (3.02–58.5)*	1.82 (0.71–4.69)	4.62 (2.47–8.62)†
WC				
Lower tertile	1.00	1.00	1.00	1.00
Middle tertile	1.05 (0.63–1.76)	3.79 (1.21–11.8)*	1.10 (0.43–2.82)	2.72 (1.52–4.86)*
Upper tertile	1.95 (1.18–3.23)*	5.79 (1.93–17.4)*	0.93 (0.37–2.34)	2.46 (1.36–4.43)*
Model 2				
VFD				
Lower tertile	1.00	1.00	1.00	1.00
Middle tertile	1.27 (0.73–2.22)	4.59 (0.99–21.3)	0.56 (0.16–1.92)	1.91 (0.99–3.70)
Upper tertile	1.06 (0.55–2.04)	6.36 (1.30–31.3)*	2.16 (0.67–6.92)	2.94 (1.40–6.17)*
WC				
Lower tertile	1.00	1.00	1.00	1.00
Middle tertile	0.65 (0.37–1.15)	2.37 (0.73–7.73)	0.90 (0.32–2.47)	1.78 (0.95–3.33)
Upper tertile	0.74 (0.37–1.45)	2.06 (0.56–7.57)	0.60 (0.17–2.05)	0.97 (0.45–2.09)

Model 1: adjusted for age; Model 2: adjusted for age and BMI. Significantly different from the Lower tertile: *$p<0.05$, †$p<0.001$. CI, confidence interval; CAD, cardiovascular disease; HBP, high blood pressure; HTG, hypertriglyceridemia; HFPG, high fasting plasma glucose; LHDL, low high-density lipoprotein cholesterolemia; VFD, visceral fat distance; WC, waist circumference.

$p<0.05$), HTG (OR: 5.79 [1.93–17.4]; $p<0.05$) and LHDL (OR: 2.46 [1.36–4.43]; $p<0.05$).

When additionally adjusted for BMI (model 2), OR increased significantly for the male VFD group in comparison to that for the low VFD group in HBP (OR: 2.75 [1.37–5.50]; $p<0.05$) and HTG (OR: 3.35 [1.35–8.32]; $p<0.05$). However, no significant association was found between WC and HBP or between WC and HTG. In addition, OR increased significantly for the female high VFD group in comparison to that for the low VFD group in HTG (OR: 6.36 [1.30–31.3]; $p<0.05$) and LHDL (OR: 2.94 [1.40–6.17]; $p<0.05$). However, no significant association was found between WC and any of the factors.

Table 5 shows the results of multiple regression analysis with SBP and DBP as dependent variables. For men, VFD was selected as a significant independent variable for both SBP and DBP. However, there was no significant association between WC and SBP or between WC and DBP.

Table 5. Results of Multiple-Regression Analysis Related to SBP and DBP

	Independent	Dependent			
		SBP		DBP	
		β	*p*-value	β	*p*-value
Men (n=353)	VFD	2.093	0.015	1.049	0.047
	WC	0.287	0.226	0.163	0.265
Women (n=457)	VFD	1.422	0.118	0.739	0.154
	WC	0.110	0.425	−0.057	0.466

Dependent variables: systolic blood pressure (SBP) or diastolic blood pressure (DBP). Independent variables: visceral fat distance (VFD) or waist circumference (WC) and additionally adjusted for age, triglyceride (TG), high-density lipoprotein-cholesterol (HDL-c), fasting plasma glucose (FPG), body mass index (BMI). β: standardized regression coefficient.

Although the data are not shown, when VFD was divided into tertiles, HOMA-IR increased significantly in the higher tertiles. Moreover, in multiple regression analysis using HOMA-IR as a dependent variable and using age, SBP, TG and VFD as independent variables, VFD was found to be a significant independent variable of HOMA-IR for both men and women.

Discussion

The significance of visceral obesity has been noted in recent years, and the accumulation of visceral fat must be accurately assessed. However, abdominal CT is not a simple technique, and WC also has the drawback of leading to an assessment that includes subcutaneous fat. In contrast, US involves no radiation exposure, the technique can be quickly learned, it is typically completed in less than 5 min, and it has been reported to have a good level of reproducibility (*15–20*). In the present study we therefore investigated whether US can be used as an easy screening method for the accurate estimation of the accumulation of visceral fat in Japanese as well.

When the correlations between VFA, SFA, BMI, VFD and WC were examined, VFD was found to have a stronger positive correlation with VFA than with SFA for both men and women. Additionally, BMI and WC each had a stronger positive correlation with SFA than with VFA. This is because measurements of BMI and WC are assessment methods that include elements of subcutaneous fat. The present study indicated that VFD measurement is a simple method for assessing visceral fat that does not include elements of subcutaneous fat and that VFD measurement is a useful means of assessing visceral fat in a large number of subjects.

The relationships between visceral fat and cardiovascular disease risk factors were then assessed in a study using US performed on inhabitants of a rural community who were not being treated for hypertension, diabetes or hyperlipidemia. The data presented in Table 4, obtained after adjustment for age and BMI (model 2), showed that VFD was significantly correlated with HBP, HTG and LHDL in men and with HTG and LHDL in women. On the other hand, WC was correlated with LHDL in men but showed only weak correlations with risk factors in women.

What eliminated the relationship between WC and cardiovascular disease risk factors in women subjects in particular was the effect of subcutaneous fat. Subcutaneous fat has less of an effect on arteriosclerosis than visceral fat and instead has antiarteriosclerotic action (*27*). In general, visceral obesity, a condition in which visceral fat readily accumulates, affects men more than women; women are affected by female sex hormones and exhibit body types that feature subcutaneous obesity (*28*, *29*). Thus, in assessment by BMI and WC, the effects of subcutaneous fat are more intensely reflected in women than in men. This fact is supported by the stronger correlation of BMI and WC to SFA than to VFA in the study of outpatient cases (Study 1).

We could not find a significant association between FPG and a rise in VFD or WC for either men or women. The reasons are threefold. First, individuals on medication for type 2 diabetes were excluded in this study and, second, the study was conducted in a homogenous population with a relatively low FPG. Third, we could not find participants with impaired glucose tolerance (IGT) because we did not conduct oral glucose tolerance test (OGTT) in this study. Thus, there was a small number of participants with high FPG and there was no significant relationship between FPG and VFD for either men or women.

The results of multiple regression analysis showed that VFD was an independent explanatory variable of blood pressure in men. No significant relationship was found between WC and blood pressure in men or women. VFD may be a good indicator of blood pressure in men. Moreover, VFD may also be a useful index for the management of blood pressure in men with metabolic syndrome.

In a state of visceral fat accumulation, it is thought that free fatty acid produced by the decomposition of TG flows into the liver and induces insulin resistance. Moreover, substances that induce insulin resistance such as tumor necrosis factor (TNF)-α are produced from visceral fat. Studies have indicated the possibility that elevation of blood pressure is induced in a state of insulin resistance by various mechanisms *via* adipocytokines (*30*). It has also been reported that compensatory hyperinsulinemia, which occurs in a state of insulin

resistance, plays a role in blood pressure elevation *via* renal mechanisms (*31*).

In multiple regression analysis, no relationship was found between VFD and blood pressure in women. Possible reasons for this are the influence of an autocorrelation due to the addition of BMI to the adjusted items and both the small mean value and the low distribution of VFD in female subjects.

WC measurement is a very useful screening method for assessing visceral fat because it is simple and cheap. It does, however, have drawbacks, such as an inability to assess tall individuals differently than short ones and a low level of reproducibility in the case of marked obesity, since WC includes subcutaneous fat. Therefore, the Japanese criteria of MS recommend assessing real visceral fat accumulation by CT when we find individuals with WC $\geq$85 cm in men and $\geq$90 cm in women. Although abdominal CT is the gold standard for visceral fat assessment, it entails exposure to radiation, lack of ease and simplicity, and high cost. General practitioners may have a good deal of opportunity to assess individuals with MS, but very few physicians have CT equipment in their clinics. Assessment by US is a simpler technique than abdominal CT and allows general practitioners to assess visceral fat accumulation in their clinics. When we find high-risk individuals with an accumulation of risk factors and without abdominal obesity (WC $<$85 cm in men, WC $<$90 cm in women), it is important to confirm their fat distribution by other methods than WC. In such cases, the US method may be useful simply assessing the accumulation of visceral fat.

One limitation of the present study is that all of the subjects were Japanese; thus the results may not apply to Westerners or individuals of certain ethnic groups. The female body type in particular differs between Westerners and Japanese. Nevertheless, diagnostic criteria for WC that take into account ethnicity have been incorporated in the International Diabetes Federation (IDF)'s diagnostic criteria for MS. While there are differences in extent, the relationship between visceral fat accumulation and cardiovascular disease risk factors is universal (*32*, *33*).

No statistical analysis was performed to evaluate the differences in the measured parameters between premenopausal and postmenopausal women in our study group. In general, postmenopausal women tend toward obesity more than premenopausal women, and their blood pressure levels and visceral fat levels are known to increase (*34*, *35*). A study taking this into account is needed in the future. Additionally, the present study involved cross-sectional studies, and additional prospective studies on the relationship between abdominal obesity and elevated blood pressure are needed.

In conclusion, US is a simpler technique than abdominal CT, and its usefulness in visceral fat assessment was demonstrated in the screening of residents of a rural community. VFD is thought to be a good index for assessing not only visceral fat accumulation but also cardiovascular risk factors. Moreover, in men VFD showed a significant correlation with blood pressure. Visceral fat assessment by US may be useful for epidemiological studies and for clinics with no abdominal CT equipment to identify high-risk individuals such as those with metabolic syndrome.

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