Visceral and Central Abdominal Fat and Anthropometry in Relation to Diabetes in Asian Indians

MOHAN ANJANA, MBBS
SREEDHARAN SANDEEP, MBBS
RAJ DEEPA, MPHIL, PHD
KARANI SANTHANAKRISHNAN VIMALESWARAN, MSC
SYED FAROOQ, BSC
VISWANATHAN MOHAN, MD, MRCP, PHD, DSC, FNASC

OBJECTIVE — The objective of the study was to examine body fat distribution using computed tomography (CT), dual-energy X-ray absorptiometry (DEXA), and anthropometry in relation to type 2 diabetes in urban Asian Indians.

RESEARCH DESIGN AND METHODS — This is a case-control study of 82 type 2 diabetic and 82 age- and sex-matched nondiabetic subjects from the Chennai Urban Rural Epidemiology Study, an ongoing epidemiological study in southern India. Visceral, subcutaneous, and total abdominal fat were measured using CT, while DEXA was used to measure central abdominal and total body fat. Anthropometric measures included BMI, waist circumference, sagittal abdominal diameter (SAD), and waist-to-hip ratio.

RESULTS — Visceral and central abdominal fat showed a strong correlation with each other ($P < 0.0001$), and κ analysis revealed a fairly good agreement between tertiles of visceral and central abdominal fat ($\kappa = 0.44$, $P < 0.0001$). Diabetic subjects had significantly higher visceral ($P = 0.005$) and central abdominal ($P = 0.011$) fat compared with nondiabetic subjects. Waist circumference and SAD showed a strong correlation with visceral ($P < 0.01$) and central abdominal ($P < 0.0001$) fat in both diabetic and nondiabetic subjects. Logistic regression analysis revealed visceral (odds ratio [OR] 1.011, $P = 0.004$) and central abdominal (OR 1.001, $P = 0.013$) fat to be associated with diabetes, even after adjusting for age and sex.

CONCLUSIONS — Visceral and central abdominal fat showed a strong association with type 2 diabetes. Both measures correlated well with each other and with waist circumference and SAD in diabetic and nondiabetic urban Asian Indians.

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Asian Indians have an increased susceptibility to type 2 diabetes and insulin resistance compared with Europeans (1–4). Recent studies indicate a rising prevalence of diabetes and insulin resistance in India (5–7). Although obesity is a major contributing factor to diabetes, Asian Indians are known to have lower BMIs than Europeans (8). However, for any given BMI, Asian Indians have greater waist-to-hip ratios and abdominal fat (8,9) than Europeans. There are very few studies on fat distribution in Indians (10,11) and virtually none comparing diabetic and nondiabetic subjects. Thus, the first objective of this study was to measure body fat distribution in Asian Indians in relation to type 2 diabetes.

From the Madras Diabetes Research Foundation & M.V. Diabetes Specialities Centre, Gopalapuram, Chennai, India.

Address correspondence and reprint requests to Professor Viswanathan Mohan, MD, MRCP, PhD, DSc, FNASc, Director of M.V. Diabetes Specialities Centre & Madras Diabetes Research Foundation, 4 Conran Smith Rd., Gopalapuram, Chennai 600 086, India. E-mail: mvdsc@vsnl.com.

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Abbreviations: CURES, Chennai Urban Rural Epidemiology Study; CT, computed tomography; DEXA, dual-energy X-ray absorptiometry; SAD, sagittal abdominal diameter.

A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.

Computed tomography (CT) is widely used to assess visceral fat (12–14). Dual-energy X-ray absorptiometry (DEXA) is usually used to measure total body fat (15) but recently has also been used to measure central abdominal fat (16). The association of visceral fat measured by CT and central abdominal fat measured by DEXA has not been studied in an Asian-Indian population, and their relationship with anthropometric variables is also not clear. Thus, the second objective of our study was to correlate visceral and central abdominal fat with each other and with anthropometric parameters.

RESEARCH DESIGN AND METHODS

— This is a case-control study of diabetic and nondiabetic subjects selected from the Chennai Urban Rural Epidemiology Study (CURES), an ongoing epidemiological study in Chennai (formerly Madras) in southern India. The methodology of CURES is published elsewhere (17). In phase 1 of CURES, 26,001 individuals were recruited using a systematic random sampling technique. Self-reported diabetic subjects were classified as "known diabetic subjects." In phase 2 of CURES, all known diabetic subjects were invited to our center for detailed studies. In addition, every tenth subject recruited in phase 1 was brought to the center for an oral glucose tolerance test using 75-g glucose load (except known diabetic subjects). Based on World Health Organization consulting group criteria (18), those with 2-h plasma glucose ≥11.1 mmol/l (200 mg/dl) were labeled as "newly detected diabetic subjects." For this study, the known and newly detected diabetic subjects together formed the "diabetic group." Those with fasting plasma glucose values <6.1 mmol/l (<110 mg/dl) and 2-h postload plasma glucose values <7.8 mmol/l (140 mg/dl) formed the "nondiabetic group." Using computer-generated random numbers, 82 diabetic and 82 age- and sex-matched nondiabetic subjects were selected. The diabetic

group had 52 known and 30 newly diagnosed diabetic subjects.

Sample size calculation

A pilot study was conducted on 30 (15 diabetic and 15 nondiabetic subjects) randomly chosen subjects, and the mean (±SD) visceral fat by CT was found to be 142 ± 53 cm^2. The sample size for the present study was calculated based on the following statistical assumptions: to determine a significant difference of 25 cm^2 in visceral fat between diabetic and nondiabetic subjects with a type 1 error of 0.05, a power of 85%, SD 53, and the ratio of case to control being 1. The sample size required was calculated to be 82 (PS, Power and Sample Size Calculations, version 2.1.30). Thus, 82 diabetic and 82 age- and sex-matched nondiabetic subjects were recruited. The study was approved by the institutional ethical committee, and informed consent was obtained from all study subjects.

DEXA and CT scans

Both these procedures were done on the same day by two different observers at the Bharat Scans, Chennai, a specialized center for imaging and radiological studies. Both the observers and the radiologist who interpreted the scans were unaware of the clinical status of the study subjects.

CT scan procedure. Subcutaneous and visceral fat were measured using a Helical CT scan (General Electric, Milwaukee, WI). The scans were done at 120 kV, 200–250 mAs**.** Subjects were requested to lie in the supine position with their arms above their head and legs elevated with a cushion. A single scan (10 mm) of the abdomen was done at the level of L4-L5 vertebrae and analyzed for a cross-sectional area of adipose tissue, which was expressed in centimeters squared. Areas were calculated by multiplying the number of pixels of a given tissue type by the pixel number (pixel density). The external contour of the waist was determined using a threshold of −160 HU (Hounsfield Unit), and the external bone contours were derived at −30 HU. The parameters studied included visceral, subcutaneous, and total abdominal fat. Visceral fat was distinguished from subcutaneous abdominal fat by tracing along the fascial plane defining the internal abdominal wall.

DEXA procedure. The machine used was a Lunar Prodigy (Model 8743-BX/1L; GE Lunar, Madison, WI). Subjects were scanned in light clothing while lying supine with arms by their sides, and total body and abdominal fat were measured. Central abdominal fat was calculated by the construction of an abdominal window as described by Carey et al. (16). The upper margin of this window was fixed at the lower border of the second lumbar vertebra (L2) and the lower margin at the lower border of the fourth lumbar vertebra (L4). The lateral margins were fixed in alignment with the outer edges of the ribcage so as to exclude most of the lateral subcutaneous fat.

Both CT and DEXA were repeated on 10 individuals (5 nondiabetic and 5 diabetic) after a period of 1 week. Test-retest variability for body fat measurements was less than 5%. Height was measured to the nearest centimeter with subjects standing upright without shoes. Weight was measured with an electronic weighing balance to the nearest 0.5 kg, and BMI was calculated based on weight in kilograms divided by the square of height in meters. Waist was measured using a nonstretchable tape with participants standing erect. One layer of clothing was accepted. Waist girth was measured as the smallest horizontal girth between the costal margins and the iliac crests at the end of normal expiration. Hip was measured as the greatest abdominal circumference at the level of greater trochanters. Measurements were made to the nearest centimeter. Waist-to-hip ratio was calculated by dividing the waist by the hip circumference.

Sagittal abdominal diameter (SAD), defined as the distance between the anterior wall of the abdomen and back, was measured with a portable sliding-beam abdominal caliper (Holtain-Kahn abdominal caliper; Holtain, Dyfed, Wales) with the subject lying supine on the examination table. The caliper's lower blade was placed under the individual's back and the upper blade was lowered to a mark midway between the iliac crest, a location that approximates the level of the L4-L5 interspace. SAD was measured as the distance between the blades of the caliper at the end of normal expiration (19).

Blood pressure was recorded to the nearest 2 mmHg in the sitting position in the right arm with a mercury sphygmomanometer (Diamond Deluxe BP apparatus; Industrial Electronic and allied products, Pune, India). A trained observer, who was unaware of the clinical status of the subjects, recorded the blood pressure. The first and the fifth Korotkoff's sounds were used to define systolic and diastolic blood pressure, respectively. Two readings were taken 5 min apart, and the mean of the two was calculated. Variations in blood pressure measurements were minimized by *1*) ensuring 10-min rest before the recording, *2*) using appropriate adult cuffs for lean and overweight individuals, and *3*) having the same observer recording blood pressure.

Fasting plasma glucose (glucose oxidase-peroxidase method) was measured on Hitachi 912 Autoanalyzer (Hitachi, Mannheim, Germany) using kits supplied by Roche Diagnostics (Mannheim, Germany). HbA_{1c} was estimated by high-pressure liquid chromatography using the Variant machine (Bio Rad, Hercules, CA).

Statistical analysis

Student's *t* test was used to compare groups for continuous variables. χ^2 test or Fisher's exact test, as appropriate, was used to compare proportions. Pearson correlation analysis was done to determine the correlation between the fat measures and other risk variables. The agreement between the tertiles of visceral and central abdominal fat was determined using κ statistics. Multiple logistic regression analysis was done using diabetes as the dependent variable and various fat measures and anthropometric variables as independent variables. All analyses were done using Windows-based SPSS Statistical Package (version 10.0; SPSS, Chicago, IL), and *P* values <0.05 were considered significant.

RESULTS — Table 1 shows the baseline characteristics of the study groups. The diabetic subjects had significantly higher BMI ($P = 0.003$), waist circumference ($P = 0.002$), and SAD ($P < 0.0001$) than nondiabetic subjects. The mean duration of diabetes in known diabetic subjects was 5.5 ± 4.6 years. None had ketonuria or a history of ketoacidosis. Among the 52 known diabetic subjects, 4 (7.7%) were on diet alone, 41 (78.8%) on oral hypoglycemic drugs (21 on sulfonylureas, 12 on metformin, and 8 on a combination of sulfonylurea and metformin), 3 (5.8%) on insulin (after treatment on oral hypoglycemic drugs for at least 5 years), and 4 (7.7%) on a combination of insulin and metformin. Thus, presumably

Table 1—*Clinical, biochemical, and body fat measurements of the study groups*

Parameters	Nondiabetic group	Diabetic group	*P*
n	82	82	
Age (years)	45 ± 9	45 ± 9	—
Men [*n* (%)]	38 (46.3)	38 (46.3)	—
BMI (kg/m^2)	24.0 ± 4.7	26.1 ± 4.2	0.003
Waist circumference (cm)	87.2 ± 11.4	92.3 ± 9.4	0.002
Waist-to-hip ratio	0.91 ± 0.07	0.93 ± 0.06	0.051
SAD (cm)	21.0 ± 2.6	22.6 ± 2.5	<0.0001
Systolic blood pressure (mmHg)	124 ± 16	125 ± 17	0.319
Diastolic blood pressure (mmHg)	78 ± 10	79 ± 11	0.480
Fasting plasma glucose (mmol/l)	4.9 ± 0.5	9.4 ± 3.3	<0.0001
HbA_{1c} (%)	5.6 ± 0.5	9.1 ± 2.1	<0.0001
CT scan			
Total abdominal fat (cm^2)	332.0 ± 135.8	371.4 ± 113.6	0.046
Visceral fat (cm^2)	119.5 ± 53.5	140.5 ± 40.6	0.005
Subcutaneous abdominal fat (cm^2)	208.7 ± 118.6	230.1 ± 97.5	0.210
Visceral–to–subcutaneous abdominal fat ratio	0.64 ± 0.34	0.71 ± 0.33	0.189
Visceral–to–total fat ratio	0.37 ± 0.12	0.38 ± 0.10	0.167
DEXA			
Total body fat (g)	18,635.1 ± 7,715.0	20,121.0 ± 6,743.9	0.191
Abdominal fat (g)	3,765.9 ± 1,613.9	4,312.4 ± 1,270.9	0.017
Central abdominal fat (g)	1,368.4 ± 510.1	1,547.7 ± 371.7	0.011
Nonabdominal fat (g)	14,873.2 ± 6,516.5	15,687.9 ± 6,101.2	0.410
Central–to–total body fat ratio	0.075 ± 0.0.02	0.081 ± 0.02	0.066
Central–to–abdominal fat ratio	0.37 ± 0.07	0.37 ± 0.06	0.585
Body fat (%)	31.3 ± 8.0	31.7 ± 8.0	0.764

Data are means ± SD unless otherwise indicated.

all had type 2 diabetes. A total of 18 (34.6%) diabetic subjects were also known to have hypertension, of whom 14 (77.8%) received antihypertensive therapy (8 on ACE inhibitors, 4 on β blockers, and 2 on calcium channel blockers). Only two of the diabetic subjects were on lipid-lowering drugs (statins). Among nondiabetic subjects, 12 (14.6.%) were known to have hypertension. Of these, nine (75%) were on antihypertensive therapy (four on ACE inhibitors and five on β blockers).

Using CT, total abdominal (P = 0.046) and visceral (P = 0.005) fat were found to be significantly higher among diabetic subjects, while subcutaneous abdominal fat, visceral–to–subcutaneous abdominal fat ratio, and visceral–to–total fat ratio showed no significant difference. Similarly with DEXA, diabetic subjects were found to have significantly higher abdominal (P = 0.017) and central abdominal (P = 0.011) fat, while none of the other parameters showed a significant difference.

When segregated based on sex, women had significantly higher subcutaneous abdominal fat (263.3 ± 117.1 cm^2 for women vs. 168.7 ± 70.3 cm^2 for men, P < 0.0001) and lower visceral fat (121.8 ± 46.8 cm^2 for women vs. 139.6 ± 49.1 cm^2 for men, P = 0.019) than men, while there was no significant difference in central abdominal fat between the sexes (1,423.6 ± 463.2 g for women vs. 1,498.0 ± 442.2 g for men, P = 0.297).

Female diabetic subjects had significantly higher visceral (diabetic: 132.7 ± 37.8 cm^2 vs. nondiabetic: 110.5 ± 45.4 cm^2, P = 0.015) and central abdominal (diabetic: 1,565.7 ± 311.2 g vs. nondiabetic: 1,281.6 ± 544.0 g, P = 0.003) fat than female nondiabetic subjects. In male diabetic and nondiabetic subjects, the difference in visceral fat (149.9 ± 50.2 cm^2 vs. 129.3 ± 39.0 cm^2, respectively, P = 0.049) reached statistical significance while the difference in central abdominal fat (1,527.1 ± 434.0 g vs. 1,469.0 ± 454.3 g, respectively, P = 0.571) did not. There was no significant difference in subcutaneous abdominal fat between diabetic and nondiabetic subjects (data not shown).

Subjects were further categorized based on the median age (44 years). Below the median age-group, diabetic sub-

Table 2 —*Pearson's correlation analysis of visceral fat measured by CT scan and central abdominal fat measured by DEXA with risk variables in the study population*

	Nondiabetic group (n = 82)				Diabetic group (n = 82)			
	Visceral fat		Central abdominal fat		Visceral fat		Central abdominal fat	
Parameters	*r*	*P*	*r*	*P*	*r*	*P*	*r*	*P*
Age	0.373	0.001	0.071	0.528	0.428	<0.0001	−0.006	0.957
BMI	0.443	<0.0001	0.788	<0.0001	0.213	0.054	0.565	<0.0001
Waist circumference	0.571	<0.0001	0.751	<0.0001	0.338	0.002	0.580	<0.0001
Waist-to-hip ratio	0.388	<0.0001	0.202	0.070	0.059	0.597	0.027	0.809
SAD	0.665	<0.0001	0.733	<0.0001	0.261	0.018	0.488	<0.0001
Systolic blood pressure	0.260	0.019	0.165	0.140	0.192	0.086	0.001	0.996
Diastolic blood pressure	0.285	0.010	0.281	0.011	0.054	0.634	0.046	0.681
HbA_{1c}	0.424	<0.0001	0.267	0.016	−0.017	0.881	−0.184	0.099
Visceral fat (measured by CT)	—	—	0.691	<0.0001	—	—	0.520	<0.0001

Table 3 —*Logistic regression analysis using diabetes as a dependent variable*

Parameters	OR (95% CI)	*P*
BMI		
Unadjusted	1.116 (1.030–1.209)	0.007
Adjusted for age and sex	1.124 (1.035–1.221)	0.005
Waist circumference		
Unadjusted	1.048 (1.014–1.083)	0.005
Adjusted for age and sex	1.048 (1.014–1.083)	0.005
SAD		
Unadjusted	1.273 (1.116–1.453)	<0.0001
Adjusted for age and sex	1.275 (1.117–1.455)	<0.0001
Visceral fat (measured by CT)		
Unadjusted	1.009 (1.003–1.016)	0.007
Adjusted for age and sex	1.011 (1.004–1.019)	0.004
Subcutaneous abdominal fat (measured by CT)		
Unadjusted	1.002 (0.999–1.005)	0.215
Adjusted for age and sex	1.002 (0.999–1.006)	0.162
Central abdominal fat (measured by DEXA)		
Unadjusted	1.001 (1.000–1.002)	0.013
Adjusted for age and sex	1.001 (1.000–1.002)	0.013

jects had significantly higher visceral fat compared with nondiabetic subjects (128.1 ± 33.8 cm^2 vs. 98.4 ± 40.7 cm^2 respectively, $P = 0.001$). Above the median age-group, although diabetic subjects had higher visceral fat, the difference did not reach statistical significance (151.8 ± 43.3 cm^2 for diabetic vs. 141.8 ± 56.8 cm^2 for nondiabetic subjects, $P = 0.234$). Similar results were obtained for central abdominal fat (below median age: 1,563.7 ± 411.2 g for diabetic vs. 1,313.5 ± 543.9 g for nondiabetic subjects, $P = 0.023$; above median age: 1,533.3 ± 335.2 g for diabetic vs. 1,426.2 ± 471.9 g for nondiabetic subjects, $P = 0.240$).

Table 2 shows the results of the Pearson's correlation analysis. Visceral fat measured by CT and central abdominal fat measured by DEXA showed a strong correlation with each other in both diabetic ($P < 0.0001$) and nondiabetic ($P < 0.0001$) subjects. Waist circumference and SAD showed a strong correlation with visceral and central abdominal fat in both diabetic and nondiabetic subjects. BMI showed a good correlation with visceral ($P < 0.0001$) and central abdominal ($P < 0.0001$) fat in nondiabetic subjects but only with central abdominal fat ($P < 0.0001$) in diabetic subjects.

Table 3 shows the results of logistic regression analysis using diabetes as the dependent variable. BMI ($P = 0.005$), waist circumference ($P = 0.005$), SAD ($P < 0.0001$), and visceral ($P = 0.004$) and central abdominal ($P = 0.013$) fat were strongly associated with diabetes, even after adjusting for age and sex. Subcutaneous abdominal fat, however, did not show a significant association with diabetes.

κ Statistics were computed to determine the agreement between tertiles of visceral and central abdominal fat (Table 4). A total of 23.8% of all study subjects were in the 1st tertile of both visceral and central abdominal fat, 15.9% in the 2nd tertile, and 23.2% in the 3rd tertile of both fat measures. Thus, 62.9% of the subjects were correctly classified by both visceral and central abdominal fat. The κ value was 0.44 ($P < 0.0001$) for the total population, 0.50 ($P < 0.0001$) for men, and 0.40 ($P < 0.0001$) for women.

CONCLUSIONS — Controversy still exists regarding the association of subcutaneous and visceral fat with diabetes (20–22). Further, the association of these fat parameters with anthropometric variables has not been studied in Asian Indians, a high-risk group for diabetes (1–7).

In this context, this study makes three important points. *1*) Visceral fat is associated with diabetes, while subcutaneous abdominal fat does not show such an association. *2*) Visceral fat measured by CT has a strong correlation with central abdominal fat measured by DEXA. *3*) Anthropometric variables, like waist circumference and SAD, have a strong correlation with visceral and central abdominal fat in both diabetic and nondiabetic subjects.

Our results of increased visceral fat in diabetic subjects are in agreement with a Japanese study (23) that showed visceral fat to be a predictor of impaired glucose intolerance. In addition, central abdominal fat measured by DEXA is also observed to be higher in diabetic subjects. DEXA is relatively cheaper in India and uses minimal radiation (12,24). Although DEXA can not differentiate between visceral and subcutaneous abdominal fat, it has been used to estimate central abdominal fat, which has been shown to have a good correlation with visceral fat measured by CT (16) and magnetic resonance imaging (25). However, there have been no studies, to our knowledge, comparing visceral fat measured by CT and central abdominal fat measured by DEXA in diabetic and nondiabetic subjects. In this study, we report that visceral and central abdominal fat show a strong correlation with each other (Table 2) in both diabetic and nondiabetic subjects. Both fat parameters also showed a fairly good agreement in categorizing subjects based on fat distribution. Since visceral and central abdominal fat had a strong association with diabetes, these fat variables could probably be used as predictors of diabetes once

Table 4 —*Agreement between visceral fat (measured by CT) and central abdominal fat (measured by DEXA) according to the tertiles in the total study population*

Tertiles of central abdominal fat	Tertiles of visceral fat					
	I	II	III	Total	κ	*P*
I	39 (23.8)	13 (7.9)	2 (1.2)	54		
II	12 (7.3)	26 (15.9)	16 (9.8)	54		
III	3 (1.8)	15 (9.1)	38 (23.2)	56		
Total	54	54	56	164 (100)	0.44	<0.0001

Data are *n* (%).

population-specific normal ranges are established.

Earlier studies (1,5,9) on Asian Indians have reported an association of waist circumference with diabetes, suggesting that increased accumulation of fat in the abdominal cavity may be one of the contributors to diabetes in this ethnic group. Waist circumference showed a strong correlation with visceral and central abdominal fat in both diabetic and nondiabetic subjects. A similar association was observed for SAD, which has been shown to be associated with glucose intolerance (26,27). However, BMI, which showed a correlation with central abdominal fat in both diabetic and nondiabetic subgroups, failed to show an association with visceral fat in the diabetic group, suggesting that BMI is not as good as waist circumference or SAD in predicting visceral adiposity in diabetic subjects.

Our finding that visceral fat was higher in men than women, while central abdominal fat was not significantly different, suggests that the latter included a subcutaneous fat component (which was markedly higher in women). This is probably a limitation of the DEXA scan.

The observation that only younger diabetic subjects had significantly higher visceral and central abdominal fat suggests that, with age, even nondiabetic subjects accumulate some visceral adiposity and, in younger individuals, visceral adiposity probably predisposes to diabetes.

One of the limitations of this study is that, due to its cross-sectional design, it cannot establish a temporal relationship between visceral fat and diabetes. However, the strengths of the study are that it is population based and done on a representative sample of an urban population of Asian Indians who have a high risk of diabetes (1–7). To our knowledge, this is the first report comparing visceral and central abdominal fat in a group of Asian-Indian diabetic and nondiabetic subjects. Future studies should address the relative contribution of genes and environment in predisposing to visceral adiposity.

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