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ARTICLES
METHODS AND TECHNIQUES

Predictive Equations for Body Fat and Abdominal Fat With DXA and MRI as Reference in Asian Indians

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Objective: To develop accurate and reliable equations from simple anthropometric parameters that would predict percentage of total body fat (%BF), total abdominal fat (TAF), subcutaneous abdominal adipose tissue (SCAT), and intra-abdominal adipose tissue (IAAT) with a fair degree of accuracy.
Methods and Procedures: Anthropometry, %BF by dual-energy X-ray absorptiometry (DXA) in 171 healthy subjects (95 men and 76 women) and TAF, IAAT, and SCAT by single slice magnetic resonance imaging (MRI) at L3–4 intervertebral level in 100 healthy subjects were measured. Mean age and BMI were 32.2 years and 22.9 kg/m^2, respectively. Multiple regression analysis was used on the training data set (70%) to develop equations, by taking anthropometric and demographic variables as potential predictors. Predicted equations were applied on validation data set (30%).
Results: Multiple regression analysis revealed the best equation for predicting %BF to be: %BF = 42.42 + 0.003 × age (years) + 7.04 × gender (M = 1, F = 2) + 0.42 × triceps skinfold (mm) + 0.29 × waist circumference (cm) – 0.22 × weight (kg) – 0.42 × height (cm) (R^2 = 86.4%). The most precise predictive equation for estimating IAAT was: IAAT (mm^2) = –238.7 + 16.9 × age (years) + 934.18 × gender (M = 1, F = 2) + 578.09 × BMI (kg/m^2) – 441.06 × hip circumference (cm) + 434.2 × waist circumference (cm) (R^2 = 52.1%). SCAT was best predicted by: SCAT (mm^2) = –49,376.4 – 17.15 × age (years) + 1,016.5 × gender (M = 1, F = 2) +783.3 × BMI (kg/m^2) + 466 × hip circumference (cm) (R^2 = 67.1).
Discussion: We present predictive equations to quantify body fat and abdominal adipose tissue sub-compartments in healthy Asian Indians. These equations could be used for clinical and research purposes.

Obesity (2008) **16,** 451–456. doi:10.1038/oby.2007.55

INTRODUCTION

Increasing prevalence of obesity has been seen not only in developed nations but also in the developing countries such as India in South Asians (1). The current data indicate high prevalence of obesity, particularly abdominal obesity; 20% in men and 55% in women as recorded in a multi-country study and evaluated by Asian cutoff points of waist circumference (WC) (2). These data emphasize that Asian Indians are particularly prone to develop abdominal adiposity. It is an important reason for predisposition of Asian Indians to insulin resistance, the metabolic syndrome and type 2 diabetes mellitus (1). In the INTERHEART study, abdominal obesity assessed by waist-to-hip circumference ratio (W-HR) showed a strong association with myocardial infarction in 52 populations, including South Asians (odds ratio for myocardial infarction by W-HR; 1.52) (3).

Interestingly, Asian Indians have increased overall adiposity, and higher amount of truncal subcutaneous and intra-abdominal fat as compared to other ethnic groups, particularly white (4–7). Although increased adiposity at both these sites contributes to surplus non-esterified fatty acids and consequent hepatic insulin resistance and dyslipidemia, relationship of truncal subcutaneous fat to insulin resistance in Asian Indians has been more impressive. Because of excessive overall adiposity at a lower body weight as compared to white, BMI may not be an accurate indicator of adiposity in Asian Indians (4–6).

Anthropometric measurements such as WC, hip circumference (HC), W-HR, and skinfold thickness are the most widely used measures of abdominal obesity and truncal subcutaneous fat. They are inexpensive and easy to use even in primary

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Received 10 March 2007; accepted 22 June 2007. doi:10.1038/oby.2007.55

health care setting. However, discrepancies in measurements are likely if the observer is untrained, and errors are reported in skinfold thickness measurement if the subject is severely obese. There are several studies on total adiposity, regional fat depots, and metabolic markers in Asian Indians using either dual-energy X-ray absorptiometry (DXA) scan, and computerized tomography or magnetic resonance imaging (MRI), which measure fat accurately with the help of special software. However, these methods are expensive, available in selected hospitals in metropolitan cities, and the software is available in only a few centers in India.

We hypothesized that equations developed from simple anthropometric measures would have a fair degree of accuracy in predicting percentage of total body fat (%BF), total abdominal fat (TAF), subcutaneous abdominal adipose tissue (SCAT), and intra-abdominal adipose tissue (IAAT). Importantly, only one previous study has been done on Asian Indians in India for predicting equations for "deep abdominal adipose tissue" using computerized tomography scan as reference, and none is available for SCAT and TAF (8). Our objective was to develop predictive equations using simple anthropometric variables for generalized and abdominal fat and then validate them.

METHODS AND PROCEDURES

The study was undertaken in the Department of Diabetes and Metabolic Diseases, Fortis Hospital; and the Department of Medicine, All India Institute of Medical Sciences, New Delhi, both being tertiary care centers. A total of 171 subjects (95 men and 76 women; equal representation from high-/middle- and low-income groups) from North India were screened in response to a local advertisement. The %BF measurements by DXA were available for 168 subjects (94 men and 74 women). Mean ± s.d. of the study subjects for age and BMI were 32.2 ± 9.5 years (range; 18–50 years) and 22.9 ± 4.0 kg/m^2 (range; 15.3–36.9 kg/m^2), respectively. Measurements for abdominal fat and its components by MRI were available for 100 subjects.

Subjects with the following problems were excluded from the study: body deformity (agenesis of any part, amputation, etc.), type 2 diabetes mellitus, manifest coronary heart disease or stroke, any severe chronic illness or major organ dysfunction, chronic smokers, chronic obstructive airway disease, alcohol and sedatives abuse, metallic implants, pacemaker leads, radioactive seeds or surgical staples in the body, pregnant or lactating women, those having undergone a procedure using iodine, barium or nuclear medicine isotopes within the last 7 days, and patients of HIV infection. Blood samples were taken to exclude the above conditions. A written, informed consent (using a standard consent form, typed in both Hindi and English languages, approved by the institutional ethics committee) was obtained from all the subjects.

Anthropometric measurements

Body weight (to the nearest 0.1 kg) and height (to the nearest 0.1 cm) were recorded without shoes and allowing only light indoor clothes. BMI was calculated using the formula, weight (Kg)/height (m)^2. Circumferences at waist, hip, mid-thigh, and calf were recorded to the nearest 0.1 cm. Mean of three readings of each circumference was taken for the calculation of W-HR. Biceps, triceps, thigh, calf, sub-scapular, anterior axillary, and supra-iliac skinfolds were measured carefully by using Lange skinfold calipers as described previously (6). Ratios of sub-scapular and triceps skinfold, and central (sum of sub-scapular and supra-iliac) and peripheral skinfolds (sum of biceps and triceps) were also calculated.

Percentage body fat

Body fat was estimated by using whole body DXA scan (Lunar Prodigy Advanced Whole Body DEXA system, GE Medical Systems). The subject was asked to lie on a padded table provided with an X-ray generator below the table and a detector above, was asked to remain still and breathe quietly for a short time while the scanner of the machine passed over the body. The data were collected at 0.5-cm intervals and reported in the standard format.

Abdominal fat

Measurement of abdominal adipose tissue was made by single slice MRI (1.5 Tesla, SIGNA High Definition MR, GE Medical Systems) at L_{3-4} intervertebral level. MRI was done in supine position with arms by the side. The abdominal region was scanned using axial 8 mm thick slice during the breath holding spell. We used a T_1-weighted spin echo sequence (TR/TE/NEX-300 ms/15 ms/1). Adipose tissue areas were easily identified on the images because fat has short T_1 and long T_2 proton relaxation times as compared to other tissues. Many pathological processes may result in prolongation of both T_1 and T_2 times. However, the short T_1 time of fat is characteristic, and it results in high signal intensity (increased brightness) on T_1-weighted images. Areas of IAAT and SCAT (mm^2) were measured on computer screen using a track-ball.

Statistical analysis

Data were collected on a pre-designed proforma and managed on an Excel spreadsheet. All entries were double-checked for any possible keyboard error. Arithmetic mean and s.d. were computed as measures of descriptive statistics for quantitative variables. The descriptive statistics for DXA and MRI samples were similar. Total sample (n = 168) was randomly divided into two parts, training data set (n = 124; 70%) and validation data set (n = 44; 30%). Predictive equations by multiple regression analysis on training data set were developed by taking %BF, TAF, Subcutaneous abdominal adipose tissue, and IAAT as dependent variables, and combinations of demographic (age and gender) and anthropometric variables as potential predictors. Predictive equations thus developed were applied on validation data set (not used in developing the equations). The validity of the predictive equations was assessed based on the mean residual (observed–predicted) and its 95% confidence interval. STATA 9.0 intercooled version statistical software (College Station Road, Houston, TX) was used for data analysis.

RESULTS

Sample description

Table 1 lists the descriptive statistics of %BF and potential predictor variables, estimated in total data, training data, and validation data sets. On average, the subjects were young, non-obese, and with a wide range of BMI. There was no significant difference in the circumferences and skinfolds measured at various sites in these three groups. **Table 2** describes the Pearson's correlation coefficients of the potential predictor variables (used in developing the individual equations) with respect to the dependent variables.

Prediction of %BF from DXA

Multiple regression equations using various combinations of 15 anthropometric and 2 demographic variables were generated (**Table 3**). Triceps skinfold was the simplest anthropometric parameter which best correlated (r = 0.82) with %BF DXA followed by thigh skinfold (r = 0.78). The simplest equation included age, gender, BMI, triceps skinfold, and WC (mean error = –0.94; R^2 = 84.4%). Replacing BMI with weight and height reduced the

Table 1 Descriptive statistics of %BF, MRITAF, MRIIAAT, MRISCAT, and set of potential predictor variables

Variables	Total group data (n = 168)	Training data set (n = 124)	Validation group (n = 44)
Dependent variables			
BFDXA (%)	29.6 ± 11.5[a]	28.9 ± 11.6	31.3 ± 11.2
MRITAF (n = 100) (mm^2)	23,809.1 ± 13,545.5	22,621.2 ± 13,750.8	22,621.2 ± 13,750.8
MRIIAAT (n = 100) (mm^2)	10,293.2 ± 7,140.5	9,664.9 ± 7,177.3	11,759.0 ± 6,950.8
MRISCAT (n = 100) (mm^2)	13,844.8 ± 8,664.4	13,153.1 ± 8,684.6	15,458.8 ± 8,542.8
Potential predictors			
Demographic			
Age (years)	32.2 ± 9.5	31.9 ± 10.0	33.1 ± 7.8
Weight (kg)	59.7 ± 12.0	58.6 ± 11.4	62.8 ± 13.0
Height (cm)	161.2 ± 9.8	161.0 ± 10.0	161.6 ± 9.2
BMI (Kg/m^2)	23.0 ± 4.0	22.6 ± 4.5	24.0 ± 4.5
Circumferences (cm)			
Waist circumference	81.4 ± 11.6	80.3 ± 11.3	84.3 ± 12.0
Hip circumference	92.2 ± 8.3	91.8 ± 8.3	93.5 ± 8.4
Mid-thigh circumference	48.5 ± 5.6	48.2 ± 5.5	49.4 ± 5.6
Calf circumference	32.5 ± 3.7	32.4 ± 3.8	32.8 ± 3.4
W-HR	0.9 ± 0.1	0.9 ± 0.1	0.9 ± 0.1
Skinfolds (mm)			
Biceps skinfold	10.2 ± 7.0	9.7 ± 7.3	11.6 ± 6.2
Triceps skinfold	18.6 ± 9.1	18.0 ± 9.2	20.3 ± 8.8
Sub-scapular skinfold	23.5 ± 11.1	22.4 ± 10.6	26.7 ± 11.7
Anterior axillary skinfold	12.8 ± 7.9	12.0 ± 7.7	15.0 ± 8.3
Supra-iliac skinfold	25.2 ± 13.6	24.1 ± 13.6	28.2 ± 13.4
Thigh skinfold	28.8 ± 13.7	28.3 ± 14.0	30.4 ± 13.9
Calf skinfold	17.9 ± 8.0	17.5 ± 8.1	19.1 ± 7.6

%BF, % body fat estimated by dual-energy X-ray absorptiometry (DXA) scan. Total abdominal fat (TAF) area estimated by magnetic resonance imaging (MRI) at $L_{3–4}$ intervertebral level. MRIIAAT, intra-abdominal adipose tissue area estimated by MRI at $L_{3–4}$ intervertebral level. MRISCAT, subcutaneous adipose tissue area estimated by MRI at $L_{3–4}$ intervertebral level.
[a] $\bar{x}$ ± s.d. (all such values).

Table 2 Pearson's correlation coefficient of body fat and abdominal adipose tissue compartments with demographic and anthropometric variables (used in respective equations)

Variables	BFDXA	MRITAF	MRIIAAT	MRISCAT
Age (years)	0.29	0.26	0.31	0.15
Weight (kg)	0.31	–	–	–
Height (cm)	–0.50	–	–	–
BMI (kg/m^2)	0.72	0.78	0.55	0.79
Waist circumference	0.53	0.76	0.69	–
Hip circumference	–	0.70	0.39	0.80
W-HR	–	–	0.66	–
Biceps skinfold	–	–	–	0.65
Triceps skinfold	0.82	–	0.26	0.64
Sub-scapular skinfold	–	–	–	0.53
Thigh skinfold	0.78	–	–	–
Calf skinfold	0.69	–	–	–

All correlations are significant, $P < 0.05$.
BFDXA, % body fat estimated by dual-energy X-ray absorptiometry (DXA) scan. MRITAF, total abdominal fat area estimated by magnetic resonance imaging (MRI) at $L_{3–4}$ intervertebral level. MRIIAAT, intra-abdominal adipose tissue area estimated by MRI at $L_{3–4}$ intervertebral level. MRISCAT, subcutaneous adipose tissue area estimated by MRI at $L_{3–4}$ intervertebral level.

overall variance (mean error = –0.60; R^2 = 86.4%). Further addition of thigh skinfold yielded the minimum mean error (0.09) of all equations. Therefore, the recommended equation for %BF is: 42.42 + 0.003 × age + 7.04 × gender + 0.42 × triceps skinfold + 0.29 × WC – 0.22 × weight – 0.42 × height.

Prediction of TAF from MRI

Multiple regression equations, with TAF as dependent and all others as independent variables, were developed (Table 4). Individually, BMI (r = 0.78) and WC (r = 0.75) had the maximum correlation with TAF. The simplest equation for estimation of TAF is: –47,657.00 + 1,384.11 × gender + 1,466.54 × BMI + 416.10 × WC (mean error = 1,820.17; R^2 = 65%). Excluding gender, the combination of BMI and WC explained 64.9% variability in TAF (mean error = 1,981.83). Statistically, the equation including age, gender, BMI, and HC had the least mean error (1,679.20), but the wide range of 95% confidence limits reduced the overall significance of this equation.

Prediction of IAAT from MRI

Multiple regression equations for estimation of IAAT were derived (Table 5), and for IAAT, WC (r = 0.69) was the strongest predictor followed by BMI (r = 0.55). The most precise predictive equation included age, gender, BMI, HC, and WC (mean error = 1,827.70; R^2 = 52.1%). Excluding HC from the equation reduced the R^2 (48.2%) considerably. Addition of more variables had a marginal influence on the variance. Hence, IAAT can be best predicted by the equation: –238.7 + 16.9 × age + 934.18 × gender + 578.09 × BMI – 441.06 × HC + 434.2 × WC.

Prediction of SCAT from MRI

HC (r = 0.80) emerged as the most outstanding index to measure SCAT, followed by BMI (r = 0.79). Irrespective of age and gender, BMI and HC explained 66.8% variability in SCAT (mean error = 410.10) on subjecting the data to multiple regressions

Table 3 Regression coefficients of predictive equations for % body fat (%BF) using DXA as standard

Eq[a]	Constant	Age	Gender[b]	BMI	Wt[c]	Ht[d]	TR sf[e]	WC[f]	Thigh sf[g]	Calf sf[h]	R^2 (%)	ME[i] (CI)
1[j]	42.42	0.00	7.04	–	–0.22	–0.42	0.42	0.29	–	–	86.4	–0.60 (–9.02, 7.82)
2	–28.45	0.08	9.82	0.96	–	–	0.38	0.15	–	–	84.4	–0.94 (–9.62, 7.75)
3	–27.58	0.11	8.50	0.90	–	–	0.22	0.15	0.18	–	85.7	–1.63 (10.50, 7.30)
4	27.76	0.13	8.21	0.86	–	–	0.19	0.14	0.14	0.15	86.3	–0.62 (–9.42, 8.19)
5	36.85	0.03	6.29	–	0.20	–0.38	0.30	0.27	0.14	–	87.1	0.09 (–8.34, 8.52)
6	40.20	0.03	6.22	–	0.19	–0.40	0.34	0.28	–	0.20	87.5	–1.10 (–9.72, 7.52)

DXA, dual-energy X-ray absorptiometry.
[a]Equation. [b]M, 1; F, 2. [c]Weights. [d]Heights. [e]Triceps skinfold. [f]Waist circumferences. [g]Thigh skinfold. [h]Calf skinfold. [i]Mean error = observed – predicted. [j]Recommended equation.

Table 4 Regression coefficients of predictive equations for total abdominal fat (TAF) area using MRI as standard

Eq[a]	Constant	Age	Gender[b]	BMI	WC[c]	HC[d]	R^2 (%)	ME[e] (CI)
1[f]	–47,657.00	–	1,384.11	1,466.54	416.10	–	65.0	1,820.17 (–8,220.22, 11, 860.57)
2	45,485.00	–	–	1,627.36	367.80	–	64.9	1,981.83 (–8,222.80, 12,185.60)
3	–46,985.90	106.60	–2,591.15	2,204.52	–	199.4	62.0	1,679.20 (–10,342.30, 13,700.50)

MRI, magnetic resonance imaging.
[a]Equation. [b]M, 1; F, 2. [c]Waist circumferences. [d]Hip circumferences. [e]Mean error = observed – predicted. [f]Recommended equation.

Table 5 Regression coefficients of predictive equations for intra-abdominal adipose tissue (IAAT) using MRI as standard

Eq[a]	Constant	Age	Gender[b]	BMI	WC[c]	HC[d]	TR sf[e]	SI sf[f]	R^2 (%)	ME[g] (CI)
1[h]	–238.70	16.90	934.18	578.09	434.20	–441.06	–	–	52.1	1,827.70 (–7,558.20, 11,213.0)
2	–21,315.80	84.84	–842.80	–18.70	366.90	–	–	–	48.2	1,515.60 (–6,869.50, 9,900.60)
3	–39,006.80	24.70	790.00	455.80	–	–	–	–	51.4	1,686.70 (–7,396.80, 10,770)
4	–2,164.47	25.25	1,277.18	634.10	407.40	–410.4	–144.80	72.90	52.9	1,858.22 (–7,907.40, 11,623)

MRI, magnetic resonance imaging.
[a]Equation. [b]M, 1; F, 2. [c]Waist circumferences. [d]Hip circumferences. [e]Triceps skinfold. [f]Supra-iliac skinfold. [g]Mean error = observed – predicted. [h]Recommended equation.

Table 6 Regression coefficients of predictive equations for subcutaneous adipose tissue (SCAT) using MRI as standard

Eq[a]	Constant	Age	Gender[b]	BMI	HC[c]	BC sf[d]	TR sf[e]	SS sf[f]	R^2 (%)	ME[g] (CI)
1[h]	–49,376.40	–17.15	1,016.50	783.30	466.00	–	–	–	67.1	349.86 (–5,981.70, 6,681.40)
2	–51,669.50	–	–	707.70	519.72	–	–	–	66.8	410.10 (–6,173.50, 6,993.50)
3	–44,300.20	–13.10	74.00	669.40	432.90	182.40	–	–	67.9	166.95 (–5,843.90, 6,177.70)
4	–46,607.00	–24.20	558.40	756.80	451.80	301.70	–169.50	–	68.4	254.70 (–5,886.30, 6,393.70)
5	–45,730.80	–17.40	–175.00	809.50	439.10	224.50	–	–100.50	68.6	288.70 (–6,085.60, 6,663.00)

MRI, magnetic resonance imaging.
[a]Equation. [b]M, 1; F, 2. [c]Hip circumferences. [d]Biceps skinfold. [e]Triceps skinfold. [f]Supra-scapular skinfold. [g]Mean error = observed – predicted. [h]Recommended equation.

Table 7 Final predictive equations for estimation of various body fat depots

Depot	Final predictive equation
%BF[a]	42.42 + 0.003 × age + 7.04 × gender[b] + 0.42 × TR sf[c] + 0.29 × WC[d] – 0.22 × Wt[e] – 0.42 × Ht[f]
TAF[g]	–47,657.00 + 1,384.11 × gender + 1,466.54 × BMI + 416.10 × WC
IAAT[h]	–238.7 + 16.9 × age + 934.18 × gender + 578.09 × BMI – 441.06 × HC[i] + 434.2 × WC
SCAT[j]	–49,376.4 – 17.15 × age + 1,016.5 × gender + 783.3 × BMI + 466 × HC

[a]% Body fat. [b]M, 1; F, 2. [c]Triceps skinfold. [d]Waist circumference. [e]Weight. [f]Height. [g]Total abdominal fat. [h]Intra-abdominal adipose tissue. [i]Hip circumferences. [j]Subcutaneous adipose tissue.

(Table 6). Further addition of age, gender, and biceps skinfold reduced the mean error appreciably (166.95) and also decreased the variance (67.9%). Therefore, the simplest and best predictive equation for SCAT is expressed as: – 49,376 – 17.15 × age + 1,016.5 × gender + 783.3 × BMI + 466 × HC.

Table 7 summarizes the final predictive equations for estimation of various body fat depots.

DISCUSSION

In this study, we have developed simple and accurate equations to predict % BF, TAF, SCAT, and IAAT using easy anthropometric variables such as age, gender, BMI, WC, HC, and skinfolds, for the first time in Asian Indians. We have also reported that these equations have predicted the amount of respective fat depots with a fair degree of accuracy. The validity of these equations for future use as predictors of body fat has also been assessed and their applicability compared with pre-existing equations. These equations can be used to calculate the fat distribution in those places where access to DXA and other experimental protocols such as MRI is not available. Importantly, for a busy general practitioner, it is not clinically feasible to measure all the parameters in every patient. Also, measurement of lower body skinfolds such as thigh may not be culturally acceptable to many Asian Indians, particularly women. Hence, the best equations have been derived keeping in mind the simplicity of performing the measurements. It is, however, important to measure abdominal adipose tissue sub-compartments, since excess IAAT and SCAT have been associated with insulin resistance and the metabolic syndrome in Asian Indians as well as in white (9–11).

Statistically, the best predictive equation for %BF involves seven variables—age, gender, weight, height, triceps skinfold, WC, and calf skinfold. The predictive power of this equation (R^2 = 87.5%) is similar to the ones derived by Van der Ploeg *et al.* (12), wherein three to nine skinfolds have been used via the four-compartment model (R^2 = 92–97%) and by Ball *et al.* (13) who used seven skinfolds (R^2 = 89%). We have shown that lower body skinfolds such as thigh and calf showed better coherence with %BF, similar to the findings of Eston *et al.* (14). However, keeping in mind the ease in measurement, an equation based on age, gender, weight, height, triceps skinfold, and WC is recommended for clinical use in Asian Indians. Interestingly, use of only a single skinfold (triceps) yielded a good R^2 in our equation. Use of weight and height individually rather than BMI predicted better %BF.

Many researchers believe that increased IAAT is the main cause for various disorders such as insulin resistance, coronary heart disease, and type 2 diabetes mellitus (15). Hence it is important to predict this regional fat depot accurately, especially in high-risk population such as Asian Indians where abdominal adiposity is more prevalent as compared to white. The simplest predictive equation for IAAT included age, gender, BMI, HC and WC (R^2 = 52%), and WC emerged as the best predictor of IAAT. Others have also reported similar findings (16). Brundavani *et al.* (8) showed that weight was a better predictor of deep abdominal adipose tissue, contrary to BMI in our study. Further, the equation developed by Brundavani *et al.* (8) explained 63% variability of deep abdominal adipose tissue in women and 74% in men. The data from the studies of Brundavani *et al.* (8) are not strictly comparable with our results, since the two population groups (south Indians vs. north Indians) and the methods of measurement of abdominal fat (computerized tomography vs. MRI) were different. It is important to note that the MRI scan is a preferable modality for estimation of abdominal adipose tissue sub-compartments and is also free of any radiation exposure (17). Poll *et al.* (18) showed a poor correlation of BMI and W-HR individually with TAF, IAAT, and SCAT in German diabetic population. However, in our study, BMI had a strong correlation with all abdominal fat sub-components. Although the R^2 of our equation is not very high, it is a simple and practical method for assessing abdominal adipose tissue sub-compartments.

Several investigators, including our group, believe that SCAT is a better determinant of insulin sensitivity than IAAT (10,11,19,20), hence measurement of SCAT is important in Asian Indians (21). This can be done using anthropometry, but it has its variability. Hence, an equation comprising age, gender, BMI, and HC (R^2 = 67.1%) is recommended for clinical use. Although the addition of biceps skinfold reduced the mean error, it made the applicability of the equation difficult. Irrespective of age and gender, HC emerged as an outstanding index to measure SCAT. An approximate method of measuring SCAT is by skinfolds; however this does not give a correct estimation as the calipers include epidermis and dermis in the skinfold thickness. Our validation study showed that the differences between the observed and predicted values of IAAT were large compared with those for SCAT. Thus, SCAT was predicted from anthropometry more accurately than IAAT.

TAF is considered a function of age, increasing with advancing age. However, this occurs at the expense of muscle mass. Interestingly, in our study, the equation which included gender, BMI, and WC was the one which most accurately predicted TAF (R^2 = 65%). Exclusion of gender had minimal effect on R^2 (64.9%), but this increased the mean error. The use of sagittal abdominal diameter has no advantage over simpler and more commonly used anthropometric measures such as the WC in older men and women (22). It is noteworthy that our study did not include subjects beyond 50 years, thus the variation of TAF with advancing age could not be assessed. However, the application of these equations in people with severe obesity will have to be validated as DXA may not work, and MRI may be difficult to perform in them.

In sum, we report reliable equations for estimation of %BF, TAF, IAAT, and SCAT for the first time in Asian Indians. These equations can be used for epidemiological purpose and in the clinics. Estimation of abdominal adipose tissue sub-compartments would become more useful if cutoff points of SCAT and IAAT, which indicate the cardiovascular risk escalation, are known. Of note, we are in the process of estimating these cutoff points for Asian Indians. Finally, the validity of these equations in pediatric age group should be assessed in future or separate equations developed for them.

ACKNOWLEDGMENTS
We appreciate the help from the staff of SRB Centre of Clinical Pharmacology, Department of Medicine, All India Institute of Medical Sciences, New Delhi. We are particularly thankful to Dr Harsh Mahajan and staff of Mahajan Imaging Center for MRI data. Cooperation of subjects who took part in the study is greatly appreciated. This study was supported by a financial grant from the Department of Science and Technology, Ministry of Science and Technology, and the Government of India.

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