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**Body Composition**

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**ACCURACY OF ESTIMATING INTRA-ABDOMINAL FAT IN OBESE WOMEN**

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**ABSTRACT**

ACCURACY OF ESTIMATING INTRA-ABDOMINAL FAT IN OBESE WOMEN. **Stephen D. Ball, Pamela D. Swan.** *JEPonline*. 2003;6(4):1-7. Intra-abdominal fatness (IAF) has been linked to a cluster of risk factors for cardiovascular disease. An accurate assessment of IAF is therefore critical for clinicians when assessing disease risk. The aim of this investigation was to examine the accuracy of a previously developed equation by Treuth, Hunter, and Kekes-Szabo (1) using dual-energy absorptiometry (DXA) combined with anthropometry for predicting IAF in obese women. Thirty-five peri- and post-menopausal obese women (age: 47.0 yr±7.0; BMI: 32.2±6.3 kg/m<sup>2</sup>; and percent fat: 43.5±6.7 %) underwent a single-slice computed tomography (CT) scan at the level of L4-L5. In addition, a total body DXA scan and anthropometric measures including waist circumference and supine sagittal diameter measures at the level of the umbilicus, were also made. DXA-IAF was predicted using the equation:  $-208.2 + 4.62(\text{SD}) + 0.75(\text{A}) + 1.73(\text{W}) + 0.78(\text{DXA})$ . (SD=anthropometric sagittal diameter, cm; A=age, yrs; W=waist circ., cm; DXA=DXA trunk fat, %). DXA-IAF was significantly correlated with CT-IAF ( $r=0.628$ ,  $P<0.001$ ,  $\text{SEE}=53.0 \text{ cm}^2$ ). However, DXA-IAF values ( $172.2\pm46.9 \text{ cm}^2$ ) significantly overestimated CT-IAF ( $114.0\pm67.1 \text{ cm}^2$ ) in this population. The results from the current study indicate that the Treuth et al. equation was not able to adequately estimate IAF in obese women. Although this equation was originally generated on a wide selection of women, a limited number of the original cohort were obese. In summary, this equation may be more generalizable for normal weight women than for obese women.

Key Words: Dual -Energy X-ray Absorptiometry, Computed Tomography, Intraabdominal Fat

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**INTRODUCTION**

Intra-abdominal fat (IAF), or more commonly called visceral fat, is the fat tissue that accumulates beneath the muscle wall that surrounds organs and other structures within the abdominal cavity. Research has consistently shown that an increased distribution of fat in and around the abdomen is associated with an increased risk for cardiovascular disease (2) and diabetes (3). Abdominal fat has been linked to a cluster of risk factors for

cardiovascular disease called “Syndrome X” (4) or the Metabolic Syndrome (5), which includes hyperlipidemia, insulin resistance, hypertension, and hyperinsulinemia (5, 6). However, it appears that increased IAF, a component of total abdominal fat, may be even more predictive of these complications than abdominal fat itself (7).

Computed tomography (CT) is an imaging technique capable of directly measuring abdominal tissue and IAF with a very high degree of accuracy (8). However, this procedure is expensive and requires skilled technicians. CT scans also expose subjects to ionizing radiation. In clinical practice abdominal adiposity has been estimated using indirect anthropometric methods such as the waist to hip ratio (WHR) or waist circumference. These are inexpensive and quick procedures that give estimates of fat distribution. Although some researchers feel that anthropometric estimates are an acceptable measure of intraabdominal fat (9) and therefore disease risk, others have suggested that this technique is only moderately related to the amount of abdominal visceral adipose tissue (10-13). For example, the percent of variance explained ( $R^2$ ) in IAF by the WHR has been reported to be  $<0.58$  (14). These estimates are also subject to variability between technicians and do not accurately assess changes in visceral fat mass (15). Researchers have thus begun to evaluate other techniques that are easy, accessible and more accurate estimates of IAF.

A safer (less radiation compared to CT) and less expensive method to assess IAF may be with dual-energy x-ray absorptiometry (DXA). DXA has typically been used to assess bone mineral density but has also been found to be a valuable tool in assessing body composition (16) and regional body composition (1, 17, 18). In 1993, Svendsen et al. (18) developed two regression equations that used DXA data along with several anthropometric measurements in order to predict IAF ( $R^2=0.63$  and  $0.71$ , respectively) in postmenopausal women. Treuth et al. (1), in an attempt to validate the Svendsen et al. equations, developed a new generalizable equation for estimating IAF from DXA in women of varying ages and body composition. The resulting equation was more highly correlated with IAF ( $R^2 = 0.81$ ) than the Svendsen equation. Utilizing CT as the criterion method, this new model used % trunk fat from DXA in conjunction with anthropometric data (sagittal diameter, waist circumference), and age in order to predict the amount of IAF fat  $\{y=-208.2 + 4.62(\text{sagittal diameter, cm}) + 0.75(\text{age, y}) + 1.73(\text{waist, cm}) + 0.78(\text{trunk fat \%})\}$ . Although Treuth et al. (1) reported that some obese women were used in developing their equation (% fat 12.9-51.6), the mean body mass index BMI ( $\text{kg/m}^2$ ) for the 151 women in the estimation sample was relatively low ( $23.8 \pm 4.7$ ) compared to the average range of BMI (26.7-28.5) reported for middle-aged women (19). It is not clear if this equation would be generalizable to women with relatively greater body fat amounts. The purpose of this study was to examine the accuracy of the Treuth, Hunter, and Kekes-Szabo (1) equation to predict IAAT in obese women.

## METHODS

### Subjects

Thirty-five obese women (total % fat  $>30\%$  from DXA) with a mean age of  $47.4 \pm 7.0$  years (range 35-65) living in a large metropolitan area in the southwestern United States volunteered to participate in the study. All subjects were informed of the procedures and risks of the study and signed a written informed consent in accordance with the policies and procedures of the University Human Subjects Institutional Review Board.

### Anthropometry

Body weight was measured to the nearest 0.1 kg and height to the nearest 0.5 cm. Duplicate circumferences were taken to the nearest 0.1 cm with a Gulick tension retractable tape. Waist circumference was measured as the narrowest part of the torso between the ribs and the iliac crest. Abdominal circumference was measured as the extension of the abdomen at the level of the umbilicus (20). In several subjects ( $N=7$ ) it was impossible to identify the waist circumference, therefore the abdominal circumference was used as an alternative. Sagittal diameter was measured as the maximum diameter of the abdomen in the sagittal plane. All sagittal diameter measurements were taken in the supine position with the knees bent using sliding calipers at the point directly above the umbilicus (21). The average of the duplicate measures was used in the statistical analysis.

### **Computed tomography**

Abdominal adipose tissue was assessed by computed tomography (CT) (Picker PQ 6000, Picker International, Cleveland, Ohio) at the level of the fourth to fifth lumbar vertebra (L4-L5). The scan was performed at 125 kV with an 8 mm slice thickness. An initial scan was taken from a lateral view to establish the bony landmarks on a radiograph of the skeleton as a reference to establish the position of the scan to the nearest mm. Each woman was examined in a supine position with her arms stretched above her head. Visceral and total fat were calculated with a fat tissue-highlighting technique using an attenuation range of -190 to -30 Hounsfield units (HU). Each area was delineated with a computerized pen and then expressed as cross sectional area of tissue (cm<sup>2</sup>). Visceral adipose tissue was distinguished by drawing a line within the inner portion of the muscle wall surrounding the abdominal cavity. Total fat area was determined by demarcating the whole abdominal scan with the electronic pen. Then visceral area was subtracted from the total fat area to calculate abdominal subcutaneous tissue. A single investigator performed all CT measures. Test-retest reliability for repeated CT scan analyses of 10 subjects yielded a correlation coefficient of 0.99.

### **Dual Energy X-ray Absorptiometry**

Dual energy x-ray absorptiometry (DXA) (model DPX-IQ 5705; Lunar Radiation Corporation, Madison, WI) was used to assess percent body fat and regional tissue composition analysis. The 20 minute scan (pencil beam) was used on all women. The Lunar DPX-IQ computer using software version 4.6b calculated total trunk % fat. Total trunk % fat was designated as all the trunk area (not arms, legs or head) below the neck and to the diagonal leg cuts.

### **Statistical Analyses**

Statistical analyses were performed using commercial computer software (SPSS v. 9 for Windows). Descriptive statistics were calculated for subject characteristics. Mean differences in IAAT between the CT measured values and the predicted values were determined with a paired t- test. Linear regression and Pearson Product-Moment correlations defined the relationship between the prediction equation ( $y = -208.2 + 4.62$  (sagittal diameter, cm) + 0.75 (age, y) + 1.73 (waist, cm) + 0.78 (trunk fat %)) and CT measured IAAT. An alpha level of 0.05 was used to indicate statistical significance.

## **RESULTS**

The descriptive characteristics of body composition for this study compared to those reported from Treuth et al. (1) are shown in Table 1. Subjects ranged from 30.1-60.4 % fat.

There was a significant difference ( $P < 0.001$ ) in measured (114.0 $\pm$ 67.1) versus predicted (172.2 $\pm$ 46.9) IAAT values. The correlation coefficients of IAAT by CT with anthropometry and DXA are shown in Table 2. IAAT was significantly correlated with weight, body mass index, sagittal diameter, waist circumference, and umbilicus circumference. The Bland and Altman (22) plot of residual scores illustrates the overestimation of IAAT by the prediction equation for each subject (Figure 1).

## **DISCUSSION**

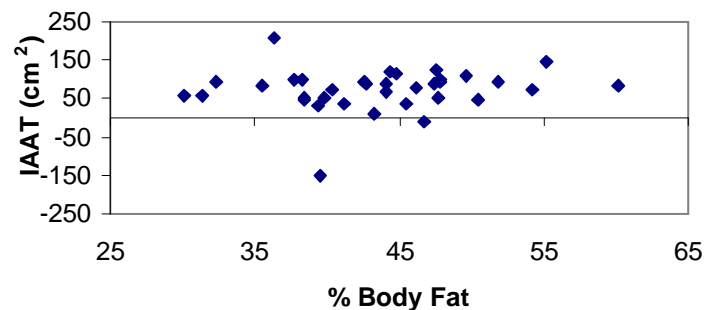
Other research has demonstrated that the combination of DXA with simple anthropometric measures can be used to estimate the amount of IAAT in women (1, 23). However, only a limited number of studies have examined the accuracy of this technique in obese women. Although more work is necessary, it appears that the equations of Treuth et al. (1) do not sufficiently estimate IAAT in obese women ( $R^2 = 0.39$ ). The possible areas of discrepancy arise from inconsistencies in anthropometric measurements and also the assumptions and limitations in DXA technology.

**Table 1. Body composition comparison data.**

	Current Study (N = 35)		Treuth et al., 1995 (N = 151)	
	Mean?SD	Range	Mean?SD	Range
Age (yrs)	47?7.07	35 - 67	44	17-77
Weight (kg)	85.6?16.9	(57.1 - 133.2)	63.5?13.3	(43.2 - 119.0)
Height (m)	1.63?0.07	(1.5 - 1.8)	1.63?0.06	(1.39 - 1.83)
BMI (kg/m <sup>2</sup> )	32.2?6.31	(21.1 - 46.3)	23.8?4.7	(16.8 - 43.7)
Sagittal diameter (cm)	30.5?4.4	(21.2 - 38.1)	20.9?4.2	(14.5 - 40.5)
Waist circ. (cm)	99.4?16.3	(76.4 - 139.8)	73.4?10.6	(57.5 - 112.0)
Umbilicus circ. (cm)	116.94?11.17	(94.6 - 142)	79.9?14.4	(10.9 - 139.0)
Total body fat (%) <sup>1</sup>	43.5?6.7	(30.1 - 60.2)	32.3?9.0	(12.9 - 51.6)
Total trunk fat (%) <sup>1</sup>	41.2?5.1	(29.6 - 55.5)	29.9?10.3	(8.3 - 53.0)
IAAT (cm <sup>2</sup> )	114.0?67.1	(35.8 - 399.3)	72.3?55.0	(10.7 - 335.4)
SAAT (cm <sup>2</sup> )	429.9?147.3	(205.9 - 775.9)	207.2?122.0	(35.5 - 612.1)

Mean?SD. Range in parentheses. IAAT=Intra-abdominal adipose tissue measured by CT; SAAT=subcutaneous abdominal adipose tissue measured by CT; <sup>1</sup>=measured by DXA.

One potential source of error is from the measurement of the anthropometric values used in the equation. For example, in some large women with primarily upper body fat distribution, the “narrow” location of the waist circumference was difficult to distinguish on the torso. In these instances (n=7), we recorded the umbilicus circumference that is easy to identify and a reliable measurement, but is located inferior to the waist and is typically a larger value. This inconsistency in measurement may limit the validity of the waist measurement in obese women. It is worth noting that substitution of the waist circumference by the umbilicus circumference for all subjects reduced the R<sup>2</sup> from 0.39 to 0.32.

**Predicted vs Measured IAAT**

**Figure 1. Values are the difference between predicted (Treuth et al. equation) IAAT and measured (CT) IAAT for each subject. Positive values represent an overestimation by the prediction equation.**

Another anthropometric source of inaccuracy may be the inconsistency in the measurement of the sagittal diameter. There are no standard procedures in measuring sagittal diameter and it was not clear in the original equation if this measurement was taken with the knees bent or straight. In this study we measured the sagittal diameter in the supine position with the knees bent. Any difference in body position may have influenced the measurement value as somewhat smaller sagittal diameter values will be obtained with the legs straight.

It is noteworthy that the correlation between IAAT with DXA trunk % fat was not statistically significant. Although some studies have found substantially higher correlations (0.6-0.8) between IAAT and DXA trunk % fat (1), others have not reported significant correlations (10). Ferland et al. (10) found that total adipose tissue from CT at the abdominal level was not significantly correlated with total body fat mass in obese women. It seems reasonable to assume that if there is not a consistent relationship between DXA measured values of trunk

% fat with IAAT, then the DXA technique may be less sensitive to subtle changes in IAAT and thus will result in invalid estimates of IAAT in obese women. Interestingly, when an analysis was run with two non-obese (% fat <30) women included in the sample, the Pearson correlation between IAAT and predicted IAAT improved slightly from 0.628 to 0.665. It is possible that an increased correlation might be expected simply because the range in IAAT was extended. But perhaps this increased correlation might imply that the Treuth et al. equation may be more appropriate for normal weight than obese women. The Treuth equation should be validated on a less obese group to determine the answer.

Interestingly, a recent study by Bertin et al. (23) using a different DXA model (QDR 2000/W HOLOGIC) also attempted to apply the Treuth et al. equation to their sample (44 overweight women) and found results similar to ours. They found that the mean difference between the estimated and measured IAAT was significantly larger (+31?8.8 cm<sup>2</sup>,  $p < 0.01$ ) with a correlation of 0.57. Thus, consistent with our findings, Bertin et al. (23) also found the Treuth et al. equation to overestimate the amount of IAAT in obese women.

However, Bertin et al. (23) did find promising results for the usefulness of DXA in estimating visceral fat in obese subjects when the abdominal trunk region was analyzed with more sophisticated software at a higher precision. Using a protocol version of the DXA software, Bertin et al. (23) identified two abdominal transverse diameters on the DXA scans. Their new prediction equation [79.6 (sagittal diameter – subcutaneous fat width) X (transverse internal diameter/height) – 149] yielded an R<sup>2</sup> of 0.86 ( $p < 0.0001$ ). Perhaps DXA software that divides the abdominal region into more precise sections is necessary in order to use DXA to measure visceral fat in obese women.

Even though DXA is gaining momentum as the gold standard for assessing body composition, it still has limitations in accurately assessing trunk fat in obese women. For example, DXA fat analysis technology has limitations in assessing and delimiting differences between breast tissue and arm fat tissue due to the overlap of fat in the scan area. Although increases in breast tissue may increase the overall regional measurement, this trunk fat tissue is not associated with IAAT. In addition, the effect of how DXA software extrapolates pixels over bone in the trunk area may influence the estimation of trunk fat in obese subjects. Since pixels directly over bone are extrapolated from non-skeleton pixels, a proportionally greater error would occur in obese subjects because a greater tissue mass is being estimated and not measured. These factors raise questions about DXA's ability to predict the amount of IAAT in obese subjects.

Others have attempted to develop prediction equations with sample sizes similar to ours (18). However, most experts agree that a minimum of 100-400 subjects are necessary to develop and validate accurate prediction equations (24). Therefore with our small sample ( $n=35$ ), it was not statistically possible or practical to develop an accurate regression equation specific to this group. Nevertheless, in an attempt to establish the relative importance of each of the variables tested by Treuth et al., stepwise linear regression was conducted using our data. The variables entered into our model were the same as those used by Treuth et al. Similar to the Treuth et al. equation, sagittal diameter was the first variable to enter into the equation. However, contrary to the Treuth equation, the R square change for the remaining variables (DXA trunk fat, age, waist circumference) were not significant, and therefore, none of these variables significantly added to our equation. Thus, DXA trunk fat % was not a significant predictor of IAAT for our sample. In regards to the Treuth et al. equation, it is surprising that the R square change (0.80 to 0.81) for the addition of DXA trunk fat % was significant.

The results from the current study indicate that the Treuth et al. equation was not able to adequately estimate IAAT in obese women. Unfortunately, it was not statistically feasible to develop a new regression equation for obese women. However, the results from this study support the call for researchers to develop new prediction equations and/or different DXA software/hardware to estimate IAAT in high-risk populations such as obese

women. Although DXA technology is a safe and fairly inexpensive estimate of body composition, its limitations in accurately assessing regional adiposity may restrict its use for estimating IAAT.

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