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Total body skeletal muscle and adipose tissue volumes: estimation from a single abdominal cross-sectional image

Wei Shen, Mark Punyanitya, ZiMian Wang, Dympna Gallagher, Marie-Pierre St-Onge, Jeanine Albu, Steven B. Heymsfield, and Stanley Heshka

Obesity Research Center, St. Luke’s-Roosevelt Hospital, and Institute of Human Nutrition, Columbia University, College of Physicians and Surgeons, New York, New York 10025

Submitted 16 July 2004; accepted in final form 12 August 2004

Shen, Wei, Mark Punyanitya, ZiMian Wang, Dympna Gallagher, Marie-Pierre St-Onge, Jeanine Albu, Steven B. Heymsfield, and Stanley Heshka. Total body skeletal muscle and adipose tissue volumes: estimation from a single abdominal cross-sectional image. J Appl Physiol 97: 2333–2338, 2004. First published August 13, 2004; doi:10.1152/japplphysiol.00744.2004.—A single abdominal cross-sectional computerized axial tomography and magnetic resonance imaging is often obtained in studies examining adipose tissue (AT) distribution. An abdominal image might also provide additional useful information on total body skeletal muscle (SM) and AT volumes with related physiological insights. We therefore investigated the relationships between abdominal SM and AT areas from single images and total body component volumes in a large and diverse sample of healthy adult subjects. Total body SM and AT volumes were derived by whole body multislice magnetic resonance imaging in 123 men [age (mean ± SD) of 41.6 ± 15.8 yr; body mass index of 25.9 ± 3.4 kg/m²] and 205 women [age of 47.8 ± 18.7 yr; body mass index of 26.7 ± 5.6 kg/m²]. Single abdominal SM and AT slice areas were highly correlated with total body SM (r = 0.71–0.92; r = 0.90 at L4–L5 intervertebral space) and AT (r = 0.84–0.96; r = 0.94 at L4–L5 intervertebral space) volumes, respectively. R² increased by only 5.7–6.1% for SM and 2.7–4.4% for AT with the inclusion of subject sex, age, ethnicity, scanning position, body mass index, and waist circumference in the model. The developed SM and AT models were validated in an additional 49 subjects. To achieve equivalent power to a study measuring total body SM or AT volumes, a study using a single abdominal image would require 17–24% more subjects for SM and 6–12% more subjects for AT. Measurement of a single abdominal image can thus provide estimates of total body SM and AT for group studies of healthy adults.

METHODS

Protocol and design. The primary study aim was to examine the relationships between single cross-sectional abdominal image areas and the total volumes of SM and AT across age and ethnicity groups in a large sample of healthy adults who completed whole body MRI studies. Although the L₄–L₅ level is the most commonly used location for estimating VAT area (1, 3, 7, 9, 10, 15, 17, 25), we also examined models using other abdominal locations.

Subjects. The model development group included 328 healthy subjects archived in the Image Analysis Laboratory database of the Weight Control Unit, 1090 Amsterdam Ave., 14th floor, New York City, NY 10025 (E-mail: WS2003@Columbia.edu).
New York Obesity Research Center (NYORC) at St. Luke’s-Roosevelt Hospital. The database was compiled from studies carried out between 1995 and 2002. We also included 42 subjects who had participated in two studies at the School of Dietetics and Human Nutrition, McGill University (27, 28). The total selected sample of the model development group included 123 men and 205 women. The model validation group consisted of a convenience sample of 49 healthy subjects from the NYORC database. The subject characteristics are summarized in Table 1.

### Table 1. Subject characteristics

<table>
<thead>
<tr>
<th>Sample size</th>
<th>Ethnicity</th>
<th>Age, yr</th>
<th>Weight, kg</th>
<th>Height, cm</th>
<th>Body mass index, kg/m²</th>
<th>Underweight, &lt;18.5</th>
<th>Normal weight, 18.5–24.9</th>
<th>Overweight, 25.0–29.9</th>
<th>Obese, ≥30.0</th>
<th>Waist circumference, cm</th>
<th>Skeletal muscle, liters</th>
<th>Adipose tissue, liters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td>Women</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>123</td>
<td>205</td>
<td>41.6±15.8</td>
<td>81.3±12.0</td>
<td>177.0±7.0</td>
<td>25.9±3.4</td>
<td>2</td>
<td>48</td>
<td>57</td>
<td>16</td>
<td>87.5±10.1</td>
<td>31.2±5.4</td>
<td>20.6±8.0</td>
</tr>
<tr>
<td>Women</td>
<td></td>
<td>47.8±18.7</td>
<td>70.0±15.4</td>
<td>162.1±7.1</td>
<td>26.7±5.6</td>
<td>7</td>
<td>87</td>
<td>48</td>
<td>63</td>
<td>82.1±14.4</td>
<td>20.5±4.1</td>
<td>28.2±12.5</td>
</tr>
</tbody>
</table>

### Anthropometric measurements

Body weight was measured to the nearest 0.1 kg and height to the nearest 0.1 cm using appropriately calibrated scales and stadiometers. WC measurements were available for all subjects at the NYORC, including 99 men and 187 women. WC was measured with the subjects wearing only their undergarments and standing with their heels together. Minimum WC was measured between the lower rib margin and the iliac crest.

### MRI

Whole body MRI was carried out as previously reported by our group (6, 11). At the NYORC, MRI scans were prepared using a 1.5-T General Electric system (6X Horizon, Milwaukee, WI), and at the School of Dietetics and Human Nutrition images were prepared using a 1.5-T Siemens system (Magnetom, Mississauga, Canada). All subjects were scanned with a T1-weighted, spin-echo sequence with a 210-ms repetition time, a 17-ms echo time, a 48-cm field of view, and a matrix of 256×256. The protocol involved acquisition of approximately forty 10-mm-thick axial images at 40-mm intervals from fingers to toes with the subject in either a prone or supine position, using the L₁–L₄ intervertebral disc as the point of origin. After image acquisition, AT and SM were segmented by trained and quality-controlled technicians using image analysis software (SliceOmatic, Tomovision, Montreal, Canada). Thresholding methods were first applied with the threshold set for each individual slice, and then manual delineation was used to draw boundaries among different tissues when necessary. The intraclass correlation coefficient for volume rendering of AT and SM by different technicians at the NYORC is 0.99 and 0.99, respectively. Total body AT and SM volumes were calculated as:

\[ V = (t + h) \sum_{i=1}^{N} A_i \]

where \( V \) is volume, \( A_i \) is each scan’s cross-sectional area, \( h \) is the between-slice interval, \( t \) is the thickness of each slice, and \( N \) is the number of total slices (22).

Six cross-sectional MRI abdominal slices from 10 cm below to 15 cm above L₄–L₅ were included for examining the correlations between image areas and total body volumes (Table 2).

### Statistical methods

Group data are presented as means ± SD. The correlations among single-slice abdominal areas and total body component volumes were calculated for each of the six slices. The results were then used to identify the slice areas showing the highest correlation with corresponding component volumes.

Two prediction models for total body SM volume were developed, one based on the selected slice showing the highest correlation between SM area and volume and the other for the commonly measured L₄–L₅ slice. The variances of the residuals from the regression model using L₄–L₅ vs. the model with the selected slice were compared using Pitman’s test for correlated variances (23). Differences between correlated correlation coefficients were tested using the method of Steiger (26). Similar models were developed for predicting AT volume from areas.

Multiple regression models were applied to establish whether the relation between SM area and volume and the other for the commonly measured L₄–L₅ slice is modified by variables including sex, age, ethnicity, and adipose tissue are presented as means ± SD. *Asian sample is a multigeneration mixture of Chinese, Indian, Korean, and Japanese. †Data for waist circumference were available in 99 men and 187 women in the model development group and in all subjects in the model validation sample.

### Table 2. Pearson correlations between component areas and volumes for individual transverse slices below or above the L₄–L₅ level

<table>
<thead>
<tr>
<th>Slices</th>
<th>Correlation Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>−10 cm</td>
<td>0.838</td>
</tr>
<tr>
<td>−5 cm</td>
<td>0.712</td>
</tr>
<tr>
<td>L₄–L₅</td>
<td>0.898</td>
</tr>
<tr>
<td>+5 cm</td>
<td>0.924</td>
</tr>
<tr>
<td>+10 cm</td>
<td>0.903</td>
</tr>
<tr>
<td>+15 cm</td>
<td>0.857</td>
</tr>
<tr>
<td>Skeletal muscle</td>
<td>0.961</td>
</tr>
<tr>
<td>Adipose tissue</td>
<td>0.963</td>
</tr>
</tbody>
</table>

All correlation coefficient are significant at \( P < 0.001 \), and coefficients at +5 cm for skeletal muscle (SM) and −5 cm for adipose tissue (AT) are significantly greater than the corresponding correlations at the L₄–L₅ level (SM, \( P < 0.01 \); AT, \( P < 0.001 \)). Negative and positive values are below and above the L₄–L₅ level, respectively. Bold numbers are the correlation coefficients of highest correlation between single slice and total tissue volume.
prone or supine subject position, body mass index (BMI), and WC. Interactions of the SM areas with other variables were explored. Two- and three-way interactions among covariates were also tested. The validity of the predicted equation when applied in samples other than the one in which it was developed was evaluated by calculating the cross-validation standard deviation of the prediction error. This procedure involves deriving a regression equation from \( n - 1 \) cases and applying the derived equation to predict the dependent variable in the excluded case, i.e., the leave-one-out method (4). Similar analyses were performed for the AT volume prediction models.

The values for total body SM and AT volumes were calculated for each subject in the model validation group using the developed prediction equations. The observed differences between estimated and actual total body SM and AT volumes were tested for significance using Student’s \( t \)-tests, and the level of agreement was assessed according to the method of Bland and Altman (2).

All statistical analyses were carried out using SPSS (SPSS for Windows, version 11.0, SPSS, Chicago, IL). Two-tailed \( (P = 0.05) \) tests of significance were used.

RESULTS

Image areas vs. volumes. The correlations between slice areas and volumes ranged between \( r = 0.712 \) and 0.963 and are summarized in Table 2. The highest correlation between a SM area and SM volume was located 5 cm above the L4-L5 level \( (r = 0.924) \). The highest correlation between an AT area and AT volume was located 5 cm below the L4-L5 level \( (r = 0.963) \) (Table 2). The highest correlation coefficients are significantly \( (SM, P < 0.01; AT, P < 0.001) \) greater than those observed at the L4-L5 level. Scatter plots showing the relations of the image areas at 5 cm above the L4-L5 level for SM and 5 cm below the L4-L5 level for AT with the volumes are shown in Fig. 1.

Estimates of SM and AT volumes. The SM area 5 cm above the L4-L5 level \( (\text{in cm}^2) \) and AT area 5 cm below the L4-L5 level \( (\text{in cm}^2) \) were selected for inclusion in the multiple regression models as independent variables, with corresponding total volumes as dependent variables. The component areas at the L4-L5 level were also investigated by multiple regression modeling with total volumes set as the dependent variables.

The coefficients for the developed regression equations are shown in Table 3 for the selected slices and Table 4 for the L4-L5 level. The standard deviation of the prediction error for the selected slices derived by the leave-one-out method was 2.663 liters for SM and 3.163 liters for AT. The standard deviation of the prediction error of the regression model for the selected slices was 2.648 liters for SM and 3.148 liters for AT. For L4-L5 level images, the standard deviation of the prediction error derived by the leave-one-out method was 3.072 liters for SM and 3.881 liters for AT. The standard deviation of the prediction error of the regression model for the selected slices was 3.057 liters for SM and 3.863 liters for AT. The small size of the difference between these two errors indicates that the developed regression equation would have a high validity when applied to similar samples other than the one on which it was developed.

The contributions of sex, age, ethnicity, prone and supine position, BMI, and WC as significant covariates to the developed model are shown in Table 3 (selected slices) and Table 4 \( (\text{L4-L5 level}) \). Although some of these factors were significant either as main effects or in two- and three-way interactions, they only improved the \( R^2 \) in the range of 0.001–0.023 for the selected slices and 0.003–0.033 for the L4-L5 level. When all of the significant factors were entered either as main effects or as interactions, the \( R^2 \) increased from 0.854 to 0.911 for SM and from 0.927 to 0.952 for AT for the selected slices, and from 0.806 to 0.867 for SM and from 0.889 to 0.933 for AT for the L4-L5 level.

With the equations using only the selected SM or AT slice area as the independent variable, the 95% confidence interval for an individual subject’s estimated SM is \( \pm 5.190 \) liters and for AT is \( \pm 6.170 \) liters. With the equations using only the L4-L5 level areas as independent variables, the 95% confidence interval for an individual subject’s estimated SM is \( \pm 5.992 \) liters and for AT is \( \pm 7.571 \) liters. Single-slice imaging using appropriate anatomic locations can thus be used to distinguish reliably between subjects who differ in SM volume by \( \pm 10.4–12.0 \) liters and AT volume by \( \pm 12.3–15.1 \) liters. Pitman’s test for correlated variances confirmed that the residual variance of the L4-L5 model was greater than that for the models using the selected slice \( (P < 0.001) \). This indicates that the errors for predictions based on the L4-L5 level are significantly larger than those based on the level 5 cm above L4-L5 for SM and 5 cm below L4-L5 for AT.

![Skeletal Muscle](image-url)

![Adipose Tissue](image-url)

Fig. 1. Relationship between total body skeletal muscle (SM) volumes and SM area 5 cm above L4-L5 \( (\text{top}) \) and total body adipose tissue (AT) volume and AT area 5 cm below L4-L5 \( (\text{bottom}) \). Both the coefficients for AT and SM areas and the intercepts of the respective equations are significantly different from 0 \( (P < 0.001) \). Note that the x- and y-axis scales are different in the top and bottom.
Innovative Methodology

2336 SINGLE-SLICE ESTIMATION

Table 3. Regression models linking skeletal muscle areas 5 cm above L4-L5 to skeletal muscle volume, and adipose tissue areas 5 cm below L4-L5 to adipose tissue volume

<table>
<thead>
<tr>
<th></th>
<th>Skeletal Muscle</th>
<th>Adipose Tissue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equation with single slice area</td>
<td>$V = 0.166 \times A_{1.5} + 2.142$</td>
<td>$V = 0.0681 \times A_{-5} + 4.142$</td>
</tr>
<tr>
<td>+ Covariates</td>
<td>$R^2 = 0.854$</td>
<td>$R^2 = 0.927$</td>
</tr>
<tr>
<td>Position†</td>
<td>0.857</td>
<td>Sex†</td>
</tr>
<tr>
<td>Sex‡</td>
<td>0.877</td>
<td>BMI‡</td>
</tr>
<tr>
<td>Age‡</td>
<td>0.860</td>
<td>WC‡</td>
</tr>
<tr>
<td>BMI§</td>
<td>0.859</td>
<td></td>
</tr>
<tr>
<td>WC*</td>
<td>0.866</td>
<td></td>
</tr>
<tr>
<td>+ Interactions§</td>
<td>$A_{1.5} \times \text{position}^*$</td>
<td>$A_{-5} \times \text{position}^*$</td>
</tr>
<tr>
<td>$A_{1.5} \times \text{age}^‡$</td>
<td>0.859</td>
<td>$A_{-5} \times \text{age}^‡$</td>
</tr>
<tr>
<td>$A_{1.5} \times \text{ethnicity}^*$</td>
<td>0.856</td>
<td>$A_{-5} \times \text{position} \times \text{sex}^†$</td>
</tr>
<tr>
<td>$A_{1.5} \times \text{age} \times \text{BMI}^*$</td>
<td>0.933</td>
<td>$A_{-5} \times \text{sex} \times \text{age}^‡$</td>
</tr>
<tr>
<td>$A_{1.5} \times \text{WC} \times \text{BMI}^*$</td>
<td>0.873</td>
<td>$A_{-5} \times \text{sex} \times \text{BMI}^*$</td>
</tr>
</tbody>
</table>

$^*P < 0.05; \; †P < 0.01; \; ‡P < 0.001. \; §These 3-way interactions include all 2-way interactions in the model. V, volume (in liters); $A_{1.5}$, area 5 cm above L4-L5 level (in cm²); $A_{-5}$, area 5 cm below L4-L5 level (in cm²); BMI, body mass index; WC, waist circumference.

With the equation using the image area as the independent variable and covariates including sex, age, ethnicity, prone and supine position, BMI, and WC, the 95% confidence interval for an individual subject’s SM volume is about ±4.097 liters for the selected slice and ±5.023 liters for the L4-L5 level. The corresponding estimates for AT volume are ±5.050 liters for the selected slice and ±5.931 liters for the L4-L5 level.

Validation of prediction in an independent group. The mean values of SM and AT volumes measured by whole body MRI and single image-predicted SM and AT volumes are presented for the validation group in Table 5. Predicted total body SM and AT volumes derived from both the best slices and the L4-L5 slice did not differ significantly from measured SM and AT volumes in the model validation group. Bland-Altman analysis did not disclose a significant bias between predicted and measured SM and AT volumes (Table 5).

Power estimates. Total body SM and AT volumes as measured by the whole body protocol were taken as the “true” values, and the squared correlations between individual slice locations and SM and AT volumes were considered estimates of individual slice reliability as a measure of SM and AT volumes. We then calculated the relative loss of power when using a single image slice to predict total volume (16). To achieve equivalent power, a study requiring $n$ subjects with multiple slice measures of SM volume as the dependent variable would require 17% more subjects if a single slice area is measured 5 cm above L4-L5 and 24% more for L4-L5. For AT, 6% more subjects for a slice area 5 cm below L4-L5 and 12% more subjects at L4-L5 would be required to achieve equivalent power.

DISCUSSION

The correlations between abdominal cross-sectional image areas and total body component volumes were examined in a large sample that included subjects varying in ethnicity, age, and BMI. Generally, we found that high correlations exist between abdominal SM and AT areas from individual slices and respective total body SM and AT volumes. This agrees with the few previously reported associations between AT area at the L4-L5 level and total body AT ($r = -0.95–0.99$) (13, 14, 19, 20). Specifically, we observed the highest correlation between a single-slice SM area and total body SM volume $\sim 5$ cm above the L4-L5 level and between a single-slice AT area and total body AT volume $\sim 5$ cm below the L4-L5 level. Regression models based on these single cross-sectional image SM and AT areas accurately predicted respective total body SM and AT volumes in a model validation sample of healthy subjects.

When we examined the effects of subject sex, age, ethnicity, body scanning position, BMI, and WC on the strength of the associations between the single-image SM and AT areas and total body SM and AT volumes, all covariates and their interactions increased the explained variance (i.e., $R^2$) by $<2.3–3.3%$. Thus a single-slice image without covariates may

Table 4. Regression models linking skeletal muscle areas to skeletal muscle volume, and adipose tissue areas to adipose tissue volume at L4-L5 level

<table>
<thead>
<tr>
<th></th>
<th>Skeletal muscle</th>
<th>Adipose tissue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equation with single slice area</td>
<td>$V = 0.173 \times A_{L4-L5} + 0.934$</td>
<td>$V = 0.0626 \times A_{L4-L5} + 5.383$</td>
</tr>
<tr>
<td>+ Covariates</td>
<td>$R^2 = 0.806$</td>
<td>$R^2 = 0.889$</td>
</tr>
<tr>
<td>Sex‡</td>
<td>0.846</td>
<td>Sex†</td>
</tr>
<tr>
<td>Age‡</td>
<td>0.849</td>
<td>BMI‡</td>
</tr>
<tr>
<td>Ethnicity*</td>
<td>0.812</td>
<td>WC*</td>
</tr>
<tr>
<td>$A_{L4-L5} \times \text{sex}^*$</td>
<td>0.849</td>
<td>$A_{L4-L5} \times \text{age}^‡$</td>
</tr>
<tr>
<td>$A_{L4-L5} \times \text{BMI}^*$</td>
<td>0.810</td>
<td>$A_{L4-L5} \times \text{BMI}^*$</td>
</tr>
<tr>
<td>$A_{L4-L5} \times \text{WC} \times \text{BMI}^*$</td>
<td>0.830</td>
<td>$A_{L4-L5} \times \text{BMI}^*$</td>
</tr>
</tbody>
</table>

$^*P < 0.05; \; †P < 0.01; \; ‡P < 0.001. \; §These 3-way interactions include all 2-way interactions in the model. $A_{L4-L5}$, component area at L4-L5 level (in cm²).
be used to represent total body SM and AT volumes across a wide range of healthy subjects.

Because single-slice imaging can only be used to distinguish reliably between subjects who differ in SM volume by \( \pm 10.4-12.0 \) liters and AT volume by \( \pm 12.3-15.1 \) liters, the use of a single-image SM or AT area estimate, therefore, has limited application when individual subjects are evaluated. However, in group studies, using an appropriate single-slice area would require only 17% more subjects for estimating total body SM and 6% more subjects for estimating total body AT than a multislice, whole body volume protocol. Using a single-slice area at L4-L5 would require 24% more subjects for SM and 12% more subjects for AT estimates than a multislice, whole body volume protocol, indicating that an appropriately selected slice can be used for group studies. For future large-scale studies, investigators thus have the option of increasing the subject sample size and thereby reducing the complexity and cost of image acquisition and analysis. Nevertheless, because increasing the sample size may be difficult and costly for certain kinds of studies (e.g., subjects with diseases), a whole body imaging protocol might remain the best choice.

Investigators who already have acquired single abdominal images in their physiological research can now use our reported models to make estimates of group total body SM or AT. The standard deviations of single-slice AT or SM areas are presented in Table 6 for investigators desiring to establish whether their sample size is adequate to detect significant between-group differences of a desired magnitude.

Over the past two decades, the L4-L5 image slice has served as a measure of abdominal AT, particularly VAT, in most studies investigating related biological questions (1, 3, 7, 9, 10, 15, 17, 25). A small number of studies included evaluation of a single image or several images other than the L4-L5 image (5, 8, 24). Our study provides an opportunity for investigators interested in total body SM and AT to derive this information from a single cross-sectional image in addition to abdominal AT. Although we identified the images showing the highest correlations between SM and AT areas with corresponding total component volumes, rather than recommend a specific slice location, we provide flexibility by presenting prediction models for different abdominal anatomic levels.

There are several limitations of the present study. We did not have continuous scans across the whole body, and we also could not study specific anatomic landmarks such as L2-L3 or L3-L4. It is also reasonable to speculate that the slices with the highest correlations with total body SM and AT volumes may be at locations other than the abdominal region, especially the thigh and leg region. However, because the starting point of our MRI protocol is at the L4-L5 level, we did not have standardized anatomic locations of the thigh or leg region. Using landmarks such as 40 cm below the L4-L5 level will represent different locations depending on subject height. Thus we did not attempt to examine single slices located outside of the abdominal region.

In conclusion, single abdominal SM or AT slice areas are highly correlated with corresponding total body SM and AT volumes. The SM area 5 cm above the L4-L5 level had the highest correlation with total body SM volume, and the AT area 5 cm below L4-L5 had the highest correlation with total body AT volume. The influence of age, sex, ethnicity, prone and supine imaging position, BMI, and WC on the relations between SM and AT areas and respective total body SM and AT volumes is relatively small. Although a single-slice image has limited applicability for estimating total body SM or AT volumes in individuals, the present results indicate that statistically powerful group comparison SM and AT volumes.

### Table 6. Standard deviation of single-slice skeletal muscle and adipose tissue areas*

<table>
<thead>
<tr>
<th></th>
<th>Caucasian</th>
<th>African American</th>
<th>Hispanic</th>
<th>Asian</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Men</td>
<td>Women</td>
<td>Men</td>
<td>Women</td>
</tr>
<tr>
<td>n</td>
<td>66</td>
<td>89</td>
<td>29</td>
<td>91</td>
</tr>
<tr>
<td>L4-L5</td>
<td>28.0</td>
<td>26.5</td>
<td>33.2</td>
<td>25.2</td>
</tr>
<tr>
<td>L5-L6</td>
<td>26.1</td>
<td>25.2</td>
<td>28.4</td>
<td>26.5</td>
</tr>
<tr>
<td>L4-L5</td>
<td>117.5</td>
<td>179.9</td>
<td>76.9</td>
<td>164.1</td>
</tr>
<tr>
<td>L5-L6</td>
<td>133.8</td>
<td>197.9</td>
<td>104.6</td>
<td>182.3</td>
</tr>
</tbody>
</table>

*Because of the small number of subjects (n), the values in Asian and Hispanic groups should be used cautiously.

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Innovative Methodology
Innovative Methodology

SINGLE-SLICE ESTIMATION

volume studies may be conducted economically using single abdominal cross-sectional SM and AT areas.

GRANTS

This study was supported by National Institutes of Health Grants DK-42618 and 1R21 DK-66360-01, R29 AG-14715, F32 AG-05679, M01 RR-00645, R01 DK-40414, and P30 DK-26687.

REFERENCES


