Comparison of dual-energy X-ray absorptiometry and magnetic resonance imaging–measured adipose tissue depots in HIV-infected and control subjects1–4

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ABSTRACT

Background: Studies in persons without HIV infection have compared adipose tissue measured by dual-energy X-ray absorptiometry (DXA) and magnetic resonance imaging (MRI), but no such study has been conducted in HIV-infected (HIV+) subjects, who have a high prevalence of regional fat loss.

Objective: We compared DXA- with MRI-measured trunk, leg, arm, and total fat in HIV+ and control subjects.

Design: A cross-sectional analysis was conducted in 877 HIV+ subjects and 260 control subjects in FRAM (Study of Fat Redistribution and Metabolic Change in HIV Infection), stratified by sex and HIV status.

Results: Univariate associations of DXA with MRI were strongest for total and trunk fat ($r \geq 0.92$) and slightly weaker for leg ($r \geq 0.87$) and arm ($r \geq 0.71$) fat. The average estimated limb fat was substantially greater for DXA than for MRI for HIV+ and control men and women (all $P < 0.0001$). Less of a difference was observed in trunk fat measured by DXA and MRI, but the difference was still statistically significant ($P < 0.0001$). Bland-Altman plots showed increasing differences and variability. Greater average limb fat in control and HIV+ subjects (both $P < 0.0001$) was associated with greater differences between DXA and MRI measurements. Because the control subjects had more limb fat than did the HIV+ subjects, greater amounts of fat were measured by DXA than by MRI when control subjects were compared with HIV+ subjects. More HIV+ subjects had leg fat in the bottom decile of the control subjects by DXA than by MRI ($P < 0.0001$).

Conclusions: Although DXA- and MRI-measured adipose tissue depots correlate strongly in HIV+ and control subjects, differences increase as average fat increases, particularly for limb fat. DXA may estimate a higher prevalence of peripheral lipodystrophy than does MRI in HIV+ subjects. Am J Clin Nutr 2008;88:1088–96.

INTRODUCTION

Both dual-energy X-ray absorptiometry (DXA) and magnetic resonance imaging (MRI) have been used in previous studies to measure regional and total adiposity, but each method relies on assumptions that are not always recognized or appropriate. Only MRI and computed tomography (CT) can directly measure adipose tissue (1) and measure visceral and subcutaneous adipose tissue (SAT) separately. The major limitations include the cost and limited availability of MRI and the radiation exposure associated with CT. Most studies use DXA because of its availability and relatively low cost. DXA uses proprietary equations to estimate the amount of fat based on relative density. DXA quantifies fat, rather than adipose tissue. According to the 5-level body-composition classification system (2), fat is a molecular-level component and adipose tissue is a tissue-level component. Eighty percent of adipose tissue is composed of fat (3, 4). On the other hand, fat can be distributed in tissue other than adipose tissue, such as liver and muscle (3). There is a high correlation between DXA-measured fat and MRI- or CT-measured adipose tissue. Compared with MRI and CT, DXA cannot separate visceral fat from subcutaneous trunk fat and cannot discern organ fatty infiltration.

In the setting of HIV infection, the introduction of combination antiretroviral therapy was followed by the observation of changes in fat distribution and metabolic abnormalities (5). In the era of antiretroviral therapy, HIV infection has been associated with a syndrome of lipodystrophy, which is characterized by a loss of SAT, particularly in the limbs and lower trunk, without loss of visceral adipose tissue (VAT) (6, 7). It is therefore of interest whether measurements of fat by DXA and MRI are comparable in patients with HIV infection and whether earlier conclusions...
based on MRI can be extrapolated to DXA. It is also of interest whether the measurement choice affects the estimated prevalence of lipoatrophy.

To date, only small studies have compared DXA and MRI measurements of regional adipose tissue depots in HIV-infected (HIV+) (8) and control (9–11) subjects. A primary aim of the Study of Fat Redistribution and Metabolic Change in HIV Infection (FRAM) was to compare regional adipose tissue quantified by both DXA and MRI in a large, nationally representative, multiethnic cohort of HIV+ and control subjects.

SUBJECTS AND METHODS

Protocol and subjects

FRAM enrolled 1175 HIV+ and 297 control men and women between 2000 and 2002. FRAM was designed to evaluate the prevalence and correlates of changes in fat distribution, insulin resistance, and dyslipidemia in a representative sample of HIV+ and control subjects in the United States. The methods were described in detail previously (12). HIV+ subjects were recruited from 16 HIV or infectious disease clinics or cohorts in 1999. Control subjects were recruited from 2 centers of the Coronary Artery Risk Development in Young Adults (CARDIA) study (13). CARDIA subjects were originally recruited as a sample of healthy white and African American men and women aged 18–30 y from 4 cities in 1985–1986 for a longitudinal study of cardiovascular disease risk factors. Subjects were recruited from the general population in 3 of the cities and from the membership of a prepaid health care program in the fourth city. CARDIA subjects from the year 15 exam were recruited for the FRAM cohort. The protocol was approved by institutional review boards at all sites.

MRI and DXA measurements were available in 78% of FRAM participants. Most of the subjects underwent DXA and MRI on the same day (76%), within the same week (9%) or the same month (9%). Only 6% of the subjects received DXA and MRI >1 mo apart. Subjects were asked to fast before MRI and DXA scanning and were excluded if they had contraindications to MRI and control subjects. Tissue areas (cm²) were calculated by summing specific tissue pixels and then multiplying by individual pixel surface area. The volume per slice (cm³) of each tissue was calculated by multiplying area by thickness. The volume of each tissue for the space between 2 consecutive slices was calculated via a mathematical algorithm (15). When a single limb was outside the field of view, volume in the measured limb was doubled to obtain total limb volume. For comparison with DXA, adipose tissue volumes from MRI were multiplied by 0.9 kg/L to convert to kg fat mass, because adipose tissue has a density of 0.9 g/cm³ (16). Anatomic sites considered in this analysis were as follows: trunk (defined as upper trunk plus lower trunk plus VAT), arm, leg, and total adipose tissue.

Dual energy X-ray absorptiometry

Total and regional body fat contents were measured with DXA scanners manufactured by GE Lunar (Madison, WI) or Hologic Inc (Bedford, MA). Lunar models used in this study included Prodigy, DPX, DPX-IQ, and DPX-L. Hologic models included QDR 2000 (pencil beam) and 4500 (fan beam) machines. To assist standardization of the values obtained on DXA scanning, a whole-body phantom was sent to all sites for scanning (Bio Imaging Technologies Inc; 17). DXA scans were analyzed centrally at the Obesity Research Center, St Luke’s–Roosevelt Hospital with the use of image analysis software provided by the respective scanner manufacturers. DXA scans from GE Lunar were analyzed by using DPX software (version 4.7E) and Prodigy software (version 12.1). DXA scans from Hologic Inc were analyzed by using QDR software (version 11.1). From the DXA scans, total body fat and 3 regions were evaluated: trunk, leg, and arm. The arm region is separated from the trunk region at the glenohumeral joint, whereas the leg region is separated from the pelvic region at an angle perpendicular to the femoral neck. The superior end of the trunk region is constrained at a level just below the chin. Fat mass was calculated as total mass minus bone mineral content minus lean soft tissue. The CV for all DXA instruments was 3.3% for fat.

Statistical methods

Spearman correlation coefficients were calculated to examine the relation of each DXA-measured adipose tissue with the corresponding MRI-measured region (trunk, leg, arm, and total), because many measures were found to be nonnormally distributed. For each region, differences between DXA and MRI were compared by using Wilcoxon’s signed-rank test. The percentage difference between DXA and MRI was calculated as follows:
Comparisons of adipose tissue mass measured by dual-energy X-ray absorptiometry (DXA) or magnetic resonance imaging (MRI) in HIV-infected (HIV+) and control subjects by sex

**TABLE 2**

<table>
<thead>
<tr>
<th>Sex and region</th>
<th>DXA (kg)</th>
<th>MRI (kg)</th>
<th>Spearman’s $\rho$</th>
<th>DXA (kg)</th>
<th>MRI (kg)</th>
<th>Spearman’s $\rho$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Men</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$n$</td>
<td>625</td>
<td>625</td>
<td>135</td>
<td>135</td>
<td>125</td>
<td>125</td>
</tr>
<tr>
<td>Trunk fat</td>
<td>7.5 (4.9–10.9)$^3$</td>
<td>7.0 (4.7–10.7)$^3$</td>
<td>0.92</td>
<td>10.7 (7.5–14.1)</td>
<td>10.0 (7.1–13.3)$^3$</td>
<td>0.94</td>
</tr>
<tr>
<td>Leg fat</td>
<td>3.2 (2.1–5.1)</td>
<td>2.6 (1.8–3.6)$^3$</td>
<td>0.87</td>
<td>7.2 (5.8–9.4)</td>
<td>4.2 (3.4–5.5)$^3$</td>
<td>0.91</td>
</tr>
<tr>
<td>Arm fat</td>
<td>1.2 (0.8–1.8)</td>
<td>0.9 (0.7–1.2)$^3$</td>
<td>0.71</td>
<td>2.3 (1.8–2.9)</td>
<td>1.0 (0.8–1.3)$^3$</td>
<td>0.82</td>
</tr>
<tr>
<td>Total fat</td>
<td>12.9 (9.1–18.7)</td>
<td>10.7 (7.9–15.5)$^3$</td>
<td>0.92</td>
<td>21.3 (16.8–27.3)</td>
<td>15.4 (11.8–20.4)$^3$</td>
<td>0.95</td>
</tr>
<tr>
<td><strong>Women</strong></td>
<td>252</td>
<td>252</td>
<td>125</td>
<td>125</td>
<td>125</td>
<td>125</td>
</tr>
<tr>
<td>Trunk fat</td>
<td>12.1 (7.6–16.2)</td>
<td>13.2 (8.2–18.8)$^3$</td>
<td>0.96</td>
<td>13.6 (7.3–19.5)</td>
<td>14.2 (8.2–20.5)$^3$</td>
<td>0.96</td>
</tr>
<tr>
<td>Leg fat</td>
<td>7.8 (5.4–11.1)</td>
<td>6.0 (4.1–8.9)$^3$</td>
<td>0.95</td>
<td>12.5 (9.6–15.8)</td>
<td>8.3 (6.1–10.7)$^3$</td>
<td>0.93</td>
</tr>
<tr>
<td>Arm fat</td>
<td>2.5 (1.6–3.6)</td>
<td>1.4 (0.9–2.1)$^3$</td>
<td>0.85</td>
<td>3.6 (2.5–4.9)</td>
<td>1.8 (1.2–2.3)$^3$</td>
<td>0.88</td>
</tr>
<tr>
<td>Total fat</td>
<td>23.6 (15.9–32.5)</td>
<td>20.9 (13.5–29.6)$^3$</td>
<td>0.96</td>
<td>31.6 (20.9–40.1)</td>
<td>25.3 (16.0–32.9)$^3$</td>
<td>0.96</td>
</tr>
</tbody>
</table>

1 Subjects with missing measurements of adipose tissue by MRI or DXA were excluded from the data. MRI volumes were multiplied by 0.9 kg/L to convert them to kg.

2 Median; interquartile range in parentheses (all such values).

3 Significantly different from DXA, $P < 0.0001$ (Wilcoxon’s signed-rank test).
continuous measures by adding quadratic terms to the models and by examining generalized additive models (20). To account for possible differences between study sites, likelihood ratio testing was used to determine whether a random site effect should be added to the model. CIs were determined by using the bias-corrected accelerated bootstrap method (21), with $P$ values defined as the one minus the highest confidence level that still excluded zero; this was necessary because the error residuals appeared to be non-Gaussian. All analyses were conducted by using the SAS system, version 9.1 (SAS Institute Inc, Cary, NC).

RESULTS

Subjects

Body composition measurements by MRI and DXA were available for 1137 subjects whose characteristics are presented in Table 1. Compared with HIV+ subjects, control subjects were slightly taller and weighed more ($P \leq 0.001$) and had greater amounts of fat and adipose tissue as measured by DXA and MRI (Table 2).

Univariate comparisons between DXA and MRI

DXA-estimated fat was consistently larger than MRI-estimated adipose tissue ($P < 0.0001$) in every depot and subgroup, with the exception of trunk in women, for which the MRI-measured value was larger than the DXA-measured value (Table 2). Despite these large differences, all DXA-measured fat depots were strongly correlated with their corresponding MRI measures ($r = 0.71$ to $0.96$; all $P < 0.0001$), but correlations tended to be slightly weaker for arm than for leg, trunk, and total fat (Table 2).

The percentage difference between DXA and MRI was greater for leg and arm and less for trunk (Figure 1). In control subjects, the median percentage difference in DXA-estimated fat compared with MRI-estimated adipose tissue was up to 69% higher for leg and up to 120% higher for arm. In HIV+ subjects, the median percentage difference in DXA-estimated fat compared with MRI was up to 30% higher for leg and up to 75% higher for arm. The difference was much less for trunk fat; the median DXA measure was 5% higher in men and 9% lower in women than was the MRI measure, for both control and HIV+ subjects. Similarly, the median percentage differences were larger for total fat in...
control subjects than in HIV+ subjects (up to 20% higher in HIV+ subjects and up to 35% higher in control subjects; \( P < 0.0001 \)).

Bland-Altman analysis was used to assess the agreement between DXA and MRI by plotting the difference (DXA - MRI) against the amount of fat by using the average of the 2 methods. The largest relative differences between DXA and MRI were found for limb fat, whereas trunk fat showed the least difference (Figure 2). More bias was seen for the control subjects than for the HIV+ subjects for leg, arm, and total fat (all \( P < 0.01 \) for HIV+ compared with control subjects; test of difference in \( \rho \)). As measured by SEE, precision appeared similar in HIV+ and control subjects.

The amount of bias increased and the precision decreased as the average amount of limb fat increased. For example, at 5 kg of average leg fat, the estimated bias (mean ± SD) was 1.3 ± 1.7 in HIV+ subjects and 1.6 ± 1.3 in control subjects. By contrast, at 15 kg of leg fat, estimated bias was 3.9 ± 5.2 in HIV+ subjects and 4.8 ± 3.9 in control subjects.

Bias in trunk fat was weaker and showed sex differences. A weak positive bias was seen in men, which indicated that DXA tended to estimate higher amounts of trunk fat than did MRI as average trunk fat increased, whereas a negative bias was seen in women. In men, more trunk fat bias was seen in control subjects than in HIV+ subjects (\( P = 0.0003 \)); in women, more bias was seen in the HIV+ subjects (\( P < 0.0001 \)).

An examination of ethnic differences found that correlations between DXA and MRI measurements tended to be slightly stronger in African Americans than in whites, regardless of HIV status (differences in \( r = 0.04 \) to 0.11, \( P < 0.003 \)). Bland-Altman analysis showed similar bias in African Americans and whites; an exception was seen for trunk fat, ie, trunk fat showed a slight positive bias (in contrast with the negative bias seen for other women) for white control women but no bias for African American HIV+ men (in contrast with the positive bias seen for other men).

### Prevalence of lipoatrophy by DXA and MRI

Because leg SAT is the depot most affected by HIV lipoatrophy, we compared the distributions of leg fat by DXA and of adipose tissue mass by MRI (Figure 3). HIV+ subjects had a dramatically lower distribution of leg fat than did control subjects as measured by both DXA and MRI (\( P < 0.0001 \) in both men and women). However, a more pronounced upward shift in the distribution of DXA-estimated leg fat than in MRI-estimated leg fat was observed in control subjects. The prevalence of lipoatrophy

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**FIGURE 2.** Bland-Altman plots of comparisons in leg fat (A), arm fat (B), total fat (C), trunk fat in men (D), and trunk fat in women (E) in HIV-infected (HIV+) (○) and control (□) subjects estimated by dual-energy X-ray absorptiometry (DXA) and magnetic resonance imaging (MRI). Note that the y axes are different in panels B and C.
in HIV+ subjects, on the basis of leg fat (defined as being in the lowest decile of control subjects by DXA and MRI), was higher with DXA than with MRI in both men (69% of HIV+ men by DXA compared with 50% of HIV+ men by MRI; \( P < 0.0001 \)) and women (47% of HIV+ women compared with 33% of HIV+ women; \( P < 0.0001 \)).

**Multivariable associations with difference between DXA and MRI**

To further explore the findings of differences in measurement of leg and trunk fat, we conducted multivariable analyses to examine the associations of HIV status, demographics, and DXA machine with DXA-MRI differences (Table 3). Trunk fat estimates showed differences between DXA and MRI for women compared with men (−1.24 kg; \( P < 0.0001 \)), for African Americans compared with whites (−0.76 kg; \( P < 0.0001 \)), for the DXA Hologic machine compared with the Lunar machine (−1.13 kg; \( P = 0.003 \)), and with increasing age (0.15-kg increase per decade; \( P = 0.039 \)), but little difference in trunk fat was seen between HIV+ subjects and control subjects (−0.96 kg; \( P = 0.084 \)) after adjustment.

Unlike the findings with trunk fat, the largest difference in leg fat by DXA compared with MRI was in HIV status, ie, the difference was larger in control subjects than in HIV+ subjects (2.2 kg; \( P < 0.0001 \)). The difference in DXA compared with MRI was larger in women than in men (0.94 kg; \( P < 0.0001 \)) and in African Americans than in whites (0.46 kg; \( P < 0.0001 \)).

**DISCUSSION**

Although DXA-measured fat is strongly correlated with MRI-measured adipose tissue, our main finding was that associations were biased in both HIV+ and control populations. As the average amount of fat increases, the difference between DXA and MRI tends to increase, with DXA giving larger estimates of fat, particularly for limb fat. Because control subjects have more limb fat than do HIV+ subjects and because control subjects showed a greater upward shift in DXA-measured fat, DXA estimated a higher prevalence of peripheral lipodystrophy than did MRI in HIV+ subjects. Although there is no accepted cutoff that defines HIV-associated lipodystrophy, we compared the prevalence of subjects with leg SAT below the 10th percentile with that of the control subjects and found a higher prevalence of this definition of lipodystrophy by DXA than by MRI. In contrast, differences in DXA and MRI trunk fat estimates were much

**FIGURE 3.** Density plots of comparisons of leg fat in HIV-infected (HIV+) and control (C) men (A and B) and women (C and D) by dual-energy X-ray absorptiometry (DXA) (A and C) and magnetic resonance imaging (MRI) (B and D). Distribution of height-normalized leg fat is shown by histogram; the smoothed density curves were created by using kernel density estimation. The decile reference line was defined by using cutoffs from the control men or women. Lipoatrophy was defined as having leg fat below the 10th percentile cutoff of control men.
smaller in all subgroups, and there were sex- and race-related
differences.

DXA and MRI measure distinct but overlapping compart-
ments. DXA estimates fat content by tissue density, whereas
MRI measures adipose tissue volume. In addition to cellular
lipids, adipose tissue contains extracellular water (≈12% of
total volume in analyses of excised specimens; 22), a small amount
of intracellular water, other types of cells besides adipocytes,
and extracellular solids. Although these relations may be affected
by fat depletion and composition changes related to lipatrophy,
these factors do not fully explain the findings because bias was
also seen in control subjects. Furthermore, if the inclusion of the
nonlipid component obtained in the MRI analysis was the cause
of the difference, one would expect MRI to give higher results
than DXA; however, the opposite was true.

Our finding that DXA and MRI are highly correlated but have
important biases is supported by previous work in smaller studies
of HIV-uninfected subjects. A positive bias was found in a com-
parison of DXA- with MRI-measured limb fat in a small study of
16 healthy men and women (11). A study of 13 healthy premeno-
pausal women found a high correlation but poor agreement be-
 tween DXA, MRI, and underwater-measured adiposity, with differences
between DXA and MRI attributed to fat calibration errors (9).
Investigators concluded that no method can yet be regarded as a satisfactory reference technique.

Our finding that bias is proportional to the average amount of
fat is similar to findings in the general population of more errors
by DXA in healthy men with higher adiposity and body thickness
(23). Park et al believe that the precision and accuracy of DXA-
measured trunk fat may be diminished by several factors, such as
observer error in delineating specific regions because of the
inability of X-rays to detect the small amount of soft tissue mass.

For the trunk, we found positive bias in men, but negative bias
in women. This may have been due to the fact that DXA
estimates do not differentiate between intraabdominal and
subcutaneous fat, and the women in our study had less VAT
but more upper and lower trunk SAT than did the men in both
the HIV + and control groups (6, 7). A small 12–16-wk study
of HIV + subjects (8) found that DXA and MRI estimates of
changes in SAT and VAT were strongly associated ($R^2 =
0.70, P < 0.001$), although DXA estimated larger changes in
total body fat than did MRI.

A possible contributor to these differences is that DXA-
measured fat also includes fat that MRI cannot detect in adipose
tissue. For example, in the trunk region, fat in the liver, intestine,
and all other visera are not included in MRI-measured adipose
tissue. Likewise, intramuscular fat cannot be detected by MRI.
In addition, small adipose tissue deposits below the resolution of MRI
are not included in MRI estimates. These small adipose tissue
depots include some of the VAT and intramuscular adipose tissue
depots in both the trunk and limb regions. These differences may
partially explain why DXA-measured fat is higher than MRI-
measured adipose tissue. Additionally, in our MRI and DXA
protocol, the cutoff between limbs and trunk in MRI and DXA
were not identical. DXA-measured limb fat may include more
hip fat than MRI-measured limb adipose tissue. The bias identi-
ified in the Bland–Altman analysis may also be due to more fat
in the hip region in heavier subjects, and women have more fat in
the hip region than do men. However, these latter issues do not
apply to arm fat, which shows similar trends.

What is the significance of these differences between DXA
and MRI? Both DXA and MRI have been used in previous
studies to estimate regional and total adiposity in HIV infection,
but results from studies using DXA may not be directly extrap-
olated to studies in which MRI or other methods are used. Con-
sequently, comparisons of HIV + and control subjects and the
prevalence or amount of lipatrophy will differ depending on
which method is used to quantify regional adipose tissue and on
how lipatrophy is defined. However, when certain guidelines
are followed (24), DXA has been found to have adequate internal
validity for measuring body-composition changes.

One limitation of our study was the lack of an absolute refer-
ence standard for estimating regional fat quantities. Another
limitation was that several different DXA machine models were
used in this study. A previous study found that, although fan- and
pencil-beam models are highly correlated, small but significant
differences exist between the instruments (25). However, sensi-
tivity analysis including only Hologic machines, admittedly in-
cluding both fan- and pencil-beam models, did not change our

### Table 3

Multivariable associations of HIV status, demographics, and dual-energy X-ray absorptiometry (DXA) machine with differences between measurements by DXA and magnetic resonance imaging (MRI)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Trunk fat Estimate (95% CI)</th>
<th>P value</th>
<th>Leg fat Estimate (95% CI)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>2.01 (0.67, 3.35)</td>
<td>0.006</td>
<td>2.83 (1.94, 3.72)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>HIV status, HIV + vs control</td>
<td>-0.96 (-2.04, 0.13)</td>
<td>0.084</td>
<td>-2.21 (-2.93, -1.49)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Sex, female vs male</td>
<td>-1.24 (-1.49, -1.00)</td>
<td>&lt;0.0001</td>
<td>0.94 (0.75, 1.13)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Age, per decade</td>
<td>0.15 (0.01, 0.30)</td>
<td>0.039</td>
<td>-0.08 (-0.19, 0.03)</td>
<td>0.16</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>African American vs white</td>
<td>-0.76 (-1.00, -0.51)</td>
<td>&lt;0.0001</td>
<td>0.46 (0.27, 0.65)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Hispanic vs white</td>
<td>0.12 (-0.31, 0.56)</td>
<td>0.57</td>
<td>0.27 (-0.07, 0.60)</td>
<td>0.12</td>
</tr>
<tr>
<td>Other vs white</td>
<td>0.04 (-0.70, 0.78)</td>
<td>0.91</td>
<td>0.05 (-0.52, 0.63)</td>
<td>0.85</td>
</tr>
<tr>
<td>DXA machine, Hologic vs GE Lunar</td>
<td>-1.13 (-1.89, -0.38)</td>
<td>0.003</td>
<td>0.25 (-0.26, 0.75)</td>
<td>0.34</td>
</tr>
</tbody>
</table>

1 Subjects with missing measurements of adipose tissue by MRI or DXA were excluded from the data. Outcome is DXA – MRI fat (kg). Each model controlled for HIV status, sex, ethnicity, age, machine type, and random site effects.
2 Age is centered so that the intercept corresponds to 40 y of age.
3 Hologic Inc (Bedford, MA) and GE Lunar (Madison, WI).
key finding that DXA is more likely than MRI to detect lipoatrophy in HIV+ subjects. DXA and MRI estimates of regional fat also differ because the cuts are slightly different: DXA cuts are at an angle perpendicular to the femoral neck, whereas MRI cuts are perpendicular to the longitudinal axis of the body. Although the vast majority of subjects had DXA and MRI scans performed on the same day, we also examined the association of time between scans on differences between DXA- and MRI-measured fat but found little association ($\rho = -0.02$ or less, $P > 0.70$). Finally, direct comparison is limited by the fact that DXA measures fat by attenuation of X-ray, whereas MRI directly measures AT volume (3).

Additional studies in other populations are required to characterize the differences between DXA and MRI measurements of adipose tissue, including a study of the effect of testing differences on the clinical outcomes of the 2 techniques. Comparison of DXA and MRI with other methods, such as CT, should also be made among HIV+ subjects, because small studies of HIV-uninfected subjects have found important differences in variability and accuracy between these 3 methods (26, 27). For example, the slice traditionally used in CT studies of VAT is not as good a marker of visceral adiposity as is that used in MRI measures (28). In the current study, we found that although DXA-measured adipose tissue correlated strongly with MRI-measures in both HIV+ and control subjects, the differences between MRI and DXA increased as the average amount of fat increased, particularly for limb fat. DXA may therefore estimate a higher prevalence of peripheral lipoatrophy in HIV+ subjects. Both leg and arm fat were higher when measured by DXA, but the DXA-MRI differences varied among important subgroups, such as leg fat between HIV+ and control subjects and trunk fat between men and women. Therefore, caution is advised when making comparisons of fat measured with different techniques.

The authors’ responsibilities were as follows—RS: contributed to the analysis and interpretation of the data, drafting of the manuscript, critical revision of the manuscript for important intellectual content, and statistical analysis; SBH, WS, and MP: contributed to the conception and design of the study, analysis and interpretation of the data, and critical revision of the manuscript for important intellectual content and statistical analysis; and Slide revising for important intellectual content and obtained funding; PB, DK, CEL, and MGS: contributed to the conception and design of the study, analysis and interpretation of the data, drafting of the manuscript, critical revision of the manuscript for important intellectual content, and statistical analysis. No conflicts of interest were declared.

REFERENCES


APPENDIX A

Sites and investigators

University Hospitals of Cleveland (Barbara Gripshover); Tufts University (Abby Shevitz and Christine Wanke); Stanford University (Andrew Zolopa and Lisa Gooze); University of Alabama at Birmingham (Michael Saag and Barbara Smith); Johns Hopkins University (Joseph Cofrancesco and Adrian Dobs); University of Colorado Health Sciences Center (Constance Benson and Lisa Kosmiski); University of North Carolina at Chapel Hill (Charles van der Horst); University of California at San Diego (W Christopher Mathews and Daniel Lee); Washington University (William Powderly and Kevin Yarasheski); VA Medical Center, Atlanta (David Rimland); University of California at Los Angeles (Judith Currier and Matthew Leibowitz); VA Medical Center, NY (Michael Simberkoff and Juan Blandes); VA Medical Center, WA DC (Cynthia Gibert and Fred Gordin); St Luke’s–Roosevelt Hospital Center (Donald Kotler and Ellen Engelson); University of California at San Francisco (Morris Schambelan and Kathleen Mulligan); Indiana University (Michael Dube); Kaiser Permanente, Oakland (Stephen Sidney); University of Alabama at Birmingham (Cora E Lewis).

Data Coordinating Center

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St Luke’s–Roosevelt Hospital Center (Steven Heymsfield, Jack Wang, and Mark Punyanitya).

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University of California (San Francisco), Veterans Affairs Medical Center, and the Northern California Institute for Research and Development (Carl Grunfeld, Phyllis Tien, Peter Bachetti, Dennis Osmond, Andrew Avins, Michael Shlipak, Rebecca Scherzer, Mae Pang, Heather Southwell, Erin Madden, and Yong Kyoo Chang).