Sex- and menopause-associated changes in body-fat distribution\(^1\)\(^{-3}\)

Christopher J Ley, Belinda Lees, and John C Stevenson

**ABSTRACT** We investigated sex- and menopause-related differences in body composition and regional fat distribution, using dual-energy X-ray absorptiometry (DEXA) in nonobese healthy volunteers. Men \((n = 103)\) had a 50% greater lean tissue mass \((P < 0.001)\) but a 13% lower fat mass \((P < 0.001)\) than the women \((n = 131)\). Postmenopausal \((n = 70)\) women had a 20% greater fat mass \((P < 0.001)\) than premenopausal \((n = 61)\) women. The proportion of android (upper body) fat was greatest in men \((48.6\%, P < 0.001)\) but was significantly lower in premenopausal \((38.3\%)\) than in postmenopausal \((42.1\%)\) women \((P < 0.001)\). The reverse was found for gynoid (lower body) fat \((P < 0.001)\). DEXA measurements thus clearly demonstrated that sex differences in total fat mass were opposite those of android fat, and that marked menopausal changes in fat mass and its distribution existed. Body mass indices did not demonstrate that men had less total fat than women whereas postmenopausal women had more total fat than did premenopausal women. Our findings suggest that DEXA measurements of fat distribution may be useful for studies related to obesity-associated disease risk. *Am J Clin Nutr* 1992;55:950-4.

**KEY WORDS** Sex, menopause, body composition, regional fat distribution

**Introduction**

Several studies have illustrated a relationship between body-fat distribution and cardiovascular-disease risk \((1{-3})\). An android pattern of fat distribution refers to the ventral or upper body fat whereas a gynoid fat is lower-body-segment fat, particularly in the hips and thighs. Android fat has been related directly to an increase in the development of cardiovascular disease \((2)\) as well as indirectly through lipid profiles associated with cardiovascular risk \((4)\), whereas gynoid fat has not. However, the significance of this concept of android and gynoid-body-fat distribution has been based on indirect measures.

Recent technological advances have refined the assessment of body-fat distribution. Commonly used measures such as skinfold thickness and girth reflect fat mass indirectly. Although highly sophisticated techniques such as hydrodensitometry, neutron-activation analysis, and computed tomography overcome these problems, they are expensive and are therefore not readily available. In addition, some involve significant radiation exposure. Thus, such methods are not suitable for routine assessment of regional body-fat distribution. By contrast, the new dual-energy X-ray absorptiometry (DEXA) technique enables both peripheral and central regional measurements of different soft tissue types \((5)\). DEXA is both rapid and safe, and the equipment required is much less expensive than for other whole-body techniques.

Although DEXA is a reliable technique for measuring body composition, with the precision of soft tissue measurements being < 4% \((5{-7})\), its usefulness in studies of large groups is yet to be demonstrated because previous assessments have usually included only small sample sizes with a narrow age range. Furthermore, relatively little emphasis has been placed on the potential of the technique for assessment of regional fat distribution. The older technique of dual-photon absorptiometry has been used to measure abdominal fat mass \((8, 9)\) but its precision is more variable and its measurement area more limited than that of total body scans.

We used DEXA to study normal, nonobese males and females to define sex differences and the effects of menopause on body composition.

**Subjects and methods**

We studied 234 healthy Caucasian adult volunteers, 103 men aged 21–79 y and 131 women aged 19–63 y. They were selected from those who either attended the Wynn Institute for Metabolic Research for a routine health check or who were acting as untreated control subjects for various sex-steroid studies. Sixty-one (aged 19–51 y) women were premenopausal as judged by a regular menstrual cycle and no menopausal symptoms; 70 women (aged 43–63 y) were postmenopausal as judged by amenorrhea and elevated gonadotrophin concentrations. None of the subjects was obese [body mass index (BMI; in kg/m\(^2\)) 18.8–28] and all were in apparent good health; none were taking any medication known to affect lipid or bone metabolism. In particular, none of the women was receiving sex-steroid therapy. Full informed consent was obtained from each subject and the study was approved by the local ethical committee. The study was conducted in accordance with the provisions of the Declaration of Helsinki (Hong Kong revision), 1989.

DEXA measurements were performed with a total body scanner (DPX, Lunar Radiation Corp, Madison, WI). Whole-body...
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FIG 2. Manually determined boxed regions of interest in the android and gynoid regions.

FIG 1. Default regions produced by Lunar software. Android (upper body segment) fat is separated from gynoid (lower body segment) fat by the oblique lines passing through the hip joints.

Measurements were taken, enabling quantification of bone, lean, and fat tissue (5, 10).

Scans were performed with a transverse speed of 16 cm/s, or 8 cm/s if body weight was > 90 kg in men and body weight was > 70 kg in women, giving scan times of 10 or 20 min, respectively, and radiation doses of 0.05 and 0.1 μGy, respectively, for the total-body measurements (5).

Default software readings provided lines positioned to divide body measurements into areas corresponding to arms, legs, and trunk (Fig 1).

The trunk region was delineated by an upper horizontal border below the chin, vertical borders lateral to the ribs, and a lower border formed by the oblique lines passing through the hip joints. This region thus included the upper-body-segment fat (android fat) and excluded most of the fat from the hips and thighs (gynoid region). The leg region was defined as the tissue below the oblique lines passing through the hip joints, thus primarily reflecting the lower-body-segment (gynoid) region. The proportion of android fat or lean tissue was determined by the amount of fat or lean tissue in the trunk region whereas the proportion of gynoid fat or lean tissue was determined by the amount of fat or lean tissue in the leg region, both expressed as a % of total fat or lean tissue. In addition, manually determined regions of interest were defined in a subgroup of volunteers as follows (Fig 2): 1) Android waist region—between the upper part of the body of D12 and the iliac crest and its sides lateral to any trunk soft tissue. 2) Android subscapular region—the same box height positioned so that its lower border was at the level of the upper part of the body of D12 and its sides lateral to any trunk soft tissue. 3) Gynoid hip region—the same box height positioned so that its upper aspect passed through the most superior points of the inner pelvis, and its sides lateral to any trunk soft tissue. 4) Gynoid thigh region—the same box height positioned so that its superior border was at the level of the inferior border of the gynoid hip boxed region. The proportion of fat in these regions was determined by the amount of fat (expressed as a % of total body fat). The precisions for these measurements were determined by four repeated measurements on five volunteers over 8 wk. Precision of total lean and total fat mass measurements in terms of CV were 1.8 ± 0.54% and 2.9 ± 1.2%, respectively; CVs for the regional measurements were all < 5%. BMI was calculated as weight/height².

Analyses of variance and covariance were used to examine differences between the groups, together with two-tailed unpaired Student's t tests (11).
TABLE 1
Demographic data and total and regional body soft tissue distribution in men, women, and subgroups of pre- and postmenopausal women*

<table>
<thead>
<tr>
<th></th>
<th>Men (n = 103)</th>
<th>Women (n = 131)</th>
<th>Premenopausal women (n = 61)</th>
<th>Postmenopausal women (n = 70)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>51 ± 13</td>
<td>43 ± 12†</td>
<td>32 ± 6</td>
<td>53 ± 5§</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>178 ± 7</td>
<td>164 ± 6†</td>
<td>164 ± 6</td>
<td>164 ± 7</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>78.2 ± 8.1</td>
<td>61.6 ± 7.1†</td>
<td>59.6 ± 6.7</td>
<td>63.3 ± 6.9§</td>
</tr>
<tr>
<td>BMI</td>
<td>24.7 ± 1.9</td>
<td>22.9 ± 2.3†</td>
<td>22.1 ± 2.2</td>
<td>23.5 ± 2.2§</td>
</tr>
<tr>
<td>Total fat (kg)</td>
<td>18.0 ± 4.0</td>
<td>20.8 ± 5.6†</td>
<td>18.8 ± 5.7</td>
<td>22.6 ± 5.0§</td>
</tr>
<tr>
<td>Total lean tissue (kg)</td>
<td>56.3 ± 5.3</td>
<td>37.6 ± 3.3†</td>
<td>37.6 ± 3.5</td>
<td>37.6 ± 3.2</td>
</tr>
<tr>
<td>Trunk fat (kg)</td>
<td>8.8 ± 2.2</td>
<td>8.5 ± 2.8</td>
<td>7.3 ± 2.7</td>
<td>9.6 ± 2.5§</td>
</tr>
<tr>
<td>Proportion of android fat (%)</td>
<td>48.6 ± 4.7</td>
<td>40.3 ± 5.2†</td>
<td>38.3 ± 5.3</td>
<td>42.1 ± 4.5§</td>
</tr>
<tr>
<td>Leg fat (kg)</td>
<td>6.3 ± 1.5</td>
<td>8.9 ± 2.2†</td>
<td>8.4 ± 2.2</td>
<td>9.4 ± 2.0§</td>
</tr>
<tr>
<td>Proportion of gynoid fat (%)</td>
<td>35.4 ± 4.3</td>
<td>43.4 ± 4.8†</td>
<td>45.1 ± 5.1</td>
<td>41.9 ± 3.9§</td>
</tr>
<tr>
<td>Scapular fat (%)</td>
<td>13.5 ± 2.2</td>
<td>11.4 ± 1.4†</td>
<td>11.4 ± 1.2</td>
<td>11.3 ± 1.5</td>
</tr>
<tr>
<td>Waist fat (%)</td>
<td>18.1 ± 2.9</td>
<td>12.8 ± 2.2†</td>
<td>12.0 ± 1.9</td>
<td>13.2 ± 2.3§</td>
</tr>
<tr>
<td>Hip fat (%)</td>
<td>18.1 ± 1.8</td>
<td>19.8 ± 2.2†</td>
<td>19.4 ± 2.3</td>
<td>20.1 ± 2.1</td>
</tr>
<tr>
<td>Thigh fat (%)</td>
<td>12.5 ± 2.3</td>
<td>17.1 ± 3.2†</td>
<td>17.8 ± 2.0</td>
<td>16.7 ± 3.6</td>
</tr>
</tbody>
</table>

* x ± SD.
† Significantly different from males, P < 0.001.
§§† Significantly different from premenopausal women: §P < 0.001, §P < 0.01, §P < 0.05.
II Body mass index (in kg/m²).

Results

Sex differences

Demographic characteristics of the groups are shown in Table 1. The men were older than the women but the age ranges were similar for both sexes. BMI was slightly greater in men than in women and was also slightly greater in postmenopausal women than in premenopausal women.

Total body mass was greater for men as was total lean mass whereas total fat mass was greater in women. Total body weight calculated from the DEXA scans closely correlated with actual body weight from scales (r = 0.999, P < 0.001).

In both men and women, 84% of the total body fat was found in the trunk and legs. Trunk fat mass was not significantly different between men and women but the proportion of android fat was significantly higher in men. Leg fat mass was significantly greater in women as was the proportion of gynoid fat.

These differences remained significant after adjusting for age and height or BMI. The manually derived regions did not provide better discrimination than the default regions (Table 1).

Menopausal-status differences

Although there was no difference in total lean tissue mass, total fat mass was greater in postmenopausal women.

Trunk fat mass and the proportion of android fat were lower in premenopausal women. Leg fat mass was greater in the postmenopausal women but the proportion of gynoid fat was actually significantly greater in premenopausal women. Again, these differences were not accentuated by comparing manually selected regions (Table 1).

All differences between pre- and postmenopausal women remained significant after adjusting for height or BMI. There was no significant relationship between body-composition measurements and age in either the premenopausal or postmenopausal women.

The differences in the proportions of android and gynoid fat between men and premenopausal and postmenopausal women are illustrated in Figures 3 and 4.

Discussion

Our results illustrate sex differences in both the amounts of soft tissue and their pattern of distribution. They confirm increased total body lean tissue in men and increased total body fat in women. The proportion of android fat is greater in men whereas that of gynoid fat is greater in women. A striking finding is the effect of menopause on fat distribution. There is an increase in android fat but a relative reduction in gynoid fat in post-
menopausal women. Thus, compared with premenopausal women, fat distribution in postmenopausal women is changing towards that of a man. These findings confirm the preliminary observations of Edwards (12).

In many different studies, standardization of data for height, degree of obesity, and age is often done but standardization of these indices for sex effects is particularly difficult. Corrections with use of BMI to standardize results are common. However, BMI is an index not a direct measure. Moreover, the use of BMI has recently attracted some criticism (13, 14). It has been suggested that BMI may be stature dependent over at least part of the age range, affected by leg length, and may reflect both lean and fat tissue to a comparable degree (13). In particular, the sex dependency of BMI is illustrated by recent studies, suggesting that BMI should be expressed as wt/ht² for men but as wt/ht or wt/ht¹.³ for women (15). Our data show that the higher BMI in men than in women reflects a greater lean tissue mass whereas the higher BMI in postmenopausal than in premenopausal women reflects a greater fat mass. By direct measurement of fat and lean tissue in different regions, the difficulties resulting from indices such as BMI are overcome. Moreover, we demonstrated that marked differences in amounts of fat in men and women exist, even after adjusting for age and height.

It has been stated that a weight-height index will never differentiate sex-related forms of obesity (android and gynoid) or the different health risks associated with them (14, 16). Similarly, our data illustrate that, although sex differences in total fat mass exist, they do not parallel the marked sex differences in coronary heart disease incidence. In contrast, the changes in fat distribution do.

Previous reports of differences in regional fat distribution used only indirect measures (17-21). The variability of these measures, such as skinfold thickness, is well known (22). Waist-to-hip ratios are claimed to be better than measures of skinfold thickness as predictors of cardiovascular risk (23). However, both types of measurements are indirect and include tissue other than fat; they provide only a qualitative assessment of regional fat mass and its distribution. In particular, hip-girth measurements reflect not only fat but also known differences between male and female pelvic structures, and thus overestimate sex differences in fat distribution. Conversely, as our findings suggest, thigh circumferences underestimate sex differences in fat distribution because the decreased lean tissue in the legs of women would reduce the effect of increased fat. In addition, our data demonstrate that there is a real difference in fat distribution in women after menopause and the pattern approaches that of men. Lack of ability to demonstrate a menopause-associated effect previously (24), with waist-hip ratios self-reported by the individuals taking part in this large population study, may be related to study design. A much earlier report (12) based on skinfold thicknesses suggested such a menopause effect even with very small sample sizes, although statistical significance of the effect was not reported.

Since the initial report of Vague (18), many other studies have shown that increased cardiovascular risk is associated with increased upper-body obesity (1, 2, 19, 25). More recently, such an association was demonstrated for angiographically documented coronary heart disease (3). Metabolic changes associated with increased android fat may be important.

Studies have demonstrated that android-body-fat distribution is associated with diabetes (18, 26, 27) where increased very-low-density-lipoprotein (VLDL) cholesterol, low-density-lipoprotein (LDL) cholesterol, insulin, and blood pressure are more prevalent (28). These factors are all known to be associated with an increased risk of developing cardiovascular disease. In non-diabetics, android-body-fat distribution has also been reported to be linked directly with hyperinsulinemia (29) and insulin resistance (29, 30) and with adverse lipid profiles (4, 31), metabolic factors that are all thought to increase cardiovascular risk.

Differences in regional fat metabolism exist and are sex dependent (32). Indeed, sex hormones themselves produce different responses in the metabolism of fat from different regions (32). Such sex differences in regional fat metabolism may in part explain the well-documented sex differences associated with the incidence of cardiovascular risk. The relationship of the amount of abdominal fat to its metabolism and to menopausal status requires further definition.

The onset of menopause has been suggested to be a risk factor for cardiovascular disease in women (33). We know of no previous reports directly assessing menopausal changes in fat distribution. Although these changes might be inferred by comparisons of data of cohorts of young and old women from previous studies (17, 20), actual menopause status was not defined. Android fat distribution is greater in postmenopausal women than in premenopausal women and is greater still in men than in postmenopausal women, a pattern that mirrors the increasing incidence of cardiovascular disease seen for these groups.

Measures produced by DEXA and other imaging techniques provide good reproducibility and provide measures of fat mass in absolute terms. DEXA also provides additional advantages over other imaging techniques in that it is safe, simple to use, and rapid. It is thus ideally suited to studies with large populations.

Our boxed regional measurements offer the opportunity to define further specific regions of fat distribution, and perhaps the potential for amplifying differences seen with the default measurements. In addition, the exclusion of trunk and hip soft tissue lying lateral to the default region lines, as well as the potential for large changes in tissue thickness to influence these measures, can be minimized.
In conclusion, our study demonstrates pronounced sex differences and effects of change in menopausal status on body composition and fat distribution in people of normal weight. DEXA is easy to use and offers the potential for determining the importance of altered fat distribution in population studies of many important disease states.

References


