Effects of age on body fat distribution and cardiovascular risk factors in women 1–3

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ABSTRACT We conducted a cross-sectional study of body fat distribution and metabolic variables and the interrelations among these factors in 134 women aged 18–71.9 y. Body fat distribution was measured with use of computerized tomography. A significant positive correlation was observed between age and visceral adipose tissue (VAT) and between VAT and body weight. When subjects were divided into five age groups, VAT values were significantly higher in older groups. Values for triacylglycerols, cholesterol, fasting glucose, 2-h glucose, and the sum of glucose values during an oral-glucose-tolerance test were significantly higher in older subjects. After adjustment for visceral fat, no significant differences in any metabolic variable studied, except cholesterol, were found across the five age groups. In conclusion, we found that regional body fat distribution in older women was different from that in younger subjects: older women had larger amounts of visceral fat. Values for metabolic variables were also higher in older subjects. Our data suggest that redistribution of body fat in older subjects is associated with changes in metabolic variables. Am J Clin Nutr 1997;66:111–5.

KEY WORDS Age, visceral fat, visceral adipose tissue, subcutaneous fat, glucose, lipids, women, cholesterol, triacylglycerols, body fat distribution

INTRODUCTION

Great interest has focused recently on patterns of body fat distribution rather than amounts of fat per se as the real risk factor for cardiovascular disease (1–4). A variety of determinants influence regional body fat distribution, such as obesity, smoking, and age (1). Because it has been shown that body weight varies with age, first increasing up to middle age and then declining (in both sexes) (5), it is important to distinguish between the effect of age and the effect of changes in body weight on body fat distribution.

Cross-sectional and longitudinal studies have shown age-related changes in the pattern of body fat distribution evaluated by measuring waist-to-hip ratios or skinfold thicknesses (6, 7) but few studies (8–10) have examined age-related changes in visceral adipose tissue (VAT) evaluated by computerized tomography (CT). It has also been shown that lipid (11) and glucose (12) concentrations increase with age but the mechanism responsible for these increases is still not fully understood. Central or visceral body fat distribution is associated with abnormalities in carbohydrate and lipid metabolism (13, 14) and thus age-related changes in VAT could be associated with metabolic aberrations in elderly subjects.

The aims of this study were to examine differences across age groups in fat distribution evaluated by CT in women and to examine whether these differences were associated with changes in metabolic variables.

SUBJECTS AND METHODS

Subjects

The study was conducted in 134 women aged 18–71.9 y who had a body mass index (BMI; in kg/m²) of 19–54.7. The subjects were recruited consecutively from patients hospitalized in our institution for treatment of obesity, except for five who were hospitalized for chest or abdominal pain who agreed to undergo CT evaluation of regional body fat distribution. The study was approved by the Ethics Committee of our institution and all subjects gave verbal consent. Subjects were included in the study only after exclusion of disease. None of the subjects had diabetes and none were taking medication known to affect carbohydrate or lipid metabolism. All subjects were free of congestive heart disease and hypertension and were not receiving estrogen replacement therapy. Subjects who had a reduction in weight > 10% over the 6 mo before the study, evaluated by self-recorded measurements of body weight, were excluded. Characteristics of the patients are listed in Table 1. An isonenergetic diet containing 55% carbohydrate, 30% lipids, and 15% protein was given to all subjects for ≥ 3 d before measurement of the metabolic variables.

Physical activity

No particular questionnaires were used to estimate physical activity but we asked each subject how many times a week she

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TABLE 1
Characteristics of the study sample

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>39.9 ± 14.1 (18–71.9)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>97.8 ± 19.3 (48.7–140.1)</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>37.2 ± 7.1 (19–54.7)</td>
</tr>
<tr>
<td>Total adipose tissue (cm³)</td>
<td>678.9 ± 211.6 (34.8–1155)</td>
</tr>
<tr>
<td>Subcutaneous adipose tissue (cm³)</td>
<td>536.2 ± 178.6 (11–946)</td>
</tr>
<tr>
<td>Visceral adipose tissue (cm³)</td>
<td>142.7 ± 76.3 (19.6–400.3)</td>
</tr>
<tr>
<td>Body fat (kg)</td>
<td>48.2 ± 15.2 (1.9–82.4)</td>
</tr>
</tbody>
</table>

1 x ± SD; n = 134; range in parentheses.
2 Calculated according to the method of Sjöström (15) and Kvist et al (16).

engaged in exercise. None of the subjects engaged in regular exercise more than once a week. All subjects had sedentary jobs. The older subjects were still working.

Metabolic variables

For the oral-glucose-tolerance test, patients were given 75 g glucose and blood samples for determining glucose and insulin concentrations were obtained 0, 30, 60, 90, 120, and 180 min after glucose administration. Plasma glucose was measured with a glucose oxidase method analyzer (Beckman Instruments Inc, Palo Alto, CA). The intraassay CV was 1.5%. We examined fasting glucose and 2-h glucose concentrations and the sum of glucose values during the oral-glucose-tolerance test in relation to age and body fat distribution.

For the lipid assessments, venous blood samples were taken after the subjects had fasted overnight. Cholesterol and triacylglycerol concentrations were determined with an automated enzymatic method (Autoanalyzer; Technicon, Tarrytown, NY) (17, 18). High-density-lipoprotein (HDL) cholesterol was measured by using the method of Warnick and Albers (19).

Anthropometric variables

The following anthropometric variables were measured in all subjects: weight, height, BMI, and body fat distribution calculated by measuring abdominal fat areas with use of CT according to the method of Sjöström (20). Total abdominal adipose tissue, abdominal VAT, subcutaneous abdominal adipose tissue, and the ratio of VAT to subcutaneous abdominal adipose tissue were evaluated by a single CT scan done at the level of L4. All CT films were assessed by a blinded observer.

Subject centering was obtained by means of a longitudinal topogram at the level of L4. The preselected attenuation interval was −150 to −50 Hounsfield units. A cursor was used to define the total cross-sectional area and the area of visceral fat (area inside the rectus abdominis muscles). Data were processed with a histogram-based statistical program. The margin of error was 1.1% for double determinations. Total volume of body fat was calculated from total adipose tissue with use of the formula of Sjöström (15) and Kvist et al (16) for female subjects as follows:

Total body fat volume

\[ = 0.0778 \text{ (total adipose tissue area) } - 0.59 \ (I) \]

Total body fat (kg) was obtained by multiplying the mean density (0.923 g/L) of human fat.

Data analysis

Results are presented as mean ± SD. Logarithmic transformation of values for triacylglycerols, cholesterol, HDL cholesterol, and glucose was done to normalize the distribution. Simple correlations were used to evaluate the relations between age and anthropometric variables. Because the effect of age in simple and multiple correlation analyses (age + age²) was negligible, the effect of age² is not reported.

To analyze age-dependent differences in mean values of the anthropometric and metabolic variables, the population sample was categorized according to age (<30, 30–39, 40–49, 50–59, and >59 y). Differences between age groups were assessed by one-way analysis of variance. We also tested for the presence of a linear trend in mean values of the considered variables across the age categories (21). Covariance analysis was used to test differences between mean values of metabolic variables for the different age groups after adjustment for VAT. A significance level of 0.05 was used in all analyses (21).

RESULTS

The correlation matrix for age in relation to the anthropometric variables is shown in Table 2. A significant positive correlation was observed between age and VAT. A positive correlation was also found between VAT and body weight and between subcutaneous adipose tissue weight and body fat.

TABLE 2
Correlation matrix for age in relation to anthropometric variables

<table>
<thead>
<tr>
<th></th>
<th>Age</th>
<th>Body weight</th>
<th>BMI</th>
<th>Total adipose tissue</th>
<th>Subcutaneous adipose tissue</th>
<th>Visceral adipose tissue</th>
<th>Body fat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>1</td>
<td>-0.04</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Body weight</td>
<td>0.098</td>
<td>0.923²</td>
<td>1</td>
<td>1</td>
<td>0.914²</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>BMI</td>
<td>0.105</td>
<td>0.877²</td>
<td>0.914²</td>
<td>1</td>
<td>0.937²</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total adipose tissue</td>
<td>0.133</td>
<td>0.858²</td>
<td>0.859²</td>
<td>0.937²</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Subcutaneous adipose tissue</td>
<td>0.601²</td>
<td>0.423²</td>
<td>0.523²</td>
<td>0.579²</td>
<td>0.258²</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Visceral adipose tissue</td>
<td>0.105</td>
<td>0.877²</td>
<td>0.914²</td>
<td>0.999²</td>
<td>0.937²</td>
<td>0.579²</td>
<td>1</td>
</tr>
<tr>
<td>Body fat</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

1 n = 134. Body fat calculated according to the method of Sjöström (15) and Kvist et al (16).
2 p < 0.001 (with correction for multiple comparisons).
3 p < 0.05.
The values for the anthropometric variables in the five age groups are shown in Table 3. No significant differences were observed in body weight, BMI, total adipose tissue, body fat, or subcutaneous adipose tissue across the five age groups whereas VAT was significantly higher in older women. A significant linear trend was found for VAT.

The values for the metabolic variables in the five age groups are shown in Table 4. The values for triacylglycerols, cholesterol, fasting glucose, 2-h glucose, and the sum of glucose values during the oral-glucose-tolerance test were significantly higher in the older groups. A significant linear trend was found for all of these variables except HDL cholesterol.

The mean values for metabolic variables in the five age groups after adjustment for VAT are shown in Table 5. The increases in fasting glucose, 2-h glucose, sum of glucose values during the oral-glucose-tolerance test, and triacylglycerols observed in older subjects disappeared after adjustment. No differences in the age-related increase in cholesterol were observed, even after adjustment for VAT. A significant difference in HDL cholesterol was observed after adjustment for VAT.

DISCUSSION

Our cross-sectional study clearly indicates that regional body fat distribution in older women is different from that in younger women: significantly larger amounts of visceral fat were found in older subjects. Our study also found higher concentrations of triacylglycerols and cholesterol as well as impairment of glucose tolerance in older compared with younger subjects. More importantly, these data suggest that the redistribution of body fat in older subjects was associated with differences in metabolic variables.

Our study expands on earlier work in that we analyzed a larger sample evaluated with CT and included a wider range of ages and BMIs. Cross-sectional studies have already shown age-related differences in VAT (8–10). Borkan et al (8) used CT to compare body fat distribution in 21 middle-aged men with that in 20 older men and reported significantly higher amounts of VAT in the older men even though they weighed 8.2 kg less than the middle-aged men. Enzi et al (9) reported similar results in 130 subjects with a wide range of BMIs. Kotani et al (10) observed significant age-related differences in visceral fat volume in both sexes. Few longitudinal studies have assessed the effect of aging on regional body fat distribution. These studies, which used measurements of skinfold thicknesses or circumferences (5, 6), found age-related increases in central fat distribution. Our cross-sectional data showing larger amounts of VAT in older women than in younger women are therefore not surprising. Actually, the relations among visceral fat, subcutaneous fat, and body weight are complex (16, 22). Relative changes in visceral fat or subcutaneous fat occurring with changes in body weight might be affected by both the initial amount of total adipose tissue and the sex of subjects. Our data seem to suggest that the greater amount of visceral fat observed in older subjects is independent of differences in body weight because we found no significant differences in body weight and BMI across age groups in our subjects.

It was shown previously that menopause itself is capable of modifying body fat distribution by increasing VAT (9, 23). In our study, the majority of women in the 40–49-y age group were premenopausal (23 compared with 6) whereas the majority of those in the 50–59-y age group were postmenopausal (17 compared with 3). Therefore, our findings may be in line with those of Kotani et al (10), who showed that visceral fat accumulates slowly in premenopausal women but that, after menopause, visceral fat increases 2.6 times as rapidly as it does before menopause.

Several possible factors may explain metabolic aberrations in older women but the mechanism is not well understood. Changes in sex steroid hormones observed in menopausal women may be associated with both redistribution of body fat and metabolic abnormalities (24); further studies are necessary to evaluate the relative contribution of these factors. No information about metabolic variables was reported in any of the papers that described redistribution of regional body fat (6–10). To our knowledge, no studies have yet addressed the relations between cardiovascular risk factors and body fat distribution in a cross-sectional analysis that evaluated body fat distribution with use of CT in a large population sample with a wide range of BMIs.

It is well known that regional body fat distribution is associated with alterations in insulin-glucose homeostasis and lipoprotein disorders (13, 14) and, thus, we may reasonably postulate that age-dependent changes in body weight, body fat, or central body fat distribution may play a central part in

### TABLE 3

<table>
<thead>
<tr>
<th>Age</th>
<th>&lt; 30 y</th>
<th>30–39 y</th>
<th>40–49 y</th>
<th>50–59 y</th>
<th>&gt; 59 y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body weight (kg)</td>
<td>98 ± 22.4</td>
<td>100.4 ± 22.9</td>
<td>97.4 ± 14.6</td>
<td>96.6 ± 17.6</td>
<td>94.6 ± 12.4</td>
</tr>
<tr>
<td>(n = 44)</td>
<td>(n = 27)</td>
<td>(n = 29)</td>
<td>(n = 20)</td>
<td>(n = 14)</td>
<td></td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>36.3 ± 7.9</td>
<td>37.7 ± 8.7</td>
<td>37.5 ± 5.2</td>
<td>37.6 ± 6.6</td>
<td>38.1 ± 5.5</td>
</tr>
<tr>
<td>Total adipose tissue (cm²)</td>
<td>647.1 ± 240.8</td>
<td>691.9 ± 256.6</td>
<td>694.3 ± 158.2</td>
<td>690.3 ± 193.5</td>
<td>705.8 ± 144.3</td>
</tr>
<tr>
<td>Subcutaneous adipose tissue (cm²)</td>
<td>558.5 ± 202.2</td>
<td>567.6 ± 215.7</td>
<td>523 ± 133.1</td>
<td>506.1 ± 153.8</td>
<td>484.6 ± 132.1</td>
</tr>
<tr>
<td>Visceral adipose tissue (cm²)</td>
<td>91.3 ± 51.9</td>
<td>124.3 ± 53.5</td>
<td>171.4 ± 69.5</td>
<td>184.2 ± 69</td>
<td>221.2 ± 82.6</td>
</tr>
<tr>
<td>Body fat (kg)</td>
<td>49.6 ± 17.3</td>
<td>49.1 ± 18.4</td>
<td>49.3 ± 11.3</td>
<td>49.0 ± 13.9</td>
<td>50.1 ± 10.4</td>
</tr>
</tbody>
</table>

1 ± SD.
2 Significant differences between age groups, *P* = 0.001, *F* = 17.2 (one-way ANOVA).
3 Significant linear trend for variable across age groups, *P* = 0.0001, *F* = 68.2.
4 Calculated according to the method of Sjöström (15) and Kvist et al. (16).
TABLE 4

Differences in metabolic variables in relation to age

<table>
<thead>
<tr>
<th>Age</th>
<th>&lt; 30 y (n = 44)</th>
<th>30-39 y (n = 27)</th>
<th>40-49 y (n = 29)</th>
<th>50-59 y (n = 20)</th>
<th>&gt; 59 y (n = 14)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glucose (mmol/L)</td>
<td>4.9 ± 0.5</td>
<td>5.4 ± 0.7</td>
<td>5.5 ± 0.7</td>
<td>5.6 ± 0.6</td>
<td>5.9 ± 1.2</td>
</tr>
<tr>
<td>2-h Glucose (mmol/L)</td>
<td>6.4 ± 1.4</td>
<td>7.0 ± 2.1</td>
<td>7.7 ± 2.2</td>
<td>8.1 ± 2.5</td>
<td>9.6 ± 3.6</td>
</tr>
<tr>
<td>Σ Glucose (mmol/L)</td>
<td>40.4 ± 6.7</td>
<td>43.5 ± 8.6</td>
<td>4.79 ± 8.5</td>
<td>47.3 ± 9.7</td>
<td>54.4 ± 17.8</td>
</tr>
<tr>
<td>Cholesterol (mmol/L)</td>
<td>4.8 ± 0.8</td>
<td>4.9 ± 1.0</td>
<td>6.1 ± 1.3</td>
<td>6.0 ± 0.7</td>
<td>6.2 ± 1.8</td>
</tr>
<tr>
<td>Triacylglycerols (mmol/L)</td>
<td>1.4 ± 0.6</td>
<td>1.7 ± 1.0</td>
<td>2.0 ± 0.9</td>
<td>1.9 ± 0.6</td>
<td>2.4 ± 2.3</td>
</tr>
<tr>
<td>HDL cholesterol (mmol/L)</td>
<td>1.2 ± 0.2</td>
<td>1.3 ± 0.4</td>
<td>1.3 ± 0.3</td>
<td>1.4 ± 0.3</td>
<td>1.3 ± 0.3</td>
</tr>
</tbody>
</table>

1 ± SD.
2 Significant differences between age groups, P = 0.0001, F = 7.83-11.1 (one-way ANOVA); significant linear trend for variable across age groups, P = 0.0001, F = 26.5-32.8.
3 Significant differences between age groups, P = 0.001, F = 5.70-6.07 (one-way ANOVA); significant linear trend for variable across age groups, P = 0.0001, F = 22.5-22.6.
4 Sum of glucose values during the oral-glucose-tolerance test.
5 Significant differences between age groups, P = 0.05, F = 4.16 (one-way ANOVA); significant linear trend for variable across age groups, P = 0.001, F = 15.1.

Several other factors or cofactors, such as dietary habits and physical exercise, can negatively influence regional body fat distribution and metabolic variables in old age. We were unable to evaluate physical activity adequately because our data were limited to the number of days a week each subject engaged in exercise. None of the subjects reported exercising more than once a week. Therefore, even if our method of assessing physical exercise appears approximate, we regarded all our subjects (younger and older) as sedentary and thus it is hard to imagine that different patterns of physical exercise may have accounted for the differences in regional body fat distribution and metabolic variables across the five age groups.

There is some evidence that dietary intake, namely, intake of saturated fat, may influence abdominal obesity (30). Unfortunately, we did not evaluate the dietary habits of our subjects and thus the possibility that different fat intakes may have been responsible for the age-related differences in visceral fat we observed cannot be ruled out.

In conclusion, our study showed that regional body fat distribution in older women was different from that in younger subjects: the older women had larger amounts of visceral fat.

Values for the metabolic variables we studied were also higher in the younger groups (women aged 18-59 y) than in the older groups (women aged 60-99 y). The mean differences in BMI, waist circumference, and waist-to-hip ratio were significant between the younger and older groups.

TABLE 5

Differences in metabolic variables in relation to age, adjusted for visceral adipose tissue

<table>
<thead>
<tr>
<th>Age</th>
<th>&lt; 30 y</th>
<th>30-39 y</th>
<th>40-49 y</th>
<th>50-59 y</th>
<th>&gt; 59 y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Σ Glucose (mmol/L)</td>
<td>43.72 [44]</td>
<td>44.49 [26]</td>
<td>46.15 [29]</td>
<td>44.69 [19]</td>
<td>49.46 [14]</td>
</tr>
</tbody>
</table>

1 ± SD.
2 Significant differences between age groups, P = 0.0001, F = 6.66 (one-way ANOVA); significant linear trend across age groups, P = 0.0001, F = 16.4.
3 Significant differences between age groups, P = 0.05, F = 3.57 (one-way ANOVA); significant linear trend across age groups, P = 0.01, F = 10.9.
in older women. Our cross-sectional data suggest that redistribution of body fat in older subjects is associated with changes in metabolic variables and that further longitudinal study of this issue is warranted.

REFERENCES