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Original Article

Increase in Android Fat Mass With Age in Healthy Women With Normal Body Mass Index

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Abstract

Body fat distribution is gender specific: men tend to accumulate adipose tissue in the android region, whereas women tend to do so in the gynoid region. The aim of the study was to assess total fat mass (TFM), android fat (AF), and gynoid fat (GF) mass in a selected group of healthy adult women with normal body mass index (BMI) to evaluate variations in fat distribution. Seventy-seven women (20−69 yr of age) with BMI values between ≥18.5 and ≤24.9 kg/m^2 were included. TMF, AF, GF, and the AF to GF ratio (A:G) were assessed using dual-energy X-ray absorptiometry. Results showed an increase in AF after the fifth decade of life (D), which reached statistical significance in the sixth and seventh decades ($p < 0.05-0.008$), a 33% increase in kg of AF between the fourth and seventh and a 20% increase in A:G between the third and the seventh, with no significant changes in TFM and GF. In normal BMI women, age appears to be associated with changes in fat mass distribution with an increase in AF, which might have potential deleterious health consequences, after the fifth D.

Key Words: Android region; fat mass distribution; gynoid region.

Introduction

The body fat distribution pattern is gender specific in healthy subjects. Men tend to accumulate adipose tissue in the abdominal region (android fat [AF] distribution pattern), whereas women do so in the femoral-gluteal region (gynoid fat [GF] distribution pattern) *(1−3)*. In women, this distribution pattern is primarily determined by the levels of estrogen. It has been demonstrated that body fat distribution tends to follow an android pattern in menopause as a result of low estrogen levels, which is reversed by exogenous administration of estrogens *(4)*. In addition, abdominal fat is distributed in 2 compartments: subcutaneous abdominal adipose tissue and visceral adipose tissue. The latter is considered an endocrine organ because of its capacity to secrete adipocytokines and other substances that are closely associated with metabolic diseases, such as hyperinsulinemia, insulin resistance, type 2 diabetes, dislipidemia, cardiovascular disease, prothrombotic alterations, and metabolic syndrome, among others *(5−9)*.

Different methodologies for estimation of total fat mass (TFM) and distribution are currently available. The most widely used in clinical practice are the anthropometric parameters. Body mass index (BMI) is an indicator of fat mass that relates weight to height, and is used to estimate overweight and obesity. However, it has certain limitations that are detrimental to its precision: it does not allow discriminating fat mass from lean mass; it varies among races, and cannot be applied in subjects who practice high performance sports and may exhibit an increase in weight because of an increase in muscle mass rather than in fat mass *(10)*. Other methods, such as determining waist circumference, waist-hip index,

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and skin fold thickness, are also indirect measures of visceral fat, but their precision is low. Another technique used to assess total body fat is the bioelectric impedance technique; the precision of this technique in estimating total body fat is medium, but its capacity to determine body fat distribution is very limited *(11)*.

Visceral adipose tissue assessment requires more complex radiographic imaging techniques, such as computed tomography (CT) and magnetic resonance imaging (MRI). Both techniques provide more precise measurements of visceral fat, a body region of clinical interest. CT is considered the standard method for assessing visceral adipose tissue. However, the use of CT to study body composition in the clinical practice is limited by its high cost, low availability, and significant exposure of the patient to ionizing radiation. As regards MRI, it does not involve the use of ionizing radiation, thus posing an advantage over CT, and allows applying digital segmentation techniques to automatically separate adipose tissue into subcutaneous fat and visceral fat, but it is a highly complex, expensive technique of limited availability. Dual-energy X-ray absorptiometry (DXA) is an alternative method because it also allows determining body composition (lean and fat mass, and mineral content). DXA offers significant advantages over CT and MRI: more availability, lower cost of equipment, rapid implementation, low cost of the study, good precision, and low radiation *(12−14)*. DXA, as a method for assessing total abdominal fat mass, has been validated against CT and MRI *(15−18)*.

In view of the high incidence of metabolic diseases observed in modern urban communities over the last years, there is increasing interest in assessing body fat. Given that DXA can be used to perform the aforementioned studies, the aim of the present work was to perform an exploratory study to investigate total fat (TF), AF, and GF mass distribution in healthy, normal BMI women, from the third to the seventh decades and analyze the potential age-related changes and the influence of menopausal status.

Methods

Population

The data corresponding to 151 women voluntarily presenting at our center in response to an osteoporosis prevention campaign to undergo densitometric and body composition assessment of total body were retrieved. All subjects were Caucasian and came from an urban area.

Prior to performing the study, a questionnaire on the patient's clinical record and history of diseases known to affect bone was completed. The following exclusion criteria were applied: (1) Women of childbearing age receiving hormonal contraceptives (HCOs) within 12 mo prior to the study; (2) Postmenopausal women receiving hormone replacement therapy (HRT) within 12 mo prior to the study; (3) Women participating in weight loss programs or receiving medication known to or suspected of altering adipose tissue; and (4) Women presenting a health condition or receiving treatment with any medication known to affect mineral metabolism within 12 mo prior to the study. Of the 151 cases retrieved, the data and studies corresponding to 77 women aged 20−69 yr (premenopausal (Pre-MP): 33 and postmenopausal (Post-MP): 44) with BMI values between ≥18.5 and ≤24.9 kg/m^2 were analyzed. Studies corresponding to 74 women were excluded because of overweight (n = 54), obesity (n = 10), HRT (n = 8), and HCO (n = 2) (Fig. 1). All participants signed an informed consent form allowing their data and densitometric studies to be reviewed.

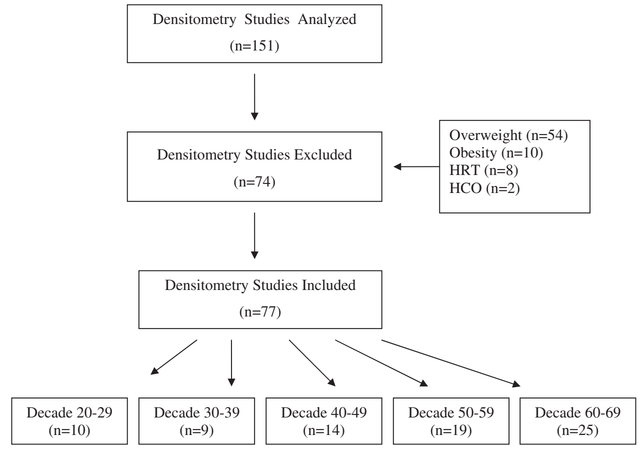

Fig. 1. Algorithm of inclusion and exclusion criteria in densitometry studies corresponding to 151 women evaluated. HRT, hormone replacement therapy; HCO, hormonal contraceptive.

Anthropometric Evaluation

Body mass index [BMI = current weight (kg)/height^2 (m^2)] was used as an anthropometric measurement to determine whether the subjects were underweight (<18.5 kg/m^2), normal weight (≥18.5 and ≤24.9 kg/m^2), overweight (≥25 and ≤29.9 kg/m^2), or obese (≥30 kg/m^2). Body weight was determined using a mechanical balance beam scale (CAM, model P-1001-P) that measures from 5 to 150 kg with 100 g precision. Height was determined using an aluminum alloy height rod with a height measurement range from 110 to 200 cm and 1 mm precision. Both instruments are calibrated once a year.

Body Composition

Body composition was determined by DXA using a Lunar-Prodigy machine (GE Healthcare, Madison, WI) and Encore (software) version 8.1. The rate of radiation exposure was <8 Sv. The patient is positioned supine on a scanning table with fixed over-couch arm for posterior-anterior measurement (the X-ray source is below the table and the detectors in the scanning arms). Scanning time was approximately 30 min for whole body scanning in a large patient. This machine allows calculating TFM, distribution of fat mass in the android

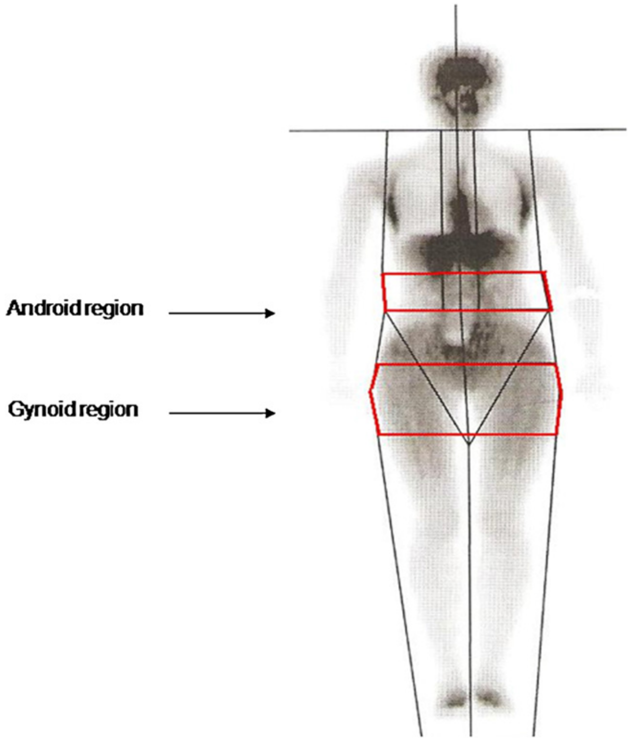

Fig. 2. Estimation of android and gynoid fat mass by dual-energy X-ray absorptiometry (*see* Methods).

and gynoid regions, and relates them providing the AF to GF ratio (A:G). The regions of interest (ROIs) are automatically placed by the device. As shown in Fig. 2, the android region is determined as follows: lower boundary at pelvis cut; upper boundary above pelvis cut line by 20% of the distance between pelvis and neck cuts; lateral boundaries are the arm cuts. The gynoid region is determined as follows: upper boundary below the pelvis cut line by 1.5 times the height of the android region; gynoid region height equal to 2 times the height of the android region; lateral boundaries are the outer leg cuts.

All the studies were assessed by a single operator. Results are expressed in kilograms and as a percentage. The coefficient of variation (CV) (given as a percentage) was determined at our laboratory in 15 healthy female volunteers with normal BMI, who were scanned 3 times, with repositioning between scans, on the same day. The CVs observed in our study for TFM (kg and %, respectively) were 1.37% and 1.42% and were in agreement with previous reports *(19)*; CVs for fat mass in the android region (kg and %, respectively) were 4.59% and 3.59% and those corresponding to fat mass in the gynoid region (kg and %, respectively) were 6.07% and 3.65%.

The machine was calibrated a minimum of 3 times per week using a phantom, and equipment maintenance was performed regularly.

Statistical Analysis

Statistical analysis was performed using SPSS 11.0 software for Windows (SPSS, Inc, Chicago, IL). To analyze the data, the population was divided according to decade of life (D) as follows: 20−29, 30−39, 40−49, 50−59, and 60−69. Results are expressed as mean ± 1 standard deviation ($X \pm SD$). Comparisons among groups were established using a nonparametric test (Mann-Whitney). Linear regression analyses were used to determine whether age and years since menopause were predictors of fat mass distribution in the android and gynoid regions. Statistical significance was set at a value of $p < 0.05$.

Results

Table 1 shows the anthropometric characteristics of the population divided according to D (third to seventh). Women in the seventh D showed higher BMI values than those in the fourth D (23 ± 2 vs 21 ± 2 kg/m^2; $p < 0.04$). This difference may be because of the significant lower height (5−7 cm)

Table 1
Reference Values of TF, AF, GF, and A:G Obtained by DXA Corresponding to Healthy Women in the Third to Seventh D

D	n	Age (yr)	Weight (kg)	Height (cm)	BMI (kg/m^2)	TF (kg)	TF (%)	AF (kg)	AF (%)	GF (kg)	GF (%)	A:G
20−29	10	24 ± 3	56 ± 9	160 ± 9	22 ± 1	18 ± 7	31 ± 8	1.2 ± 0.6	31 ± 11	4.0 ± 1	43 ± 6	0.71
30−39	9	32 ± 3	57 ± 6	164 ± 6	21 ± 2	18 ± 5	31 ± 6	1.2 ± 0.4	31 ± 8	4.3 ± 1	43 ± 7	0.71
40−49	14	44 ± 2	57 ± 6	161 ± 6	22 ± 1	19 ± 4	32 ± 6	1.3 ± 0.4	35 ± 9	4.1 ± 1	43 ± 5	0.80
50−59	19	53 ± 3	58 ± 6	162 ± 4	22 ± 2	20 ± 4	33 ± 5	1.5 ± 0.5†‡	36 ± 8	4.1 ± 1	44 ± 4	0.81
60−69	25	65 ± 3	56 ± 6	157 ± 7*	23 ± 2**	20 ± 4	35 ± 5	1.6 ± 0.5‡	38 ± 8	4.0 ± 1	44 ± 4	0.85δ

Abbr: BMI, body mass index; TF, total fat; AF, android fat; GF, gynoid fat; A:G, android to gynoid fat ratio; DXA, dual-energy X-ray absorptiometry; D, decade of life.
*$p < 0.04$ vs D30−39 and D50−59.
**$p < 0.04$ vs D30−39.
†$p < 0.05$ vs D20−29.
‡$p < 0.05$ vs D30−39.
δ$p < 0.02$ vs D20−29 and D30−39.

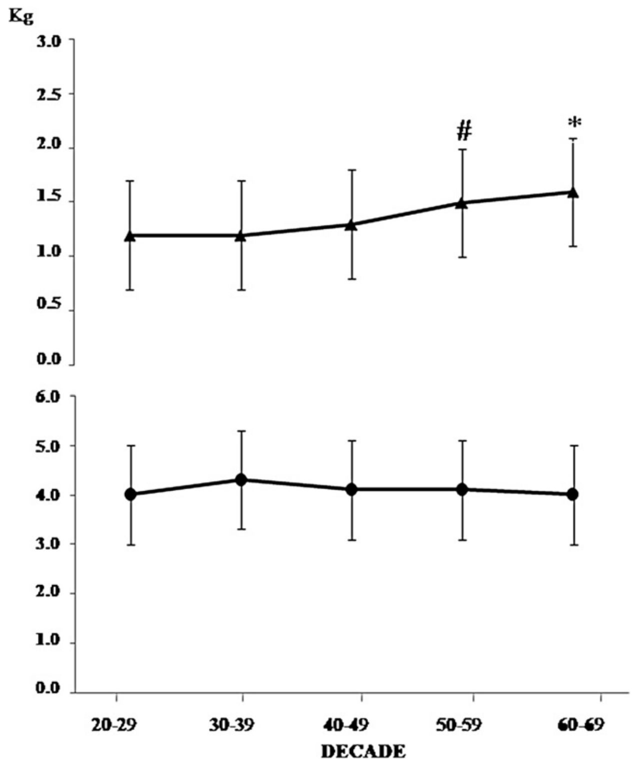

Fig. 3. Distribution of android (▲) and gynoid (●) fat mass throughout decades of life in the 77 healthy women included in the study ($X \pm 1$ SD). #$p < 0.05$ vs D20−29 and D30−39; *$p < 0.05$ vs D30−39.

observed in women in the seventh D when compared with those in the fourth (157 ± 7 vs 164 ± 6 cm; $p < 0.04$) and sixth D (157 ± 7 vs 162 ± 4 cm; $p < 0.04$).

Total body fat, expressed both in kilograms and as a percentage, tended to be higher with age, but no statistical significant differences were observed among the studied decades.

As regards fat distribution in the android and gynoid regions, AF (kg) was found to be 25% higher in the sixth D than in the third D and the fourth D (1.5 ± 0.5 vs 1.2 ± 0.6 and 1.2 ± 0.4; $p < 0.05$), and 33% higher in the seventh D than in fourth D (1.6 ± 0.5 vs 1.2 ± 0.4 kg; $p < 0.05$). However, no statistically significant changes in GF (kg and %) were observed among decades (Fig. 3).

The A:G was found to be significantly higher (20%) in women in the seventh D than in those in the third and fourth Ds (0.85 vs 0.71; $p < 0.02$). Given that TF, AF, and GF mass and the A:G were found to be normally distributed, regression analysis was performed to study the association of each of these variables with age. A very weak association was observed between age and A:G ($r = 0.337$; $p < 0.05$). No association was observed between age and TF, AF, or GF. Table 2 shows analysis of TF, GF, AF, and A:G according to menopausal status. AF (1.5 ± 0.5 vs 1.3 ± 0.5 kg; $p < 0.04$) and A:G (0.8 vs 0.7; $p < 0.01$) were a significantly 13% higher in Post-MP women when compared with Pre-MP women. No association was observed between years since menopause and TF, AF, or GF (Table 3).

Discussion

The present exploratory cross-sectional study was conducted using data on body composition (TF, AF and GF distribution) gathered from 77 normal BMI women aged 20−69 yr, from the city of Buenos Aires (Argentina).

The selected studied population showed no changes across the Ds in body weight and GF. Whereas the higher total body fat did not reach statistical significance, AF and A:G were significantly higher as of the sixth D. No association was observed between age and TF or AF, possibly because of the study sample size, although age was found to be associated with A:G index. Analysis of data according to menopausal status showed that AF mass and A:G index were 13% higher in Post-MP women when compared with Pre-MP women. However, no association was found between years since menopause and any of the fat mass parameters. This would seemingly indicate that the decrease in endogenous estrogen levels is not, *per se*, the cause of the changes in fat mass distribution observed throughout the D. Although the relation between estrogen and fat mass distribution has been extensively studied, the age-related changes in fat mass distribution may also depend on variations in other hormones, such as Growth Hormone- Insulin-like Growth Factor I and the hormones of the hypophyseal-adrenal axis *(2,20,21)*. Trémollieres et al *(22)* used DXA to study the effect of menopause on body composition in a group of normal BMI women aged 45−70 yr. They found a 4.5% increase in the proportion of AF in the first 3 yr after the onset of menopause and an 8.8% increase in trunk fat/leg fat, and suggested that the

Table 2
Values of TF, AF, GF Mass and A:G Divided by Menopausal Status ($X \pm$ SD)

	Characteristics		TF		AF		GF		
Menopausal Status	Age (yr)	BMI (kg/m^2)	kg	%	kg	%	kg	%	A:G
Pre-MP (n = 33)	34 ± 9	22 ± 2	18.3 ± 5	31.9 ± 7	1.3 ± 0.5	33.3 ± 9	4.2 ± 0.9	43.4 ± 5	0.7
Post-MP (n = 44)	59 ± 9	22 ± 2	19.6 ± 3	34.1 ± 4	1.5 ± 0.5	37.2 ± 8	4.0 ± 0.7	44.1 ± 4	0.8
p	0.001	ns	ns	ns	0.04	ns	ns	ns	0.01

Abbr: SD, standard deviation; Pre-MP, premenopausal; Post-MP, postmenopausal; ns, nonsignificant.

Table 3
Linear Regression Analysis Model Between Years Since Menopause and TF, AF, and GF Mass, and A:G

	Years since menopause			
Parameter	TF (kg)	AF (kg)	GF (kg)	A:G
Formula	$0.100 \times \text{aged} + 18.64$	$0.013 \times \text{aged} + 1.453$	$-0.003 \times \text{aged} + 4.05$	$0.006 \times \text{aged} + 0.776$
r^2	0.027	0.025	0.001	0.059
p	ns	ns	ns	ns

increase might be associated with the decrease in the concentration of estrogen levels. The authors used a previous version of the software (Lunar DPX; Madison, WI), which allowed determining trunk fat (considered a surrogate of AF) and leg fat (considered a surrogate of GF). This hypothesis is supported by the finding that the more central distribution of body fat is reversed. The authors also found approx 10−11% increase in both trunk and leg fat during late menopause (women aged 60−70 yr). Conversely, we found no increase in GF in any of the analyzed decades, including the seventh. Unlike the above authors, and because DXA technology has improved significantly in the last decade, we used an advanced software (Encore, version 8.1), which allows setting the ROI precisely and is able to quantify android and gynoid mass accumulation more exactly. AF measurement by DXA assesses TF in the upper abdomen including visceral fat in the liver and lower part of the heart. An excess of visceral fat in these latter areas is known to be associated with increased risk for metabolic diseases, such as diabetes and dislipidemia, cardiovascular diseases, and metabolic syndrome *(23−25)*. Moreover, according to a recent report, excess of AF mass evaluated by DXA may be a better predictor of risk for cardiometabolic diseases than visceral fat at the umbilical level assessed by CT *(26)*.

The present study has certain limitations that must be considered. The sample size is small, and corresponds to a population of women presenting for densitometric assessment in response to an osteoporosis prevention campaign. It must also be pointed out that the subjects included in the study were not randomly selected, and only those with BMI $\geq$18.5 and $\leq$24.9 kg/m^2 were enrolled. Moreover, only Caucasian women were included in the study, so the variations in fat mass distribution among races reported in the literature could not be evaluated *(27−29)*. The study did not involve performing hormone tests, which would allow analyzing the relation with hormonal status, or analyzing other humoral factors associated with metabolic or cardiovascular risk, such as C-reactive protein and lipid profile, which are considered indicators of increased cardiometabolic risk.

Our results allow concluding that despite having normal BMI values, women show changes in the distribution pattern of adipose tissue after the fifth D, with progressive higher values in android adiposity and in A:G. Thus, normal BMI would not seem to be sufficient to rule out an increase in abdominal fat and its possible deleterious health consequences and suggests the importance of assessing body composition using more precise methods such as DXA.

Further studies, including both regional and TFM evaluation by DXA (performed with the advanced software) as well as laboratory and clinical parameters of cardiometabolic diseases, would contribute to developing simple clinical risk indicators and establishing the cutoff point for each of the regions and for A:G, which would allow identifying the population at risk of developing cardiovascular disease and metabolic syndrome.

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