Age- and Menopause-Associated Variations in Body Composition and Fat Distribution in Healthy Women as Measured by Dual-Energy X-Ray Absorptiometry

Ole Lander Svendsen, Christian Hassager, and Claus Christiansen

To assess the variation with age and menopause, 407 healthy normal women aged 18 to 75 years had body composition and fat distribution measured by dual-energy x-ray absorptiometry (DEXA). The mean ± SD are given for different age decades. Postmenopausal women had significantly more fat, a more central fat distribution, and less lean tissue mass (LTM) than premenopausal women. In premenopausal and postmenopausal women, age only correlated with the abdominal to total-body fat tissue ratio ($r \sim .24$, $P < .05$), whereas the years since onset of menopause correlated with fat tissue mass (FTM), fat%, abdominal fat%, and the abdominal to total-body fat tissue ratio ($r \sim .2$, $P < .05$). To assess the independent impact of age, menopausal status, and years since menopause, multiple linear regressions were performed. FTM, fat%, and abdominal fat% were significantly related to menopausal status and years since menopause independently of age. The abdominal to total-body fat tissue ratio was statistically significantly related to age, but tended also to be independently related to years since menopause. LTM was statistically significantly related to menopausal status independently of age and years since menopause. In summary, we suggest that in healthy women total-body and abdominal fat may increase and LTM may decrease in the years after menopause, primarily in the perimenopausal years, without significant changes before menopause.

BODY COMPOSITION and fat distribution are related to disease and premature death.[1-3] Body composition changes with age, ie, bone mass and lean tissue mass (LTM) decrease and fat tissue mass (FTM) increases.[4-10] There is an accelerated loss of bone mineral content after menopause,[2] whereas the impact of menopause independently of age on LTM and FTM is uncertain.[8,11] Central body fat distribution is associated with age, sex, and sex hormones.[12-15] Thus, as indicated recently,[16,17] fat distribution in women may become more central, or android, after menopause.

Many methods for measurement of body composition and fat distribution have been introduced, but they all have shortcomings, ie, they either are rather expensive, are tedious to use, and involve a high radiation dose or are indirect in the sense that they depend on algorithms with various constants that may vary within and between subjects.[18-22]

The use of dual-energy x-ray absorptiometry (DEXA) for measurement of body composition in clinical and research settings is becoming more widespread, most likely because it offers several advantages such as being precise and accurate, measuring bone mineral and fat distribution, permitting regional analysis, being safe and practical, and involving only a negligible radiation dose.[23-25] Thus, the aim of the present study was to assess the variations with and independence of age and menopause on body composition and fat distribution as measured by DEXA in healthy women.

SUBJECTS AND METHODS

We studied 407 healthy women aged 18 to 75 years who had participated in various studies of bone and lipid metabolism and body composition at the Center for Clinical and Basic Research, Ballerup, Denmark. None had any disease or were taking any medications known to affect lipid or bone metabolism. Subjects were pooled for this study, and there were no significant differences in body mass index, height, and weight between these women and two Danish reference populations of similar sex and age[26,27] (Table 1). Thus, they may be a representative subsample of healthy women.

All studies were performed in accordance with the Declaration of Helsinki II and with approval of the Copenhagen County ethics committee.

DEXA

Body composition was measured[23,24] with the same total-body DEXA scanner (DPX, Lunar Radiation, Madison, WI; software version 3.1 and 3.2). Abdominal fat content was measured between the first and fourth lumbar intervertebral disks by adjusting the lines of the rib box (standard software option).[25] Measurements were performed at all times of the year independently of age or menopausal status.

By DEXA, the body consists of soft tissue and bone. Soft tissue consists of fat and lean tissue. FTM is not adipose tissue (which includes connective tissue, vessels, and blood), but is the sum of all chemical elements in the soft tissue. Similarly, LTM is not an anatomic entity, but represents the sum of all chemical fat-free soft tissue elements. Thus, DEXA measures total-body bone mineral content (TBBMC) and density (TBBMD), FTM, and LTM, with a precision (coefficient of variation) of 0.9%, 4.7%, and 1.5%, respectively.[24] The precision for abdominal FTM and fat% is 4.3% and 3.4%, respectively.[25]

With subjects wearing light indoor clothes and no shoes, weight was measured to the nearest 0.1 kg and height to the nearest 0.5 cm. Women were defined as postmenopausal if they had no menstrual bleeding within the previous 6 months (all women had an intact uterus). In 38 elderly women, age at onset of menopause was not assessed.

Statistical Analysis

The abdominal to total-body fat tissue ratio (by DEXA) was calculated as an indicator of fat distribution. Comparisons between

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Address reprint requests to Ole Lander Svendsen, MD, Center for Clinical and Basic Research, Ballerup Byvej 222, DK-2750 Ballerup, Denmark.

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Table 1. BMI, Height, and Weight in Women in Our Population and Two Danish Reference Populations

	Age (yr)					
	18-29	30-39	40-49	50-59	60-69	70-79
BMI (kg/m²)						
This study*	21.9 ± 2.7	22.3 ± 2.9	23.7 ± 2.4	24.9 ± 3.9	25.3 ± 4.0	25.1 ± 4.3
Glostrup†	—	22.7 ± 3.4	24.4 ± 4.1	25.3 ± 4.3	25.5 ± 4.7	25.8 ± 4.6§
Østerbro‡	20.9 ± 2.9	22.2 ± 3.7	24.2 ± 4.7	24.4 ± 4.6	24.9 ± 4.7	25.5 ± 4.5
Height (cm)						
This study*	168.2 ± 6.2	167.9 ± 5.9	166.0 ± 5.7	163.1 ± 5.6	159.6 ± 5.8	159.8 ± 6.7
Glostrup†	—	166.4 ± 5.9	164.4 ± 5.7	162.0 ± 5.4	160.3 ± 5.8	157.6 ± 5.7§
Østerbro‡	167.1 ± 6.5	165.2 ± 6.2	163.3 ± 6.1	161.6 ± 6.2	160.1 ± 5.9	157.7 ± 5.8
Weight (kg)						
This study*	62.0 ± 8.4	63.0 ± 9.6	65.6 ± 9.5	66.1 ± 10.7	64.2 ± 9.5	63.9 ± 10.4
Glostrup†	—	63.0 ± 10.0	66.1 ± 11.6	66.4 ± 11.9	65.6 ± 12.6	64.1 ± 11.8§
Østerbro‡	60.0 ± 8.9	62.1 ± 10.6	65.5 ± 12.9	65.0 ± 12.5	64.9 ± 12.4	64.5 ± 11.5

NOTE. Results are the mean ± SD.

Abbreviation: BMI, body mass index.

*N = 407.

†N = 1,672.[26]

‡N = 6,288 (adapted from reference 27).

§Heitmann BL, unpublished observations, 1989.

groups were made by Student's unpaired t test. Product-moment correlation coefficients were calculated. Significance and independence of predictive variables (age, menopausal status [pre/post, dummy code 0/1], and years since menopause) were assessed by multiple linear regression analyses. The Statistical Analysis System (SAS Institute, Cary, NC) was used for all analyses.

RESULTS

As shown in Fig 1, FTM, abdominal fat%, and the abdominal to total-body fat tissue ratio increased and LTM decreased with age. This increase tended to be more pronounced between the forties and fifties. Table 2 lists the mean ± 1 SD for body composition and fat distribution as measured by DEXA in normal healthy women in different age decades.

As shown in Fig 2, postmenopausal women had statistically significantly higher total-body fat% (and FTM, not shown), abdominal fat%, and abdominal to total-body fat tissue ratio and lower LTM than premenopausal women. However, the mean age of postmenopausal women was of course higher than that of premenopausal women. When women in the same age decade (40 to 49 years) were compared (Fig 2B), postmenopausal women had significantly lower LTM and bone mineral content (TBBMC: 2,383 v 2,822 g, $P < .001$; TBBMD: 1.061 v 1.178 g/cm², $P < .001$) and higher total-body and abdominal fat% ($P < .07$) than premenopausal women. There was no significant difference in the abdominal to total-body fat tissue ratio ($P > .1$).

Table 3 lists correlations between body composition, fat distribution, and age and years since menopause. In the pooled population of both premenopausal and postmenopausal women (not shown), FTM and fat distribution were positively ($r = .34$ to $.45$, $P < .001$) and LTM negatively ($r = -.30$, $P < .001$) correlated with age. Except for a positive correlation with the abdominal to total-body fat tissue ratio (and bone mineral content), there were no significant correlations with age in either premenopausal or postmenopausal women alone. On the other hand, except for LTM, years since menopause correlated significantly with all body components and fat distribution.

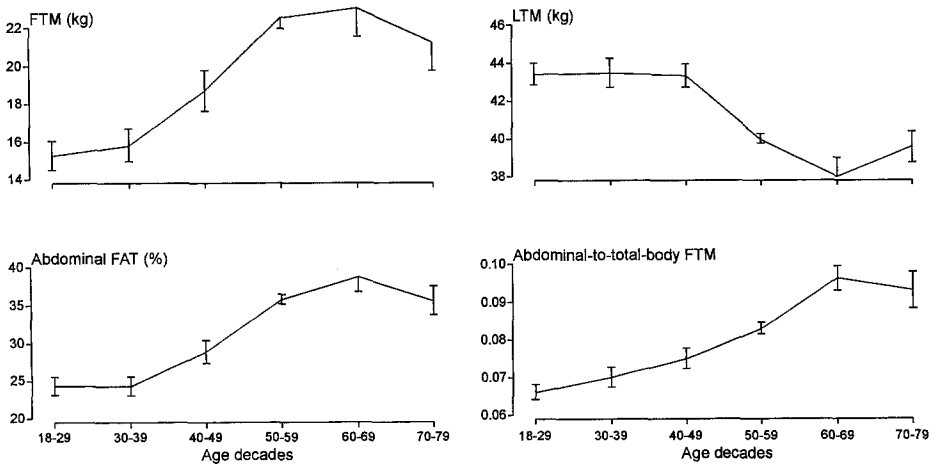

Fig 1. Variation in FTM, LTM, abdominal fat%, and abdominal to total-body fat tissue ratio (as measured by DEXA) with age in healthy women (N = 407), mean ± SEM).

Table 2. Body Composition and Fat Distribution as Measured by DEXA in Healthy Women in Different Age Decades (N = 407)

	Age (yr)					
	18-29 (n = 59)	30-39 (n = 53)	40-49 (n = 41)	50-59 (n = 196)	60-69 (n = 26)	70-79 (n = 32)
FTM (kg)	15.3 ± 6.2	15.8 ± 6.5	18.7 ± 6.9	22.5 ± 7.9	23.0 ± 7.5	21.2 ± 8.4
LTM (kg)	43.4 ± 4.5	43.5 ± 5.6	43.4 ± 3.7	40.0 ± 3.7	38.0 ± 3.8	39.6 ± 4.5
TB fat%	25.4 ± 7.0	26.1 ± 7.0	29.4 ± 6.9	35.1 ± 6.8	36.8 ± 8.0	33.8 ± 9.0
Abdominal fat%	24.4 ± 9.8	24.2 ± 10.3	28.9 ± 9.8	35.7 ± 9.6	38.7 ± 9.5	35.4 ± 10.3
Abdominal/TB FTM (10^{-3})	66.4 ± 16.4	69.9 ± 20.6	75.0 ± 17.8	83.3 ± 21.0	96.4 ± 18.2	93.0 ± 23.0
TBBMC (g)	2,782 ± 356	2,820 ± 434	2,799 ± 349	2,449 ± 365	2,110 ± 350	2,111 ± 414
TBBMD (g/cm^2)	1.170 ± 0.068	1.180 ± 0.068	1.162 ± 0.075	1.079 ± 0.086	1.012 ± 0.113	0.980 ± 0.111

NOTE. Results are the mean ± SD.
Abbreviation: TB, total-body.

To assess further the independent association of age, menopausal status, and years since menopause with body composition and fat distribution, multiple linear regression analyses were performed (Table 4). FTM, fat%, and abdominal fat% were significantly related to menopausal status and years since menopause independently of age. The abdominal to total-body fat tissue ratio was statistically significantly related to age, but also tended to be independently related to years since menopause. LTM was statistically significantly related to menopausal status independently of age and years since menopause. TBBMC and TBBMD were statistically significantly negatively associated with menopausal status and years since menopause independently of age.

DISCUSSION

DEXA is a relatively new method for reliable, practical, and direct measurement of body composition and fat distribution,[23-25] for which its use is increasing. No age-dependent reference values for body composition and fat distribution measurements by DEXA have been published. Body composition and fat distribution vary with age and menopause, and the present study gives reference values for healthy Danish women in different age decades. (Software versions 3.1 and 3.2 were used. The newer software versions will probably give similar results and conclusions.)

Since the present study was cross-sectional, as are most studies on this topic, it describes differences in body composition and fat distribution between subjects of a given age at a given time, and caution must be used when interpreting the results as changes with time and age. Furthermore, attention must be given to the selection bias of the population studied. Thus, populations studied previously have been selected to be non-obese,[17] to be obese,[28] to be students and/or hospital staff,[4,10] to be recruited by advertising in the media,[17] or to cover a wide range of body

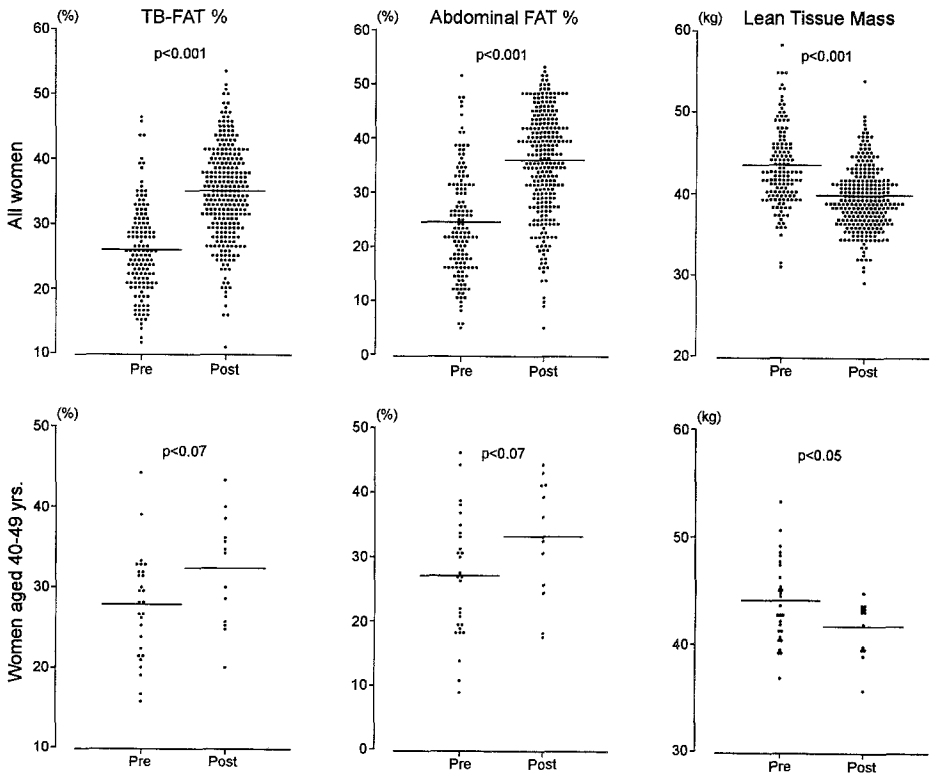

Fig 2. Total-body (TB) fat%, abdominal fat%, and LTM measured by DEXA, in healthy women. (A) All premenopausal (n = 141) and postmenopausal (n = 266) women. (B) Premenopausal (43.6 ± 2.6 years, n = 28) and postmenopausal (48.5 ± 0.7 years, n = 13) women from the same age decade (40 to 49 years). (—) mean.

Table 3. Correlations Between Body Composition as Measured by DEXA, and Age and Years Since Menopause in Healthy Women (N = 407)

	Age		Years Since Menopause
	Premenopausal (n = 141)	Postmenopausal (n = 266)	(n = 228)
FTM	NS	NS	.21†
LTM	NS	NS	NS
TB fat%	NS	NS	.23
Abdominal fat%	NS	NS	.25
Abdominal/TB FTM	.19*	.25	.25
TBBMC	.19*	−.39	−.34
TBBMD	NS	−.39	−.27

Abbreviation: TB, total-body.
NS, $P > .05$.
*$P < .05$.
†$P < .01$.
Otherwise, $P < .001$.

habitus, or the selection procedure has not been given.[8,29] The population in the present study was a representative subsample of healthy Danish women.

Our data suggest that body composition and fat distribution of healthy normal women do not change significantly during premenopausal years. Total-body and abdominal fat may increase with the years since menopause and primarily in the perimenopausal years independently of age itself. LTM may decrease in the perimenopausal years with no effect of age or years since menopause, which is in accordance with previous reports of accelerated loss of LTM in the perimenopausal years.[11,29] It is well known that bone mineral content declines after menopause due to estrogen deficiency,[2] but the effect of estrogen deficiency on FTM and LTM is more uncertain. Our study suggests that estrogen deficiency in the perimenopausal years increases FTM and decreases LTM. Estrogen-progestogen treatment of early-postmenopausal women may prevent the increase in FTM and the decrease in LTM.[16,30] However, the decrease in LTM may also be a result of an increasingly sedentary life-style, disuse, and decreased protein intake with increasing age,[1,29] and the increase in FTM, a result of reduced energy expenditure and increased energy intake. The fact that exercise and energy-restrictive diets in postmenopausal women and the elderly can reduce FTM and increase LTM[31,32] supports this point of view.

Compared with premenopausal women, postmenopausal women have a more central/android fat distribution, more visceral abdominal adipose tissue (as measured by computed tomography), lower lipolytic activity in abdominal adipose tissue, and higher lipoprotein lipase activity in femoral adipose tissue.[13-15,17,28] However, in all these cross-sectional studies, postmenopausal women were significantly older than premenopausal women, and whether the effect of menopause is independent of age is uncertain. In the present study, we found that the abdominal to total-body fat tissue ratio increases with years since onset of menopause, but this was not independent of age. This is in accordance with a previous report in which the waist to hip ratio was higher in postmenopausal women, but when it was adjusted for age, there was no difference between premenopausal and postmenopausal women.[13] On the other hand, the present study suggests that abdominal fat% is increased with years since menopause, primarily in the perimenopausal years, independently of age. We have previously shown in a longitudinal study that 2 years of estrogen-progestogen therapy in healthy early-postmenopausal women prevented an increase in abdominal fat%.[16] Thus, overall, the menopause-associated estrogen deficiency is followed by increased abdominal fatness, probably independently of age, but longitudinal studies are needed to clarify this.

In summary, we suggest that in healthy women, total-body and abdominal fat may increase and LTM may decrease in the years after menopause, primarily in the perimenopausal years, without significant changes before menopause.

Table 4. Multiple Linear Regressions With Body Composition and Fat Distribution as Measured by DEXA as Dependent Variables and Age, Menopausal Status, and YSM as Independent Variables

	Independent Variables			
Dependent Variables	Age	Menopausal Status	YSM	R^2
FTM	0.10 ± 0.08	3.1 ± 1.6*	0.018 ± 0.009†	.19
LTM	0.03 ± 0.04	−4.0 ± 1.0§	−0.004 ± 0.005	.16
TB fat%	0.11 ± 0.07	5.4 ± 1.6§	0.02 ± 0.008†	.31
Abdominal fat%	0.12 ± 0.10	6.7 ± 2.2‡	0.03 ± 0.01†	.27
Abdominal/TB FTM	0.6 ± 0.2†	−1.3 ± 4.5	0.04 ± 0.02*	.16
TBBMC	7.5 ± 3.8*	−406.9 ± 83.2§	−2.4 ± 0.4§	.33
TBBMD	0.0009 ± 0.0008	−0.100 ± 0.018§	−0.0004 ± 0.0001§	.28

NOTE. R^2 is the fraction of variation in dependent variable explained by variation in independent variables.
Abbreviations: YSM, years since menopause; TB, total-body.
*$P < .07$.
†$P < .05$.
‡$P < .01$.
§$P < .001$.

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