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BODY COMPOSITION IN NORMAL AND OSTEOPOROTIC WOMEN

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Summary Body composition and bone mineral density using dual-energy X-ray absorptiometry (DEXA) was determined in a large group of normal women and osteoporotic patients with atraumatic vertebral fractures. Between the third and seventh decades, there was an increase of 9.5 kg of body weight and 7.5 kg of fat mass in the normal women. The percentage of fat augmented from 33% to 42%. However, the lean mass showed no modifications over these decades. Fat mass in the osteoporotic women was significantly less than that in the age and sex matched controls (22.4 ± 1.0 vs 26.6 ± 1.0 kg; $p < 0.006$). However, lean tissue mass was similar in the two groups. The decrease in fat mass explain 74% of the difference of body weight between osteoporotics and controls. The fat mass of 13 osteoporotic patients (30%) was lower than the lowest value found in the controls and 20(45%) were lower than minus one standard deviation of the values for controls. The osteoporotic patients had less fat mass in the three subregions evaluated, but the difference was more significant in the trunk (-18%) and legs (-17%) than in the arms (-11%). Fat mass may have an important protective effect on the skeleton. The mechanism has yet to be elucidated.

Key words: body composition, osteoporosis

Various authors have reported that patients with osteoporosis have lower body weight than that of controls of the same age and sex.[3, 7, 16, 18, 19, 21] However, very few studies have examined the body composition of these patients. Hassager and Christiansen[7], observed by dual photon ^{153}Gd absorptiometry that the fat mass of osteoporotic patients with vertebal or hip fractures was lower than that of controls, although the difference was not statistically significant. The lean mass was similar in the two groups. Rico et al[16] observed by infrared interactance that both lean mass and percentage of fatty tissue were significantly lower in patients with senile vertebral osteoporosis than in controls. The current study determined total and regional body composition of normal women and of osteoporotic patients with crush vertebral fractures using the method of X-ray absorptiometry. The results indicate a significant reduction in the fat tissue without alterations in the lean tissue in the osteoporotic patients.

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Subjects and methods

We studied 121 normal volunteers between ages 21 and 80. Those up to age 60 were hospital employees. Those between 60 and 80 were relatives of the subjects studied or of the staff of our Department. In all cases, a questionnaire excluded subject with any illness or chronic ingestion of medications that might alter the skeleton or body composition. In controls over age 60, lateral X-rays of the dorsal and lumbar regions of the spine were taken in order to exclude controls with vertebral fractures as defined below.

The study also included 43 women with osteoporosis. The patients had at least one atraumatic vertebral fracture defined as a reduction of the anterior height (wedge fracture) or complete diminution of the vertebral body height (crush fracture) readily visible on naked eye on a lateral radiograph of the thoracic and lumbar spine. The

patients were seen consecutively at the outpatient Bone clinic of the Hospital de Clínicas.

Criteria for exclusion in controls or osteoporotic patients were the following: 1) The presence of endocrine, renal, hepatic, gastro-intestinal or rheumatic disorders; 2) Prolonged immobilization; 3) Chronic ingestion of corticoids, anticonvulsants or previous treatments with calcitonins, estrogens, bisphosphonates or sodium fluoride for more than a 3 months period; 4) pronounced scoliosis that might affect BMD determination.

Patients and controls are part of a study designed to establish the critical skeletal areas that are most sensitive to differentiate the two groups by determining the bone mineral density[1].

In controls and in patients, the following parameters were determined by X-ray absorptiometry (DEXA): fat mass; lean mass; percentage of fat in soft tissue; bone mass and mineral density of the skeleton. Regional body composition (arms, trunk, legs) was also determined by the computer program provided by the manufacturer.

DEXA measurements were made with a total body scanner (Lunar DPX) that uses a constant potential X-ray source at 78 KVp and a K-edge filter (cerium) to achieve a congruent beam of stable, dual-energy radiation with effective energies of 40 and 70 KeV. The DPX unit performs a series of transverse scans moving from head to toe and 1 cm intervals; the scan area was approximately 60 cm x 200 cm. Data was collected for about 120 pixel elements per transverse scan, with each pixel approximately 5 x 10 mm. Total body measurements were completed in 10 minutes with a scan speed of 16 cm/sec.

The precision (coefficient of variation) observed in our laboratory was: lean mass: 0,8% ; fat mass: 4,8%; percentage of fat: 3,5%; bone mineral density: 0,6%; skeletal mass: 1,0%.

Statistical analysis

The data are expressed as mean ± 1 SEM (Standard error of the mean). Student's t-test and Mann-Whithney test were used to determine differences between means. Multiple regression analysis was used to determine the relative contribution of fat and postmenopausal years over bone mineral density.

Results

Table 1 shows the results obtained in normal women grouped by decades of age. Between the third and seventh decades, there was an increase of 9.5 kg of body weight and 7.5 kg of fat mass. The percentage of fat augmented from 33% to 42%. However, the lean mass showed no modifications over these decades (Figure 1). The control women in the eighth decade showed a decrease of 7.0 kg body weight and 5.0 kg of fat

TABLE 1- *Body composition and bone mineral density in normal women. (Average ± 1 SEM)*

Age (Years)	n	Weight (Kg)	Height (cm)	BMI	Fat (Kg)	% Fat	Lean (Kg)	BMC (Kg)	BMD (g/cm²)
21-30	(19)	57.4	160.2	22.4	19.9	32.6	36.2	2.36	1.12
		1.8	1.5	0.8	2.4	1.6	0.8	0.06	0.01
31-40	(19)	58.2	160.8	22.5	17.9	31.5	37.6	2.41	1.11
		1.8	1.3	0.6	1.5	1.5	0.8	0.06	0.01
41-50	(23)	59.9	157.3	24.4	21.0	35.6	36.4	2.25	1.09
		2.3	1.1	0.9	1.7	1.6	0.7	0.07	0.02
51-60	(24)	65.7	159.4	25.9	25.5	40.1	37.6	2.32	1.08
		1.6	1.3	0.7	1.1	1.0	0.8	0.07	0.02
61-70	(18)	67.0	156.4	27.4	27.3	41.8	37.3	2.07	1.02
		2.2	1.0	0.7	1.6	1.2	0.9	0.07	0.02
71-80	(18)	59.7	150.7	26.3	22.0	38.1	34.9	1.99	0.98
		1.8	1.3	0.7	1.5	1.9	0.9	0.07	0.03

BMI: Body mass index: Weight (Kg) / Height (m)2. Fat: Fat body mass. Lean: Lean tissue mass.
BMC: Bone mineral content. BMD: Bone mineral density.

when compared to those of the previous decade. Due to the small number of control women in this decade, it is not possible to establish whether this difference is attributable by chance to the population sampled or to a real change in the body composition of the elderly women.

Between the sixth and eighth decades, there was a very significant decrease in height (9 cm). Since the X-rays of the spine revealed no alteration of the vertebral bodies, this difference must largely reflect a secular trend.

Table 2 shows the results found in the 43 osteoporotic patients and in 39 age-matched controls. The osteoporotic patients had significantly less body weight, height, fat mass and, as foreseeable, skeletal mass. However, the lean mass was similar in the two groups. Also the years since the start of menopause were significantly greater in osteoporotic patients. The relative contribution of fat mass and postmenopausal years over bone mineral density was assessed by a multiple regression analysis. The fat mass was a significant contributor ($r = 0.47$; $p < 0.001$) but postmenopausal years were not significant ($r = 0.23$; p.n.s.) in osteoporotic women.

On the average, the difference in weight of controls and patients was 5.7 kg. Of this difference, 74% is due to the decrease in the fat mass

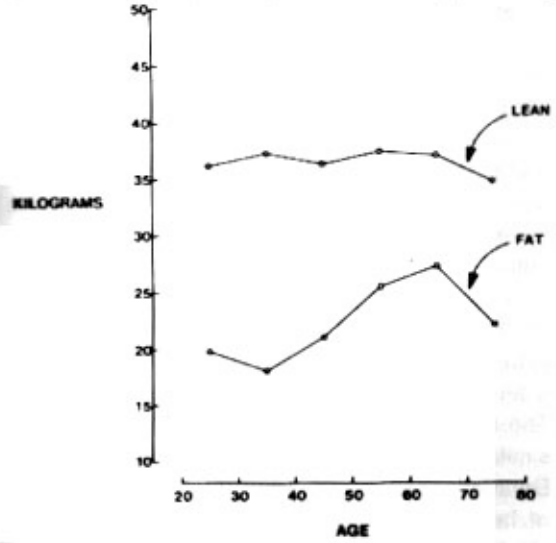

Fig. 1.- Average lean and fat mass in normal women from 20 to 80 years of age.

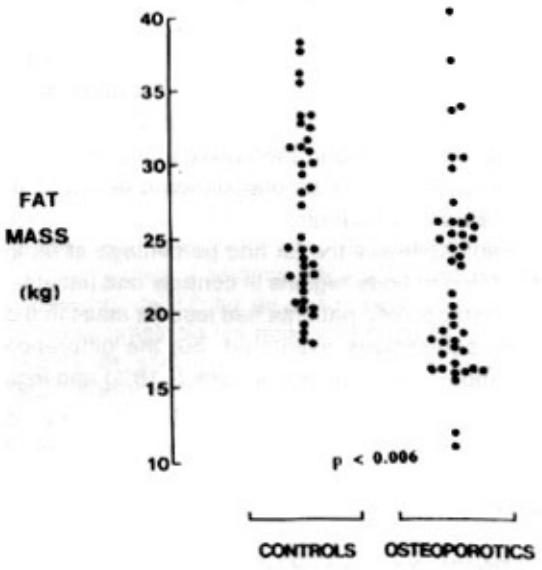

Fig. 2.- Fat mass in osteoporotic women with vertebral fractures and age matched controls ($p < 0.006$; Mann-Whitney test).

TABLE 2.- *Body composition and bone mineral density in osteoporotic and control women (Aveage ± 1 SEM)*

	n	Age (Years)	PM (Years)	Weight (Kg)	Height (cm)	BMI	Fat (Kg)	% Fat	Lean (Kg)	BMC (Kg)	BMD (g/cm²)
Control	(39)	59.6	9.6	66.2	157.3	26.7	26.6	41.3	37.2	2.18	1.05
		0.9	1.1	1.3	0.8	0.5	1.0	0.8	0.6	0.05	0.01
Osteoporotics	(43)	61.6	14.4**	60.7*	154.1*	25.5	22.4*	37.7*	36.1	1.79**	0.91**
		0.8	0.9	1.5	0.9	0.5	1.0	0.9	0.6	0.04	0.01

PM: Postmenopausal period. Other legends as in Table 1.
* $p < 0.01$; ** $p < 0.001$.

TABLE 3.- *Fat distribution in different body regions in osteoporotic and normal control women (Average ± 1 SEM).*

		ARMS		LEGS		TRUNK	
		FAT Kg	% FAT	FAT Kg	% FAT	FAT Kg	% FAT
Controls	(37)	3.20	45.1	10.73	44.5	11.26	37.5
		0.17	1.1	0.43	0.9	0.45	0.8
Osteoporotics	(41)	2.85	40.9*	8.95***	41.1	9.21***	33.9***
		0.26	1.4	0.40	0.9	0.41	0.9

* $p < 0.025$; ** $p < 0.01$; *** $p < 0.005$.

(- 4.2% kg), 19% to a non-significant difference in lean mass (- 1.1 kg) and 7% to a significant reduction in skeletal mass (-0.4 kg)

Figure 2 shows the individual results for fat mass in controls and patients. The fat mass of 13 osteoporotic patients (30%) was lower than the lowest value found in the controls and 20 (45%) were lower than minus one standard deviation of the values for controls.

Table 3 shows the fat and percentage of fat in the different body regions in controls and patients. The osteoporotic patients had less fat mass in the three sub-regions evaluated, but the difference was more significant in the trunk (- 18%) and legs (- 17%) than in the arms (- 11%).

Discussion

The DEXA method allows determination of body composition whose results are comparable to those found by classic methods[8, 13, 22]. The values obtained by X-ray absorptiometry are also comparable to those obtained by absorptiometry of ^{153}Gadolinium [17]. The advantage of determining body composition by X-ray absorptiometry is that the study requires only 10 minutes, radiation is minimal, total as well as regional values can be determined and the bone mineral density of the skeleton is determined simultaneously[10].

The precision of the method evaluated in this study is excellent for determinations of lean mass and of bone mineral density. It is less so for determinations of fat mass and of percentage of fat in soft tissues (4%). Similar precision was reported by other authors with the same equipment used in this study[10, 17].

Results in control women indicate a net increase in fat mass and in percentage of fat in soft tissue between the fourth and seventh decades, while at the same time lean mass remains unchanged. However, normal women between 70 and 80 showed a significant decrease in fat mass and in percentage of fat in comparison with the values from the previous decade. Since the number of observations is small, no firm conclusions can be drawn. The precise determination of the body composition of the elderly woman is extremely important, since significant changes in it can have a great impact on their general health[2]. The fat mass of elderly women in this study was similar to that observed in 23 women age 75 in Denmark (22.0 vs 21.2 kg), but the percentage of fat in soft tissues was greater in our study (38.5% vs 33.7%)[20].

Significantly less fat mass was observed in the osteoporotic patients with vertebral fractures in comparison with controls. In around a third of the patients, fat mass was below the lowest values found in age-matched controls. The decrease in total fat explains more than two thirds of the difference in body weight between controls and patients. Decrease in fat mass was also observed in two studies of body composition in osteoporotic patients with crushed vertebrae[7, 16]. However, the difference observed by Hassager and Christiansen[7] was not statistically significant (21 to 22 kg vs 24 kg). Study of the regional distribution of the body composition established that the major decrease in fat mass in osteoporotic patients is in the trunk and legs.

However, the osteoporotic patients had no decrease in lean mass, confirming previous reports[7]. Rico et al[16] observed a decrease in lean

mass in osteoporotic patients, but the difference in body weight of controls and patients was very large (10 kg) in comparison to that observed in other studies[7, 19, 21] and in the current study (3 to 5 kg).

The mineral density of the vertebral bodies, radius and proximal femur on the other hand, correlate positively with body weight[3, 4, 12]. Obesity protects the skeleton after menopause by avoiding the decrease in mineral density accompanying estrogen deprivation[15]. Two studies have reported a correlation between body weight and the calcium/creatinine ratio in urine[5, 7], a postulated indicator of the velocity of bone resorption without changes in the levels of osteocalcin, an indicator of skeletal formation[7, 15].

The physiopathology of the protective role of body weight on the skeleton has not been fully explained. One hypothesis is that there may be a mechanical factor. Body weight could stimulate bone formation or inhibit its resorption. However, it is not easy to accept that 5% differences in body weight might have a very significant influence on the process of bone remodeling. Another interpretation of the possible mechanical role of body weight is that the larger deposit of adipose tissue would dissipate the energy produced by a fall and thus significantly decrease the risk of fracture. This explanation is acceptable in the case of patients with trochanteric hip fractures, but not for patients with crushed vertebrae, events in which fat mass cannot have a role of mechanical protection.

Finally, the prevalent hypothesis on the protective role of body weight was related to a hormonal effect of the fat mass. Adipose tissue seems to be the major site of conversion of androstenedione to estrone, the predominant estrogen after menopause[9].

However, a recent study of Reid et al[14] in normal post menopausal women disclosed that total body fat was the most significant predictor of BMD throughout the skeleton, but the influence of total fat was not explicable in terms of estrone conversion in the adypocites or in terms of skeletal load-bearing of body weight.

In other illness there is also significant associated decrease in fat and skeletal mass. In anorexia nervosa, the substantial decrease in adipose tissue is especially associated to a decrease in mineral density of the spine[11]. In the celiac disease, a severe decrease in fat mass has been observed, associated to a very significant mineral deficit in total skeleton and spine[6].

The review of different studies indicates the important protective effect of the fat mass on the skeleton. It is possible that the predominant mechanism is of a humoral type, but its exact nature has yet to be elucidated.

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Resumen

Composición corporal en mujeres normales y osteoporóticas

Se estudió la densidad mineral ósea y la composición corporal mediante absorciometría de rayos X (Lunar DPX) en una población de 121 mujeres normales entre 21 y 81 años de edad. Entre la tercera y séptima década se registró un incremento de 9,5 kg de peso corporal y 7,5 kg de masa grasa en las mujeres normales. El porcentaje de grasa aumentó de 33% a 42%. La masa magra no mostró modificaciones en estas décadas (Figura 1 y Tabla 1). Cuarenta y tres mujeres osteoporóticas con fracturas vertebrales atraumáticas fueron simultáneamente estudiadas. En las mujeres osteoporóticas la masa grasa fue significativamente más baja con respecto al grupo control de la misma edad (22,4 ± 1,0 kg vs 26,6 ± 1,0 kg; $p < 0,006$). Sin embargo la masa magra fue similar en los dos grupos. La disminución de la masa grasa explica el 74% de diferencia en el peso corporal entre la población osteoporótica y control (Tabla 2). Trece pacientes osteoporóticas (30%) presentaron una masa grasa menor al valor más bajo encontrado en los controles y 20 (45%) fueron menores a menos un desvío standard del valor para los controles (Figura 2). Las pacientes osteoporóticas tenían una masa grasa disminuida en las tres subregiones evaluadas, pero la diferencia fue más significativa en el tronco (-18%) y piernas (-17%) con respecto a los brazos (-11%) (Tabla 3). La masa grasa puede tener un efecto protector importante sobre el esqueleto. El mecanismo no ha sido dilucidado aún.

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Para poder cumplir con la vocación que cada uno de nosotros lleva adentro en mayor o menor grado, es imprescindible gozar de tranquilidad espiritual. Ella nos da ecuanimidad para juzgar y actuar y nos permite mantener un optimismo, que aunque sea a veces irracional, es el único motor de repuesto que nos queda en las actuales circunstancias.

Alfredo Lanari (1910-1985)

Vocación y convicción. Alfredo Lanari. Buenos Aires: Fundación Alfredo Lanari, 1995, p 244.