ARTICLE ORIGINAL / ORIGINAL ARTICLE

RELATIVE IMPORTANCE of LEAN MASS and FAT MASS on BONE MINERAL DENSITY in a GROUP of LEBANESE ELDERLY MEN

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ABSTRACT • OJECTIVE : The aim of this study was to determine the relative importance of lean mass and fat mass on bone mineral density (BMD) in a group of Lebanese elderly men.

METHODS AND RESULTS : Seventy Lebanese men (aged 65-84 years) participated in this study. Body weight and height were measured and body mass index (BMI) was calculated. Body composition (lean mass, fat mass and fat mass percentage) was assessed by dual-energy X-ray absorptiometry (DXA). Bone mineral content (BMC) of whole body (WB) and BMD of WB, total hip (TH), femoral neck (FN), ultra distal (UD) radius and 1/3 radius were measured by DXA. The ratios WB BMC/height and WB BMD/height were calculated. Fat mass and lean mass were found to be positively correlated to WB BMC, WB BMC/height, and to WB, TH, FN, UD radius and 1/3 radius BMD. After controlling for age and height, fat mass was more strongly correlated to TH BMD and FN BMD than lean mass while lean mass was more strongly correlated to WB BMC, WB BMD, UD radius BMD and 1/3 radius BMD than fat mass.

CONCLUSION : This study suggests that, in elderly men, fat mass is a stronger determinant of TH and FN BMD than lean mass while lean mass is a stronger determinant of WB BMC, WB BMD, UD radius BMD and 1/3 radius BMD than fat mass.

RÉSUMÉ • OJECTIF : Explorer la contribution relative de la masse maigre et de la masse grasse aux valeurs de densité minérale osseuse (DMO) chez des hommes libanais âgés.

METHODES ET RÉSULTATS : Soixante-dix hommes libanais âgés de 65 à 84 ans ont participé à cette étude. Le poids et la taille ont été mesurés et l'indice de masse corporelle (IMC) a été calculé. La composition corporelle et les densités minérales osseuses du corps entier, de la hanche, du col fémoral, du radius ultra-distal et du 1/3 radius ont été mesurées par absorptiométrie biphotonique à rayons-X (DEXA). La masse maigre et la masse grasse étaient positivement corrélées aux valeurs de DMO à tous les sites osseux mesurés. Cependant, après ajustement pour l'âge et la taille, la masse grasse était un meilleur déterminant positif de la DMO de la hanche et de la DMO du col fémoral que la masse maigre alors que la masse maigre était un meilleur déterminant positif du contenu minéral osseux (CMO) du corps entier, de la DMO du corps entier, de la DMO du radius ultra-distal et de la DMO du 1/3 radius que la masse grasse.

CONCLUSION : Cette étude suggère que chez les hommes âgés, la masse grasse est un meilleur déterminant positif de la DMO de la hanche et de la DMO du col fémoral que la masse maigre alors que la masse maigre est un meilleur déterminant positif du CMO du corps entier, de la DMO du corps entier, de la DMO du radius ultra-distal et de la DMO du 1/3 radius que la masse grasse.

INTRODUCTION

Osteoporosis is a systemic skeletal condition characterized by low bone mineral density (BMD) and microarchitectural deterioration of bone tissue, leading to decreased bone strength and increased risk of fragility fractures [1]. Although osteoporosis is known to mainly affect postmenopausal women, there is enough evidence to support substantial bone loss with aging in men as well [1-10].

Factors contributing to BMD variance include genetics, race, gender, body mass index (BMI), dietary intakes (e.g. calcium and vitamin D intake), physical activity pattern (e.g. practising impact sports) and lifestyle characteristics (e.g. sun exposure) [1, 10-15]. Body weight is correlated to BMD in both genders, and BMI is a strong independent determinant of fracture risk [16-23]. A controversy remains concerning the relative contributions of the lean and fat components of body weight to BMD variance and fracture risk [17, 19]. Fat mass has been shown to be a strong

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determinant of BMD in postmenopausal women [19-20]. In fact, adipocytes are important sources of oestrogen derived from aromatization in the postmenopausal period [19-20]. Insulin resistance of fat cells may increase circulating free sex hormones such as oestrogen [19-20]. These two mechanisms may partially explain the positive association between fat mass and bone mass in postmenopausal women [19-20]. However, in elderly men, little is known about the relation between fat and lean masses on one hand and BMC and BMD on the other hand.

The main aim of this study was to explore the relative contribution of lean mass and fat mass to BMC and BMD variances in a population-based random sample of Lebanese elderly men.

MATERIAL AND METHODS

Subjects
Seventy Lebanese men (aged 65-84 years) participated in the study. The men were randomly selected from the Greater Beirut area. The estimated resident population of Beirut is around one million (a mixture of the various Lebanese communities) [7].

Exclusion criteria • Subjects with any medical condition likely to affect bone metabolism including history of chronic disease with vital organ involvement or intake of medications that may affect bone metabolism (i.e. steroid intake for more than six months, treatment with bisphosphonates or other bone antiresorptive drug) were excluded. Also were excluded subjects with diabetes mellitus, a history of radiotherapy or chemotherapy, or bed rest for more than one month within six months prior to the study. Subjects with conditions technically interfering with DXA assessment were also excluded (i.e. previous spine or hip surgery). The study was approved by the Institutional Review Board of Hôtel-Dieu Hospital-Saint Joseph University, and informed consent was obtained from all study participants [7].

Anthropometric measurements
Height (cm) was measured in the upright position to the nearest 1 mm with a Seca standard stadiometer. Body weight (kg) was measured on a Taurus mechanic scales with a precision of 100 g. The men were weighed wearing only underclothes. Body mass index (BMI) was calculated as body weight divided by height squared (kg/m^2). Body composition (lean mass, fat mass, body fat percentage) was assessed by DXA (Hologic QDR-4500W; Waltham, MA).

Bone mass measurements
Bone mineral content (BMC, in g) and density (BMD, in g/cm^2) were determined for each individual. DXA measurements were completed for the whole body (WB), the total hip, the femoral neck, the ultra distal radius and the 1/3 radius. In our center, the coefficients of variation were < 1.5% for BMC and BMD [7]. To adjust for whole body

bone size, WB BMC/height and WB BMD/height were calculated [24-25]. The same certified technician performed all analyses using the same technique for all measurements.

Statistical analysis
The means and standard deviations (SD) were calculated for all clinical data and for the bone measurements. Associations between clinical and bone data were given as Pearson correlation coefficients. Multiple linear regression analysis models were used to test the relationship between bone data (BMC and BMD) with age, lean mass and fat mass, and r^2 were reported. Data were analyzed with Number Cruncher Statistical System (NCSS, 2001). A level of significance of $p < 0.05$ was used.

RESULTS

Clinical characteristics and bone measurements of the study population
Age, anthropometric characteristics and bone data (WB BMC, WB BMC/height, WB BMD, WB BMD/height, TH BMD, FN BMD, UD radius BMD and 1/3 radius BMD) are displayed in Table I.

Correlations between clinical characteristics, lean and fat masses and bone data
Weight and BMI were positively correlated to WB BMC, WB BMC/height, WB BMD, WB BMD/height, TH BMD, FN BMD, UD radius BMD and 1/3 radius BMD ($p < 0.05$). Height was positively correlated to WB BMC,

TABLE I CLINICAL CHARACTERISTICS and BONE DATA of the STUDY POPULATION		
	Mean ± SD	**Range**
Age (years)	74.2 ± 5.0	65 - 84
Weight (kg)	73.5 ± 12.2	44 - 102
Height (cm)	165 ± 5	151 - 180
BMI (kg/m^2)	22.3 ± 3.3	13.2 - 29.7
Fat mass (kg)	19.5 ± 6.2	8.0 - 36.1
Fat mass/height (g/cm)	118 ± 36	50 - 203
Fat mass (%)	26.7 ± 5.5	16.4 - 38.1
Lean mass (kg)	51.7 ± 6.6	34.0 - 66.1
Lean mass/height (g/cm)	301 ± 34	204 - 379
WB BMC (g)	2041 ± 385	1141 - 3132
WB BMC/height (g/cm)	12.3 ± 2.0	7.1 - 17.4
WB BMD (g/cm^2)	1.01 ± 0.10	0.787 - 1.32
WB BMD/height ($g/cm^2/cm$)	0.0061 ± 0.0005	0.0048 - 0.0082
Total hip BMD (g/cm^2)	0.839 ± 0.136	0.587 - 1.25
Femoral neck BMD (g/cm^2)	0.696 ± 0.116	0.506 - 1.01
UD radius BMD (g/cm^2)	0.414 ± 0.075	0.230 - 0.584
1/3 radius BMD (g/cm^2)	0.683 ± 0.085	0.432 - 0.855
BMI: body mass index **BMD**: bone mineral density	**WB**: whole body **UD**: ultra distal	**BMC**: bone mineral content

	WB BMC (g)	WB BMC/height (g/cm)	WB BMD (g/cm^2)	WB BMD/height (g/cm^2/cm)	TH BMD (g/cm^2)	FN BMD (g/cm^2)	1/3 Radius BMD (g/cm^2)	UD Radius BMD (g/cm^2)
TABLE II CORRELATIONS BETWEEN CLINICAL CHARACTERISTICS and BONE DATA								
Age (years)	− 0.23	− 0.23	− 0.33**	− 0.33**	− 0.39***	− 0.37**	− 0.36**	− 0.38 **
Weight (kg)	0.71***	0.66***	0.49***	0.33**	0.62***	0.56***	0.39***	0.44 ***
Height (cm)	0.64***	0.50***	0.44***	0.10	0.29*	0.28*	0.15	0.19
BMI (kg/m^2)	0.62***	0.62***	0.44***	0.35**	0.62***	0.55***	0.40***	0.45 ***
Fat mass (kg)	0.48***	0.46***	0.32**	0.23	0.54***	0.46***	0.25*	0.30 *
Fat mass/height (kg/cm)	0.41***	0.41***	0.27*	0.22	0.52***	0.44***	0.29*	0.24 *
Fat mass (%)	0.48***	0.21	0.32**	0.11	0.38**	0.29	0.25*	0.30 *
Lean mass (kg)	0.73***	0.68***	0.52***	0.34**	0.52***	0.48***	0.39***	0.43 ***
Lean mass/height (kg/cm)	0.65***	0.47***	0.47***	0.37**	0.51***	0.47***	0.45***	0.42 ***

WB: whole body   **BMC**: bone mineral content   **BMD**: bone mineral density   **TH**: total hip   **FN**: femoral neck   **UD**: ultra distal   **BMI**: body mass index
*$p < 0.05$ **$p < 0.01$ ***$p < 0.001$

WB BMD, TH BMD, FN BMD and 1/3 radius BMD ($p < 0.05$). Age was negatively correlated to WB BMC, WB BMC/height, WB BMD, TH BMD, FN BMD, 1/3 radius BMD and UD radius BMD ($p < 0.05$) (Table II). Lean mass and fat mass were positively correlated to WB BMC, WB BMC/height, WB BMD, TH BMD, FN BMD, UD radius BMD and 1/3 radius BMD (Table II).

Multivariate analysis

Lean mass was positively correlated to WB BMC, WB BMD, UD radius BMD and 1/3 radius BMD after controlling for age, height and fat mass (Table III). Fat mass was not significantly related to WB BMC, WB BMD, UD radius BMD and 1/3 radius BMD after controlling for age, height and lean mass. Fat and lean masses were positively correlated to TH and FN BMD after controlling for age and height (Table III). However, fat mass was a stronger determinant of TH BMD and FN BMD than lean mass after controlling for age and height (Table III).

DISCUSSION

This study conducted on 70 Lebanese elderly men showed that both fat mass and lean mass were positive determinants of total hip BMD and femoral neck BMD after controlling for age and height. This result is clinically important because it suggests that both fat mass and lean mass may have a protective role against osteoporosis in elderly men. However, the strength of association between fat mass, lean mass and BMD may vary by site of BMD measurement.

In our study, body weight and body mass index (BMI) were positively correlated to BMC and BMD values. These data confirm previous reports that BMD is closely related to body weight and BMI in elderly men [26-34]. Several mechanisms may explain the weight-BMD relationship in this period of life [19-23]. For instance, increased body weight is associated with increased mechanical loading on bone.

The correlation coefficient between lean mass and

BMC was higher (r = 0.73) than those between lean mass and TH BMD (r = 0.52) and lean mass and FN BMD (r = 0.48). Furthermore, the correlation coefficient between lean mass and TH BMD was higher (r = 0.52) than those between lean mass and UD BMD (r = 0.43) and lean mass and 1/3 radius BMD (r = 0.39). As a matter of fact, increased lean mass is associated with increased mechanical loading on weight-bearing bones. The hip is a weight-bearing site while the forearm is a non-weight bearing site. Lean mass was a positive determinant of whole body BMC, whole body BMD, TH BMD, FN BMD, 1/3 radius BMD and ultra distal BMD after controlling for age, height and fat mass. Fat mass was not correlated to whole body BMC, whole body BMD, 1/3 radius BMD and ultra distal BMD after controlling for age, height and lean mass. However, fat mass was a stronger determinant of TH BMD and FN BMD than lean mass after controlling for height and age. This finding suggests a site-specific effect of fat mass on BMD in elderly men. Moreover, our study suggests that the influence of fat mass on TH BMD and FN BMD increases with age. Our results are in accordance with those of Bleicher et al. [35] who showed that in elderly men losing weight, loss of hip BMC and BMD was more strongly related to loss of fat rather than lean body mass. Yerges-Armstrong et al. [36] showed in Afro-Caribbean men aged > 40 years that higher total adipose tissue area was associated with lower cortical volumetric BMD at the proximal tibia, while Bhupathiraju et al. [37] underlined that centrally located body fat is associated with lower hip BMD in older Puerto Rican adults. The different results concerning the influence of fat mass on BMD may be related to disparities in study design, statistical analyses (e.g. correction for body weight) and age profile of the study sample. Also, we cannot exclude a racial and ethnic influence on the relationship between fat mass and BMD in elderly men. Fat mass may influence bone tissue by different mechanisms [19]. First, increased fat mass augments mechanical loading on the skeleton (especially on the cortical component of the hip). Second, a number of hormones may link the two tissues. For

example, increased fat mass is associated with increased oestrogen (by aromatization of androgen to oestrogen) and leptin circulating levels [4, 20, 22]. It is well established that oestrogen is a positive determinant of BMD in men while leptin increases osteoblastic proliferation and differentiation and may regulate production of osteoprotegerin and receptor activator of NF-$_k$B ligand (RANKL) which results in diminished recruitment of osteoclasts and reduced bone resorption [19-20, 22]. In addition, increased fat mass may positively influence the secretion of ß-Cell hormones such as insulin, leptin and preptin which all stimulate osteoblast proliferation in vitro and in vivo

TABLE III		
MULTIPLE LINEAR REGRESSION ANALYSIS MODELS		
Coefficient	SE	p
Dependent variable: WB BMC (r^2 = 0.60)		
Constant	– 1750	1020	0.09
Height (cm)	19.19	6.35	0.004
Fat mass (g)	0.010	0.005	0.08
Lean mass (g)	0.025	0.006	< 0.001
Age (years)	– 11.07	6.04	0.07
Dependent variable: WB BMD (r^2 = 0.34)		
Constant	0.635	0.370	0.09
Height (cm)	0.003	0.002	0.17
Fat mass (g)	0.000001	0.000002	0.38
Lean mass (g)	0.000005	0.000002	0.03
Age (years)	– 0.005	0.002	0.008
Dependent variable: Total hip BMD (r^2 = 0.46)		
Constant	1.250	0.415	0.004
Height (cm)	– 0.001	0.002	0.57
Fat mass (g)	0.000008	0.000002	< 0.001
Lean mass (g)	0.000006	0.000002	0.02
Age (years)	– 0.008	0.002	< 0.001
Dependent variable: Femoral neck BMD (r^2 = 0.36)		
Constant	0.975	0.389	0.01
Height (cm)	– 0.000	0.002	0.78
Fat mass (g)	0.000006	0.000002	0.006
Lean mass (g)	0.000005	0.000002	0.04
Age (years)	– 0.007	0.002	0.002
Dependent variable: UD Radius BMD (r^2 = 0.22)		
Constant	0.846	0.282	0.004
Height (cm)	– 0.002	0.001	0.22
Fat mass (g)	0.000001	0.000001	0.47
Lean mass (g)	0.000004	0.000001	0.01
Age (years)	– 0.004	0.001	0.009
Dependent variable: 1/3 Radius BMD (r^2 = 0.27)		
Constant	1.135	0.305	< 0.001
Height (cm)	– 0.002	0.001	0.26
Fat mass (g)	0.000001	0.000001	0.26
Lean mass (g)	0.000005	0.000001	0.008
Age (years)	– 0.005	0.001	0.004

WB: whole body   **BMC**: bone mineral content   **BMD**: bone mineral density

[19-20]. Moreover, increased fat mass may be associated with decreased sex hormone-binding globulin (SHBG) [19-20]. This will result in increased free concentrations of sex hormones which would be expected to reduce osteoclast activity and increase osteoblast activity [19-20]. In contrast, weight loss is associated with increased levels of SHBG, which in turn accelerates bone loss in elderly men [32-33].

Another potential mechanism for fat is its effect as absorber of environmental toxins thus protecting other tissues from their harmful effect [38-40]. A larger fat mass leads to a lower circulation of environmental toxins thus reducing their negative impact on bone during bone formation years [38-40].

In our study, after controlling for age, height and lean mass, fat mass was a positive determinant of total hip and femoral neck BMD but not of whole body, 1/3 radius and UD radius BMD. These results are in contrast with those of our previous study conducted among Lebanese postmenopausal women in whom fat mass remained a strong determinant of whole body, total hip, femoral neck, 1/3 radius and UD radius BMD after controlling for years since menopause and lean mass [41]. This suggests that the relation between fat mass and BMD differs by gender and by skeletal site. Reid *et al*. [19, 25] and other researchers [42-43] underlined that the fat-BMD relationship depends on gender (the fat-bone relationship is weaker in men), exercise status (the relationship is stronger in sedentary populations) and menopausal status (the fat-bone relationship is stronger in postmenopausal women).

Our study has some limitations. First, the cross-sectional nature of this study is a limitation because it cannot properly evaluate the effect of the confounding variables. Second, our small study sample may not be accurately representative of the general elderly population. Third, we did not perform blood samples to assess endocrine factors such as growth hormone (GH), insulin-like growth factor 1 (IGF-1), testosterone, estrogen and dehydroepiandrosterone (DHEA) which are well-known to have an impact on BMD in elderly men. Fourth, DXA cannot distinguish between subcutaneous and visceral fat, or between subcutaneous and intramuscular peripheral fat [44]. However, subcutaneous and visceral fat have different effects on bone structure and strength [45]. Finally, we did not assess several determinants of BMC and BMD such as physical activity, daily calcium intake, protein intake and vitamin D status. Nevertheless, up to our knowledge, it is the first study that has aimed at exploring the relative contribution of lean and fat masses to bone mineral density variance in Lebanese elderly men highlighting the strength of association between fat mass and lean mass on one hand and BMC and BMD on the other hand, and the potential relevance of body composition assessment for osteoporosis management.

In conclusion, this study suggests that, in elderly men, lean mass is a stronger determinant of WB BMC, WB BMD, UD radius BMD and 1/3 radius BMD than fat mass

while fat mass is a stronger determinant of TH BMD and FN BMD than lean mass. Further prospective research is needed to study the effect of changes in fat and lean masses on BMD and BMC in elderly men.

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