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Original article

DXA-based variables and osteoporotic fractures in Lebanese postmenopausal women

M.-L. Ayoub[a], G. Maalouf[b], F. Bachour[b], A. Barakat[b], B. Cortet[c,f], I. Legroux-Gérot[c,f], G. Zunquin[d], D. Theunynck[d], A. Nehme[e], R. El Hage[a,*]

[a] Department of Physical Education, Faculty of Arts and Social Sciences, University of Balamand, El-Koura, Lebanon
[b] Musculoskeletal Department, Bellevue Medical Center, Faculty of Medicine of Saint-Joseph University, Mansourieh, Lebanon
[c] Department of Rheumatology, Roger Salengro Hospital, CHU de Lille, 59037 Lille cedex, France
[d] Départment of STAPS, URePSSS-EA 4110/EA448, ULCO, 59383 Dunkerque cedex 01, France
[e] Department of Orthopedic Surgery and Traumatology, Saint-Georges University Medical Center, University of Balamand, P.O. Box 166378, Achrafieh, 1100 2807 Beirut, Lebanon
[f] EA4490, 62327 Boulogne-sur-Mer cedex, France

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ABSTRACT

Introduction: The aim of this study was to assess DXA-based variables (bone mineral density, bone mineral apparent density, compressive strength index of the femoral neck and trabecular bone score) in Lebanese postmenopausal women having presented a previous fracture.
Materials and methods: One thousand Lebanese postmenopausal women between 45 and 89 years participated in this study. The women were recruited by advertisements offering bone mineral density measurements at a reduced cost. Subjects with previous history of radiotherapy or chemotherapy were excluded. Informed written consent was obtained from all the participants.
Results: Femoral neck compressive strength index (FN CSI) was significantly ($P < 0.001$) associated with the presence of fracture using a simple logistic regression (odds ratio = 0.51 [0.385–0.653]). When a multivariate logistic regression analysis was performed with the presence of fracture as a dependent variable and each of age, FN BMD and FN CSI as independent variables, only FN BMD ($P = 0.005$) and FN CSI ($P = 0.004$) were found to be associated with the presence of fracture.
Conclusion: This study suggests that FN CSI is associated with history of osteoporotic fractures in postmenopausal women. The use of FN CSI in clinical practice may help to identify patients with high risk of fracture.
Level of evidence: Epidemiological study, level IV.

1. Introduction

Bone mineral density (BMD) is a strong predictor of fracture risk in elderly women [1–6]. BMD is influenced by several factors such as ethnicity and origin [7,8]. For instance, it has been demonstrated that BMD values for Lebanese subjects are lower compared with the American/European subjects [7,8]. The low BMD values in Lebanese subjects may be explained by several factors such as low calcium and vitamin D intakes and high prevalence of sedentary lifestyle [9–12]. These factors may affect the fracture incidence in the Lebanese population [13,14]. Nevertheless, bone size and body size also play important roles in fracture risk and contribute differentially to fracture risk in different groups [15–18]. Based on this, Karlamangla et al. [19] have examined the prediction of incident hip fracture risk by composite indices of femoral neck strength, constructed from dual X-ray absorptiometry (DXA) scans of the hip. These indices integrate femoral neck size and body size with bone density, and they reflect the structure's ability to withstand axial compressive forces and bending forces and the ability to absorb energy in an impact [19–23]. Several studies have shown that these indices have the potential to improve hip fracture risk assessment [19–21]. However, the relation between these indices and the incidence of major osteoporotic fractures needs to be clarified. The main aim of this study was to assess DXA-based variables — bone mineral apparent density (BMAD), compressive strength index (CSI) of the femoral neck and trabecular bone score (TBS) — in a population of prior osteoporotic fractures in Lebanese postmenopausal women. The secondary aim of this study was to verify

* Corresponding author.
E-mail address: rawadelhage21@hotmail.com (R. El Hage).

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Table 1
Clinical characteristics and bone variables of the study population.

	Whole population (n = 1000)	Women without previous fracture (n = 836)	Women with previous fracture (n = 164)
Age (years)	61.1 ± 11.7	60.4 ± 11.6***	65.0 ± 11.5
Weight (kg)	67.4 ± 13.7	67.2 ± 13.8	68.5 ± 12.8
Height (cm)	155.5 ± 7.7	156.0 ± 7.8***	152.7 ± 6.5
BMI (kg/m^2)	27.9 ± 5.3	27.6 ± 5.3***	29.4 ± 5.3
L2-L4 BMD (g/cm^2)	0.960 ± 0.158	0.974 ± 0.162***	0.894 ± 0.146
TBS	1.310 ± 0.116	1.329 ± 0.118***	1.275 ± 0.098
TH BMD (g/cm^2)	0.830 ± 0.140	0.835 ± 0.144**	0.799 ± 0.126
FN BMD (g/cm^2)	0.789 ± 0.147	0.796 ± 0.158***	0.736 ± 0.120
FN BMAD (g/cm^3)	0.167 ± 0.097	0.170 ± 0.105*	0.152 ± 0.029
FN CSI (g/kg m)	3.84 ± 0.07	3.88 ± 0.81***	3.55 ± 0.74
Total radius BMD (g/cm^2)	0.533 ± 0.101	0.561 ± 0.098***	0.509 ± 0.099
1/3 radius BMD (g/cm^2)	0.715 ± 0.123	0.725 ± 0.120***	0.660 ± 0.129
UD radius BMD (g/cm^2)	0.368 ± 0.080	0.372 ± 0.080***	0.348 ± 0.077

BMI: Body Mass Index; TBS: Trabecular Bone Score; BMD: bone mineral density; TH: total hip; FN: femoral neck; BMAD: bone mineral apparent density; CSI: Compressive Strength Index; UD: ultra-dsital.
*Significant differences between women without incident fracture and women with incident fracture, $P < 0.05$; **Significant differences between women without incident fracture and women with incident fracture, $P < 0.01$; ***Significant differences between women without incident fracture and women with incident fracture, $P < 0.001$.

whether these DXA-based variables remain associated with history of osteoporotic fractures after controlling for BMD and age.

2. Material and methods

2.1. Subjects and study design

One thousand Lebanese postmenopausal women (mean age 61.1 ± 11.7, extr 45–89 years) participated in this study. The women were recruited by advertisements offering bone mineral density measurements at a reduced cost. Subjects with previous history of radiotherapy or chemotherapy were excluded. Informed written consent was obtained from all the participants. Health service records were assessed for osteoporotic fractures (not associated with trauma codes). Hip fractures and major osteoporotic fractures (i.e., hip, clinical spine, forearm, and humerus fractures) were recorded because these are the basis for the 10-year absolute fracture risk estimates published by Kanis et al. [4].

2.2. Anthropometric and bone measurements

Weight and height were measured, and Body Mass Index (BMI, kg/m^2) was calculated. Lumbar spine (L2-L4), bone mineral density (BMD), total hip (TH) BMD, femoral neck (FN) BMD and radius BMD were measured by DXA (GE Healthcare Lunar Prodigy). Femoral Neck Compressive Index (FN CSI) was calculated as previously described [19–23]. FN CSI (FN BMD * FN width/weight) expresses the forces that the femoral neck has to withstand in weight bearing. Bone mineral apparent density (BMAD), an estimate of volumetric bone mineral density (g/cm^3), of the femoral neck was calculated as previously described [24,25]. For FN, the formula BMAD = BMC/BMA^2 (BMC = Bone mineral content) was used [24,25]. Lumbar spine trabecular bone score (TBS) was derived from DXA lumbar spine examinations [26]. In our laboratory, the coefficients of variation were less than 1% for BMC and BMD measurements [26]. The same certified technician performed all analyses using the same technique for all measurements.

2.3. Statistical analysis

The means and standard deviations were calculated for all the clinical data and for the bone measurements. Clinical characteristics and bone variables were compared between the two groups using a one-way analysis of variance (ANOVA). Odds ratios for age, FN BMD, FN CSI, TBS and FN BMAD were estimated using multiple logistic regressions having at least one major osteoporotic fracture as the dependent variable. Data were analyzed with SPSS (version 16.0). A level of significance of $P < 0.05$ was used.

3. Results

3.1. Clinical characteristics and bone variables of the study population

In our study group, mean age was 61.1 ± 11.7 years, and mean BMI was 27.9 ± 5.3 kg/m^2. At the time of baseline DXA scan, women with previous fracture (n = 164) were shorter ($P < 0.001$), older ($P < 0.001$), with a higher BMI ($P < 0.001$), a lower FN BMD ($P < 0.001$) and a lower FN CSI ($P < 0.001$) than women without fracture (n = 836). Body weight was not significantly different between women with previous fracture and women without fracture (Table 1).

3.2. Clinical characteristics and fracture incidence

Age, height and BMI were significantly associated with the presence of previous fracture using simple logistic regressions ($P < 0.001$). FN BMD was significantly ($P < 0.001$) associated with the presence of previous fracture using a simple logistic regression (odds ratio [95% confidence interval] = 0.041 [0.011–0.152]).

3.3. Femoral Neck Compressive Strength Index and fracture incidence

FN CSI was significantly ($P < 0.001$) associated with the presence of previous fracture using a simple logistic regression (odds ratio [95% confidence interval] = 0.51 [0.385–0.653]). When a multivariate logistic regression analysis was performed with the presence of a previous fracture as a dependent variable and each of age, FN BMD and FN CSI as independent variables, only FN BMD ($P = 0.005$) and FN CSI ($P = 0.004$) were found to be associated with the presence of previous fracture (Table 2).

3.4. Bone mineral apparent density and fracture incidence

Using a multiple logistic regression analysis, BMAD of femoral neck was significantly associated with a previous osteoporotic fracture even after controlling for age ($P < 0.05$). The significant relation between BMAD and fracture incidence disappeared after controlling for FN BMD and age using a multiple logistic regression (Table 3).

Table 2
Relation between femoral neck compressive strength index and incidence of major osteoporotic fractures using a multiple logistic regression.

	Odds ratio	5% confidence lower	95% confidence higher	*P*-value
Constant	2.46	0.26	22.90	0.42
Age (years)	1.01	0.997	1.034	0.09
FN BMD (g/cm^2)	0.082	0.014	0.469	0.005
FN CSI (g/kg m)	0.654	0.488	0.875	0.004

FN: femoral neck; BMD: bone mineral density; CSI: Compressive Strength Index.

Table 3
Relation between femoral neck bone mineral apparent density and incidence of major osteoporotic fractures using a multiple logistic regression.

	Odds ratio	5% confidence lower	95% confidence higher	*P*-value
Constant	0.446	0.063	3.2	0.42
Age (years)	1.021	1.003	1.040	0.03
FN BMD (g/cm^2)	0.229	0.014	3.618	0.140
FN BMAD (g/cm^3)	0.001	0.000	169.3	0.267

FN: femoral neck; BMD: bone mineral density; BMAD: bone mineral apparent density.

3.5. Trabecular Bone Score (TBS) and fracture incidence

TBS was significantly ($P < 0.001$) associated with the presence of a previous fracture using a simple logistic regression (odds ratio [95% confidence interval] = 0.0259 [0.004–0.144]). This association remained significant after controlling for age and FN BMD (Table 4). When a multiple logistic regression analysis was performed with the presence of fracture as a dependent variable and each of BMI, age, lumbar spine BMD and TBS as independent variables, only lumbar spine BMD ($P = 0.001$) and TBS ($P = 0.01$) were found to be associated with the presence of fracture.

4. Discussion

This study conducted on 1000 Lebanese postmenopausal women mainly shows that femoral neck compressive strength index and trabecular bone score are associated with history of osteoporotic fractures.

As expected, women with incident fracture were older and had lower BMD values compared to women without fracture. Furthermore, FN CSI, FN BMAD and TBS values were also lower in women with incident fracture compared to women without fracture. Our results are in line with those of several previous studies [19–21,27–32]. For instance, FN CSI is shown to be associated with fractures in elderly women [19–21]. Moreover, Sardinha et al. [22] demonstrate that physical activity exerts a positive effect on FN CSI in children. We have recently confirmed this positive effect of physical activity on FN CSI in young adults [23]. In our study, FN CSI is associated with history of osteoporotic fractures in Lebanese postmenopausal women. Accordingly, the use of FN CSI may help physicians to identify patients with high risk of fracture.

Table 4
Relation between trabecular bone score and incidence of major osteoporotic fractures using a multiple logistic regression.

	Odds ratio	5% confidence lower	95% confidence higher	*P*-value
Constant	117	5.3	2589	0.003
Age (years)	0.988	0.966	1.010	0.27
FN BMD (g/cm^2)	0.0758	0.0161	0.356	0.001
TBS	0.072	0.0105	0.508	0.008

FN: femoral neck; BMD: bone mineral density; TBS: Trabecular Bone Score.

As for BMAD, several studies show associations between BMAD and fractures [27–29,33,34]. Although the clinical use of BMAD in growing children is well justified considering the technical limitations of DXA [24,25], its use in postmenopausal women remains controversial. In our study, FN BMAD was lower in women with previous fracture compared to women without fracture, and it was associated with the presence of fracture using a simple logistic regression. However, we cannot consider that BMAD is independently associated with a fracture since the multiple logistic regression analysis shows no association between BMAD and incident fracture after controlling for age and FN BMD. Accordingly, the use of BMAD only to determine fracture risk in elderly women cannot be justified based on our results.

Concerning TBS, several previous studies suggest a relation between low TBS and high fracture risk [30–32,35–37]. In a recent study, we showed that the correlation between TBS and BMD is poor suggesting that these two parameters reflect two different bone properties [26]. In this report, TBS is associated with history of osteoporotic fractures in Lebanese postmenopausal women. These results have clinical implications since they encourage physicians to use TBS in order to identify patients with high risk of fracture.

This study has several limitations. First, the cross-sectional nature of the study is a limitation. Second, increased abdominal fat mass may alter BMD and TBS measurements [38–40]. Third, only major osteoporotic fractures were included in this study. Fourth, several bone mass and fracture risk determinants (e.g. hormones, physical activity level, sleep duration and nutritional intakes) were not taken into account in our study. Fifth, the time between the fracture and the DXA measurement was not precise; this point is important since the fracture may directly influence DXA-variables (FN CSI or TBS) and may generally cause secondary bone loss which influences DXA-variables. Finally, the sample of our population is low; larger cohort of patients and longitudinal studies are needed to confirm our observations. However, up to our knowledge, it is the first study that aims at studying the relations between FN CSI, BMAD and TBS on one hand and the incidence of osteoporotic fractures on the other hand in Lebanese postmenopausal women.

In conclusion, this study suggests that FN CSI and TBS are associated with history of osteoporotic fractures in postmenopausal women. The use of FN CSI and TBS in clinical practice may help to identify patients with high risk of fracture.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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