

Screening post-menopausal women for bone mineral level by bioelectrical impedance spectroscopy of dominant arm

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Abstract

Dominant arm bioimpedance spectroscopy (BIS) and lumbar and hip dual energy X-ray absorptiometry (DXA) measurements were conducted simultaneously on 48 post-menopausal women, aged between 43 and 86 years, with no hip or arm fracture history at Department of Radiology of Istanbul University Cerrahpasa Hospital. According to lumbar DXA results, 21 women were classified as normal, 22 as osteopenia and 5 as osteoporosis; whereas hip DXA results classified 30 women as normal, 15 as osteopenia and 3 as osteoporosis. Only 26 participants had identical lumbar and hip bone mineral density (BMD) diagnostic results. Dominant arm characteristic frequencies of normal subjects were statistically significantly different from osteoporotic subjects based on both lumbar ($p < 0.005$) and hip classification groups ($p < 0.001$). Hip and lumbar spine DXA BMD values were significantly correlated ($r = 0.55$, $p < 0.005$). The dominant arm BIS characteristic frequency, considered as the single predictor in earlier diagnosis of osteoporosis, was found negatively correlated with DXA measurements for both hip and lumbar spine regions. The Spearman rank correlation coefficient of BIS values with the hip DXA values ($r = -0.53$, $p < 0.001$) was higher than that of lumbar spine ($r = -0.37$, $p < 0.001$). In receiver operating characteristic (ROC) curve analysis, the best discrimination of dominant arm characteristic frequency was made between normal and osteoporotic subjects based on the hip subgroups ($p < 0.001$). Both lumbar bone mineral content (BMC) ($r = -0.47$, $p < 0.001$) and hip BMC ($r = -0.4340$, $p < 0.005$) were statistically significantly correlated with dominant arm characteristic frequency.

Keywords: bioimpedance spectroscopy, dual energy X-ray absorptiometry, bone mineral content, bone mineral density, osteoporosis, osteopenia.

Introduction

Bone strength is a factor that notably affects the daily life of a person, where decreased bone strength could cause challenges such as hip fractures and fragilities [1,2]. Osteoporosis is defined as the decrease in bone strength and bone mineral density (BMD) and occurs with ageing (senile osteoporosis) or during the post-menopause period [3,4]. The probability of osteoporosis occurrence is higher if the body did not reach its maximum bone density at early ages [5,6].

Post-menopausal osteoporosis is the loss of trabecular bone after menopause with changes in body composition and hormones [7]. The proportions of fat, muscle, and lean body mass in the body vary with estrogen deficiency [7]. A current study revealed that there was a strong association between vitamin D level and BMD in women during the menopausal and post-menopausal period [8].

Osteoporosis progresses silently and its symptoms are not always visible [9–11]. Several methods have been proposed for estimating BMD, including dual energy X-ray absorptiometry (DXA), single energy X-ray absorptiometry (SXA), quantitative computed tomography (QCT), radiographic absorptiometry, quantitative ultrasound, computed tomography (CT) and magnetic resonance imaging (MRI). Despite the vast amount of information they provide, radiation dose and contrast agent intake are some of the drawbacks of the CT and MRI methods, respectively. Moreover, both systems are expensive and the preparation process is long [12–14]. Bone mineral density is usually

measured with DXA and SXA in peripheral regions. The gold-standard method to assess BMD is dual X-ray absorptiometry (DXA). DXA measures the bone mineral density of total body through the hip or lumbar spine. The forecast of hip fracture is performed effectively by measuring both hip and lumbar spine regions; as hips are the most effective regions for fracture comparisons [12-14].

Body bioimpedance characteristics are a function of body composition as well as bone mineral content. With foot to foot, single frequency (50 kHz, 0.8 mA) bioimpedance measurements of the whole body in postmenopausal women (42 – 84 years) and men (42 – 94 years), it was shown that the bioimpedance was correlated to the BMD, with a relatively higher correlation in men [15]. In a recent study, Cole characteristics of complex electrical impedance measurements from different body compartments in post-menopausal women were compared against their reference DXA bone mineral density classifications and the characteristic frequency, i.e. the frequency at which the impedance phase shift is maximized in magnitude, was shown to have the strongest correlation with BMD, for the dominant arm [16, 17].

Osteoporosis is very commonly encountered in post-menopausal women. There is an increased need for a low cost and efficient screening alternative to address this population. In this study, a segmental bioimpedance spectroscopy of only the dominant arm and DXA measurements of lumbar and hip regions were collected simultaneously on post-menopausal women to investigate the usability of bioimpedance analysis (BIA) as a screening tool in bone mineral density assessment.

Materials and methods

Data collection and analysis

Forty-eight post-menopausal women, aged 43-86 years, with no hip or arm fracture history, participated in the study. All subjects were DXA patients clinically requested to undergo bone mineral density (BMD) analysis. The weight and height of the patients were measured before performing their BMD analysis using the Hologic QDR 4500SL DXA machine. Body mass index (BMI) was calculated as the ratio of the subject's weight to his height squared (kg/m^2). The DXA scans were performed in the supine position at the L1-L4 vertebra of lumbar spine and the femur hip and completed within approximately ten minutes.

Shortly after DXA scan, multifrequency complex bioimpedance measurements of the dominant arm were performed at 132 discrete frequencies in the range of 10 kHz to 200 kHz, with Impedimed Multifrequency Analyzer (IMA) (model SFB7) using the four electrode technique, and repeating each measurement 20 times. The subjects were in sitting position and they were requested to remove all

metallic items such as bracelets, necklaces, rings, watches, etc. from the dominant arm [18].

The placement of electrodes was above the third metacarpal bone for the positive current electrode, above the wrist for the positive voltage electrode, on the infraclavicular fossa for the negative voltage electrode, and between shoulder and negative voltage electrode for the negative current electrode (Figure 1). A small guarding distance was kept between the electrodes. Following the placement of electrodes, it was checked that the limbs were not adjacent and the patient was not in contact with any metallic surface. The patient remained motionless during the entire measurement process. The bioimpedance spectroscopy (BIS) mode was selected on the IMA device and the patients were alerted before the measurements began. From the Cole circle of the complex electrical impedance measurements, the dominant arm characteristic frequency was calculated.

T scores, z scores and BMD values were also estimated from DXA results. According to the WHO classification system, the participants were classified as normal, osteopenic, or osteoporotic based on T and Z scores [3].

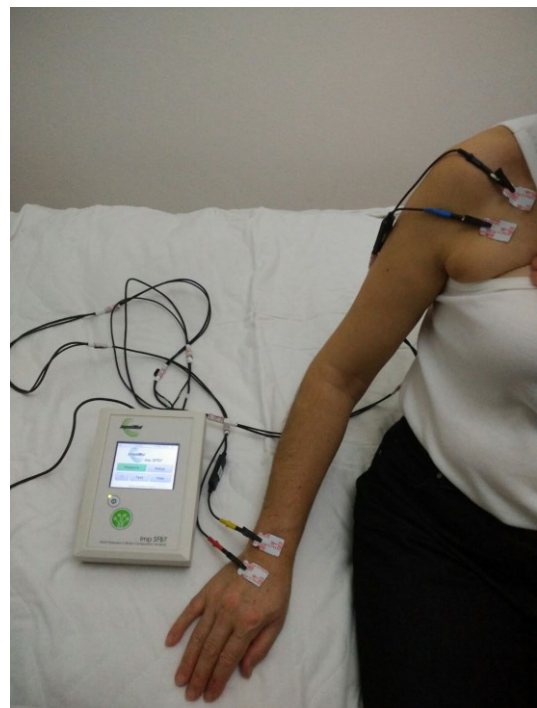


Figure 1. Placement of electrodes and the BIS device.

Hip and lumbar DXA BMD results were separately analyzed and were classified accordingly as normal, osteopenic or osteoporotic (T-score ≥ -1 normal, $-1 > \text{T-score} > -2.5$ osteopenia, T-score ≤ -2.5 osteoporosis).

In untreated, older post-menopausal women, when the BMD is lower, the fracture risk is greater.

Table 1. The classification and statistical analysis of patients based on lumbar spine BMD values.

Parameter	Type	N	Mean \pm SD [Min, Max]	Osteopenia	Osteoporosis
Age (year)	Normal	21	60.2 \pm 9.68 [43, 79]	NS	NS
	Osteopenia	22	57.7 \pm 9.1 [45, 86]	-	NS
	Osteoporosis	5	60.4 \pm 8.88 [47, 69]	-	-
Age at Menopause (year)	Normal	21	48.4 \pm 5.2 [40, 58]	NS	NS
	Osteopenia	22	46.05 \pm 3.6 [40, 52]	-	NS
	Osteoporosis	5	45.6 \pm 7.01 [40, 57]	-	-
BMI (kg/m ²)	Normal	21	30.76 \pm 5.51 [19.82, 43.57]	NS	NS
	Osteopenia	22	29.97 \pm 6.02 [16.41, 43.42]	-	NS
	Osteoporosis	5	25.25 \pm 1.33 [24.03, 27.33]	-	-
Dominant arm Characteristic Frequency (kHz)	Normal	21	51.72 \pm 8.57 [39.92, 69.57]	NS	P < 0.005
	Osteopenia	22	55.91 \pm 10.01 [39.96, 75.68]	-	NS
	Osteoporosis	5	65.42 \pm 12.96 [57.98, 88.30]	-	-
Total Lumbar Spine BMD (g·cm ⁻²)	Normal	21	1.048 \pm 0.08 [0.934, 1.259]	P < 0.001	P < 0.001
	Osteopenia	22	0.855 \pm 0.05 [0.784, 0.929]	-	P < 0.001
	Osteoporosis	5	0.732 \pm 0.04 [0.694, 0.773]	-	-
Total Lumbar Spine Z Scores	Normal	21	1.52 \pm 1.08 [-0.4, 3.6]	P < 0.001	P < 0.001
	Osteopenia	22	-0.53 \pm 0.6 [-1.5, 0.9]	-	NS
	Osteoporosis	5	-1.4 \pm 0.89 [-2.7, 0.5]	-	-
Total Lumbar Spine T Scores	Normal	21	0.0 \pm 0.78 [-1.0, 1.9]	P < 0.001	P < 0.001
	Osteopenia	22	-1.8 \pm 0.43 [-2.4, -1.1]	-	P < 0.001
	Osteoporosis	5	-2.86 \pm 0.34 [-3.2, -2.5]	-	-
Total Lumbar BMC (g)	Normal	21	59.36 \pm 8.31 [45.88, 80.05]	P < 0.001	P < 0.001
	Osteopenia	22	46.94 \pm 5.44 [39.56, 60.49]	-	NS
	Osteoporosis	5	39.7 \pm 6.52 [32.98, 49.6]	-	-

NS: Not Significant; P values calculated with Tukey-Kramer post-hoc test.

In general, fracture risk approximately doubles for each -1 decrease in T-score. The Z-score of < -2 represents BMD below the expected age range while for $z > -2$ BMD is within the expected age range.

Statistical analysis

Statistical analysis was performed using MATLAB R2017b (Mathworks Inc., Natick, MA) program. DXA BMD measurements and characteristic frequencies were compared between all patients subgroups (osteopenic, osteoporotic or normal) defined based on hip or lumbar BMD values using one-way analysis of variance (ANOVA).

If any resultant F-value was statistically significantly high, then Tukey-Kramer test was applied for post-hoc analysis. A total α of 0.05 was contained by using multiple comparison correction.

The parameters such as age, age at menopause, weight, height, BMI, bone mineral density, T score, Z score, bone mineral content and characteristic frequency of dominant arm were also compared between the patient subgroups using ANOVA followed by multiple comparison tests.

Spearman rank correlation coefficients were computed to assess the correlation between the DXA BMD results and dominant arm characteristic frequencies; the relationship

between hip and lumbar DXA results and BMI and BMD and BMC of the subjects. The Bland Altman method was used to evaluate if there was any systematic bias between the hip and lumbar DXA BMD results. ROC curve analysis was further carried out to determine the cut-off values of dominant arm characteristic frequency that was calculated along with the area under curve, sensitivity, specificity and Youden's index.

Ethical approval

This research was conducted in accordance with the Helsinki Declaration, at Department of Radiology of Istanbul University Cerrahpasa Hospital and was approved by their Ethical Committee of Clinical Research.

Informed consent

Informed consent was obtained from all participants before starting this study.

Results

The mean values of total BMD, dominant arm characteristic frequency, BMI, age, and age at menopause of the normal, osteopenic, and osteoporotic patients based on lumbar spine and hip DXA results are displayed in Tables 1 and 2,

respectively. According to lumbar spine DXA results, 21 participants were classified as normal, 22 as osteopenic and 5 as osteoporotic (Table 1). Similarly, according to hip DXA results, 30 participants were classified as normal, 15 as osteopenic and 3 as osteoporotic (Table 2). Ages or ages at menopause were not statistically significantly different between the normal, osteopenic and osteoporotic patients, in either of the lumbar spine or the hip DXA groups. BMI values were higher in normal participants than osteopenic patients ($p < 0.001$) based on hip DXA results.

BMD values of both lumbar spine and hip regions decreased with the bone strength ($p < 0.001$). Dominant

arm characteristic frequency values of the osteoporotic patients were statistically significantly higher than normal patients for both the lumbar spine ($p < 0.005$) and hip ($p < 0.001$) subgroups.

The lumbar BMD results were lower than hip BMD results in 32 out of 48 participants. Twenty-six patients had the same bone density classification based on both hip and lumbar spine DXA. There was a disagreement between the bone density classifications of hip and lumbar DXA results for the remaining 22 patients (Table 3). The hip BMD results were lower than those of the lumbar spine region in five subjects, and higher in the remaining 17 subjects.

Table 2. The classification and statistical analysis of patients based on hip BMD values.

Parameter	Type	N	Mean \pm SD [Min, Max]	Osteopenia	Osteoporosis
Age (year)	Normal	30	60.2 \pm 10.1 [45, 86]	NS	NS
	Osteopenia	15	58.1 \pm 6.2 [49, 69]	-	NS
	Osteoporosis	3	25.8 \pm 3.5 [43, 68]	-	-
Age at Menopause (year)	Normal	30	47.4 \pm 4.9 [40, 58]	NS	NS
	Osteopenia	15	47.4 \pm 4.5 [40, 57]	-	NS
	Osteoporosis	3	41.0 \pm 1.0 [40, 42]	-	-
BMI (kg/m ²)	Normal	30	32.05 \pm 4.51 [24.46, 43.57]	$P < 0.001$	NS
	Osteopenia	15	26.01 \pm 5.81 [16.41, 37.89]	-	NS
	Osteoporosis	3	25.77 \pm 3.49 [23.12, 29.72]	-	-
Dominant arm Characteristic Frequency (kHz)	Normal	30	51.63 \pm 8.48 [39.92, 71.35]	$P < 0.001$	$P < 0.001$
	Osteopenia	15	59.69 \pm 11.41 [43.12, 88.30]	-	NS
	Osteoporosis	3	66.40 \pm 6.32 [59.14, 70.70]	-	-
Total Hip BMD (g·cm ⁻²)	Normal	30	0.939 \pm 0.1 [0.821, 1.232]	$P < 0.001$	$P < 0.001$
	Osteopenia	15	0.736 \pm 0.05 [0.657, 0.805]	-	$P < 0.001$
	Osteoporosis	3	0.569 \pm 0.07 [0.497, 0.631]	-	-
Total Hip Z Scores	Normal	30	0.9 \pm 0.7 [-0.1, 2.6]	$P < 0.001$	$P < 0.001$
	Osteopenia	15	-0.8 \pm 0.41 [-1.7, -0.1]	-	$P < 0.001$
	Osteoporosis	3	-2.4 \pm 0.86 [-3.30, -1.6]	-	-
Total Hip T Scores	Normal	30	-0.1 \pm 0.74 [-1.0, 1.7]	$P < 0.001$	$P < 0.001$
	Osteopenia	15	-1.7 \pm 0.39 [-2.3, -1.1]	-	$P < 0.001$
	Osteoporosis	3	-3.0 \pm 0.55 [-3.6, -2.5]	-	-
Total Hip BMC (g)	Normal	30	33.40 \pm 7.25 [26, 62.03]	$P < 0.001$	$P < 0.001$
	Osteopenia	15	23.86 \pm 2.13 [21.4, 28.2]	-	NS
	Osteoporosis	3	20.03 \pm 4.04 [15.7, 23.7]	-	-

NS: Not Significant; P values calculated with Tukey-Kramer post-hoc test.

Table 3. The disagreement between DXA results from hip and lumbar spine regions. Lumbar spine and hip DXA results were consistent in 26 participants.

Number of Patients	Hip Results	Lumbar Results
3	Osteopenia	Normal
13	Normal	Osteopenia
1	Osteoporosis	Osteopenia
4	Osteopenia	Osteoporosis
1	Osteoporosis	Normal

The Bland Altman test results for the differences of BMD of hip and lumbar body parts of all participants measured by DXA are shown in Figure 2. There was not any

systematic bias between the two measures according to the mean and standard deviation of the differences (-0.075 ± 0.127 g·cm⁻²). However, there were two outliers. The first

outlier point had a difference of $0.209 \text{ g} \cdot \text{cm}^{-2}$ between the two measures, and this patient was classified as normal and osteopenic based on hip and lumbar DXA, respectively. BMI of this patient was 31.96 kg/m^2 . The second outlier point had a difference of $-0.349 \text{ g} \cdot \text{cm}^{-2}$ between the two measures. This patient was classified as osteoporotic and osteopenic according to the hip and lumbar DXA, respectively. This patient's BMI was 29.72 kg/m^2 .

According to ranges of BMI (kg/m^2) that are used to describe levels of obesity participants were classified as 9

normal ($\text{BMI} < 25.0$), 13 as overweight (not obese) ($30 > \text{BMI} > 25.0$); 18 as Class 1 (low-risk) obese ($35.0 > \text{BMI} > 30.0$); 3 as Class 2 (moderate-risk) obese ($40.0 > \text{BMI} > 35.0$) and 3 as Class 3 (high-risk) obese ($\text{BMI} > 40.0$). The relationships between DXA BMD, dominant arm characteristic frequency, BMI, age, and age at menopause are given in Table 4. Total hip BMD and total lumbar BMD results were statistically significantly correlated ($r = 0.55$, $p < 0.001$).

Table 4. The relationship between lumbar spine or hip BMD, the dominant arm characteristic frequency, age, and age at menopause.

Subjects	Relationship	Number of Subjects	Spearman Correlation Coefficient	Significance level P
All	Total Hip BMD and Total Lumbar BMD	48	0.5503	< 0.0001
	Total Hip BMD and Characteristic Frequency	48	-0.5311	< 0.0001
	Total Lumbar BMD and Characteristic Frequency	48	-0.3669	0.0107
	Total Hip BMC and Characteristic Frequency	48	-0.4340	< 0.005
	Total Lumbar BMC and Characteristic Frequency	48	-0.4699	< 0.001
Normal (hip)	Total Hip BMD and Characteristic Frequency	30	-0.2598	0.1657
Osteopenia (hip)		15	-0.3607	0.1870
Osteoporosis (hip)		3	0.5000	1
Normal (lumbar)	Total Lumbar BMD and Characteristic Frequency	21	-0.2143	0.3493
Osteopenia (lumbar)		22	-0.0785	0.7280
Osteoporosis (lumbar)		5	-0.5000	0.4500
Normal (hip)	Total Hip BMC and Characteristic Frequency	30	-0.0954	0.6146
Osteopenia (hip)		15	-0.3429	0.2110
Osteoporosis (hip)		3	1.0000	0.3333
Normal (lumbar)	Total Lumbar BMC and Characteristic Frequency	21	-0.2403	0.2928
Osteopenia (lumbar)		22	-0.4207	0.0524
Osteoporosis (lumbar)		5	-0.6000	0.3500
All	Age and Characteristic Frequency	48	0.1183	0.4233
	Age and Total Hip BMD	48	-0.1223	0.4076
	Age and Total Lumbar BMD	48	0.0558	0.7064
All	Age at Menopause and Characteristic Frequency	48	-0.0250	0.8659
	Age at Menopause and Total Hip BMD	48	0.1297	0.3797
	Age at Menopause and Total Lumbar BMD	48	0.0752	0.6115
Normal (hip)	Age and Total Hip BMD	30	-0.5150	0.0036
Osteopenia (hip)		15	-0.3396	0.2155
Osteoporosis (hip)		3	-0.5000	1
Normal (lumbar)	Age and Total Lumbar BMD	21	0.0988	0.6700
Osteopenia (lumbar)		22	-0.0295	0.8964
Osteoporosis (lumbar)		5	0.6669	0.2667
Normal (hip)	Age at Menopause and Total Hip BMD	30	0.1782	0.3461
Osteopenia (hip)		15	0.3971	0.1427
Osteoporosis (hip)		3	0.5000	1
Normal (lumbar)	Age at Menopause and Total Lumbar BMD	21	0.1461	0.5275
Osteopenia (lumbar)		22	-0.1380	0.5402
Osteoporosis (lumbar)		5	-0.4000	0.5167

BMD and dominant arm characteristic frequency were inversely correlated. Hip BMD had higher correlation with dominant arm characteristic frequency ($r = -0.53$, $p < 0.0001$), than lumbar BMD ($r = -0.37$, $p < 0.05$).

While the correlation between dominant arm characteristic frequency and hip BMD were higher ($p = -0.53$, $p < 0.001$) than hip BMC ($r = -0.43$, $p < 0.005$), the relationship between the dominant arm characteristic frequency and lumbar BMD ($r = -0.37$, $p < 0.05$) were lower than lumbar BMC ($r = -0.47$, $p < 0.001$).

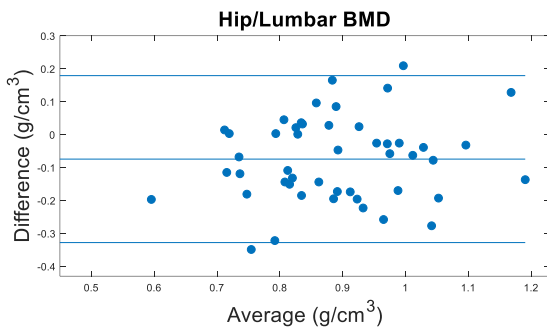


Figure 2. Comparison of Hip and Lumbar Spine DXA BMD. Results by Bland Altman method.

The correlation coefficient between hip BMD and dominant arm characteristic frequency ($r = -0.36$, $p = 0.01$) were higher than lumbar BMD in the osteopenic groups ($r = -0.08$, $p = 0.73$).

Although the correlation coefficients between the BIS results and hip or lumbar BMD results were high in osteoporotic patients ($r = 0.5$ and $r = -0.5$), p values ($p = 1$ and $p = 0.45$, respectively) were not statistically significant.

BMC and dominant arm characteristic frequency were inversely associated. Both lumbar BMC ($r = -0.47$, $p < 0.001$) and hip BMC ($r = -0.4340$, $p < 0.005$) were statistically significantly correlated with dominant arm characteristic frequency. BMC and dominant arm characteristic frequency were not statistically significantly correlated in all subgroups.

No statistically significant correlations were observed between age, age at menopause; BMD or BIS results for all patients or patient subgroups.

The results of ROC curve analysis are given in Table 5. An optimal cut-off value of 59.14 kHz for dominant arm characteristic frequency resulted in an area under the curve (AUC) of 0.91, with 83.3 % sensitivity, 100.0 % specificity and a Youden's index of 0.8333, to discriminate between normal and osteoporotic patients in hip region ($p < 0.01$).

For normal and osteoporotic patients' discrimination in lumbar spine region, an optimal cut-off value of 57.98 kHz was determined, with 0.87 AUC, 76.2 % sensitivity, 100.0 % specificity and a Youden's index of 0.7619 ($p < 0.001$).

A statistically significant discrimination of normal and osteopenic subjects were observed only in hip region;

where an optimal cut-off value of 52.79 kHz was established, with 0.74 AUC, 63.3 % sensitivity, 80.0 % specificity and a Youden's index of 0.4333 ($p < 0.001$). The discrimination of normal against osteopenia and osteoporosis was analyzed and an optimal cut-off value was evaluated as 54.0 kHz with 0.76 AUC, 72.2 % sensitivity, % 73.3 specificity and a Youden's index of 0.456 ($p < 0.001$).

An optimal cut-off value for the discrimination of osteoporosis against normal and osteopenia based on hip region was found as 58.58 kHz with 0.87 AUC, 100.0 % sensitivity, 75.6 % specificity and a Youden's index of 0.756 ($p < 0.005$). Cut-off values of dominant arm characteristic frequencies were statistically significant in all hip classification groups except the discrimination between osteopenia and osteoporosis.

Discussion

In the assessment of BMD of different parts of the body using DXA, it is possible to obtain different BMD results since the diagnosis is usually based on the area of measurement (hip or lumbar spine), and this might cause confusion [19]. Some radiologists prefer choosing the hip or femoral neck areas as diagnostic reference, while others prefer choosing the area of the lowest BMD [20]. Both hip and lumbar spine areas are effective in estimating hip fractures. Moreover, hip region measurements could prevent all fractures. Also, hip region has been reported to be less affected by hormones, medications and degenerative arthritis [20].

It has been reported that around 30% discrepancies exist between the bone mineral densities of right and left hips in post-menopausal women [21,22]. The femoral neck and trochanteric areas' BMD measurements are statistically significantly different as shown in a previous study and bilateral hip scan is recommended for a better diagnosis [23].

In our results, it was also observed that 22 out of 48 subjects were classified differently based on hip and lumbar spine DXA measurements, and in 32 participants the lumbar BMD values were higher than hip BMD values. Also, when hip and lumbar spine BMD results of the subjects were compared by the Bland Altman method, it was seen that they were not the same. The subjects, whose lumbar spine and hip BMD results had a disagreement, had high BMI. 17 out of 22 subjects had higher hip BMD than lumbar BMD values. Contrary to the general measurements, the high values of the hip BMD in the mismatches could have been caused by a failure during the lumbar DXA scanning. L4 has the highest BMD in L1 – L4, so the total lumbar BMD results may change due to an incorrect selection of L4 or L1 having too low BMD [24].

Table 5. ROC curve analysis.

	Area Under Curve (AUC) [95% CI]	Significance level P	Cut-off Dominant Arm Characteristic Frequency (kHz)	Sensitivity (%) [95% CI]	Specificity (%) [95% CI]	Youden's Index
Characteristic Frequency (osteoporosis vs. normal & osteopenia) (hip)	0.87 [0.60-1.00]	< 0.005	58.58	100.0 [100.0-100.0]	75.6 [63.0-88.1]	0.756
Characteristic Frequency (osteoporosis vs. normal & osteopenia) (lumbar)	0.80 [0.55-1.0]	0.0085	57.07	100.0 [100.0-100.0]	69.8 [56.0-83.5]	0.698
Characteristic Frequency (normal vs. osteopenia and osteoporosis) (hip)	0.76 [0.62-0.91]	< 0.001	54.0	72.2 [51.5-92.9]	73.3 [57.5-89.2]	0.456
Characteristic Frequency (normal vs. osteopenia and osteoporosis) (lumbar)	0.66 [0.51-0.82]	0.0184	50.43	74.1 [57.5-90.6]	52.4 [31.0-73.7]	0.2654
Characteristic Frequency (normal vs. osteoporosis) (hip)	0.91 [0.79 – 1.0]	< 0.001	59.14	83.3 [70.0 - 96.7]	100.0 [100.0 – 100.0]	0.8333
Characteristic Frequency (normal vs. osteoporosis) (lumbar)	0.87 [0.72 – 1.0]	< 0.001	57.98	76.2 [58.0 – 94.4]	100.0 [100.0 – 100.0]	0.7619
Characteristic Frequency (normal vs. osteopenia) (hip)	0.74 [0.59 – 0.88]	< 0.001	52.79	63.3 [46.1 – 80.6]	80.0 [59.8 – 100.0]	0.4333
Characteristic Frequency (normal vs. osteopenia) (lumbar)	0.62 [0.45 – 0.79]	0.09	-	-	-	-
Characteristic Frequency (osteopenia vs. osteoporosis) (hip)	0.78 [0.45 – 1.0]	0.05	-	-	-	-
Characteristic Frequency (osteopenia vs. osteoporosis) (lumbar)	0.73 [0.46 – 1.0]	0.05	-	-	-	-

CI: Confidence interval.

Lumbar BMD is highly affected by degenerative arthritis and this might raise the lumbar spine BMD values. For this reason, while the BMD measurements in other areas decline, the lumbar spine BMD may even rise in patients of 65 years of age and older [20]. It could be concluded that the hip region measurements are more reliable since both hip regions detect all fractures and are less affected by other factors (hormones, medications, degenerative arthritis). Previous studies have already shown that there exists a correlation between bioimpedance analysis (BIA) and BMD [15]. BIA and BMD results of both hip and lumbar spine areas were previously found to be correlated in men; meanwhile, only hip BMD were found to be associated with bioelectrical impedance results in women [15].

In this study, BIS results were found to be negatively correlated with hip and lumbar BMD. Moreover, with post-menopausal women, a higher correlation coefficient was found between hip BMD results and dominant arm characteristic frequencies compared to lumbar spine BMD results. Also, ROC curve analysis showed that the dominant arm characteristic frequency could be used to discriminate hip subgroups. While ROC analysis was successful in discrimination all but osteopenic and osteoporotic hip

subgroups, only normal and osteoporotic subjects were separable based on lumbar results.

A previous study showed that the forearm bone mineral content discrimination was same as spinal bone mineral density for vertebral fractures, while the forearm BMC had better discrimination than spinal BMD for peripheral fractures [25].

The impact of weight and body mass index on bone mineral density is still not fully understood. Some studies have shown that obese or overweight people have lower risk of osteoporosis [26,27]. Additionally, there exist studies that have shown that weight and high BMI are positively associated with BMD, while other studies have shown that body fat percentage influences BMD negatively [28]. Central or peripheral body fat mass have been reported to be inversely associated with BMD [29]. Visceral fat has also been reported to have negative impact on trabecular bone mass [30]. Here, body mass index was analyzed between groups to better understand the effects of weight and height on the skeletal bones.

Bone loss is accelerated with decreasing estrogen in women after menopause. Also, it is known that bone loss occurs with aging [31]. In this study, age and age at menopause were not correlated with BMD and characteristic

frequency. The lack of correlation may result from limited number of subjects.

The characteristic frequencies obtained with the BIS method are influenced by parameters such as fat mass (FM), fat free mass (FFM), intracellular water (ICW) and extracellular water (ECW). BIS studies should be carried out with more subjects by including more parameters.

Conclusion

A statistically significant negative correlation was observed between the characteristic frequency of the dominant arm and both hip and lumbar spine DXA BMD; with a higher correlation with the hip. Although the best available evaluation of one's bone density is performed with a DXA scan, the gold-standard method, possible problems may negatively influence DXA results such as different manufacture's machines or different machines from the same manufacturer or even the same machines from the same manufacturer at different locations; varying machine operators and different anatomical areas in the scan. Being simple, cheap, safe and easy to use, bioelectrical impedance spectroscopy can be suggested as a screening alternative tool in assessing the bone mineral deficiency in post-menopausal women.

Conflict of interest

Authors state no conflict of interest.

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