Prediction of Bone Mineral Density of Lumbar Spine, Hip, Femoral Neck and Ward's Triangle by Forearm Bone Mineral Density

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Abstract

Bone mineral density (BMD) of dual energy X-ray absorptiometry (DEXA) at both radius and ulna were measured to evaluate the correlation of those and BMD at lumbar (L) spine, hip, femoral neck and Ward's triangle. The 64 simple linear regression analysis was calculated to postulate the predicted equation by using the BMD at supradistal, distal 1/10, distal 1/6 and distal 1/3 of both forearms as independent variables, while the dependent variables were BMD at L1-L4 spine, total hip, femoral neck and Ward's triangle. 115 patients aged between 41-79 years (mean age 55.97±8.34 years) from the menopausal clinic, Pramongkutklao Hospital, were scanned at both forearms by Panasonic (DXA-70) DEXA and at non forearm regions by Hologic (QDR 4500) DEXA on the same day. The results showed that the BMD of each of the 4 parts of both radius and ulna had positive correlation to those of L-spine, total hip, femoral neck and Ward's triangle with r = 0.4012 to 0.7032 (P<0.001 for all). The greater distal of the forearm, the better correlation of BMD to the non forearm BMD. The 64 simple linear regression equations were constructed with regression coefficient ranging from 0.6048 to 1.9011 (P<0.001 for all). When considering the non forearm BMD, the mean BMD at Ward's triangle significantly declined more rapidly than that of L-spine, total hip and femoral neck (P<0.05 for all). It indicated that there was an early change of BMD at Ward's triangle. However, this change followed the forearm BMD. Distal forearm BMD was the earliest sign of bone loss. We can predict non forearm BMD by supradistal and distal 1/10 of forearm BMD.

Key word : Prediction, Bone Density

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BMD of the human forearm can be measured by determining the amount of bone or bone loss at the scanning site and predict the risk of forearm fractures. The load at fracture was the most specifically predicted (R^2 = 0.74) by bone mineral and geometric measures of the cortex at the shaft of the radius(1). The forearm measurements were also used to estimate bone loss at remote anatomical locations and thereby estimate the risk of hip, vertebral and other fractures(2,3).

To evaluate the correlation of forearm DEXA and DEXA at lumbar spine, hip and proximal femur (femoral neck and ward's triangle), BMD at 4 parts of both radius and ulna were carried out for comparison with the non forearm BMD. To predict the BMD at lumbar spine, hip femoral neck and Ward's triangle, simple linear regression was analyzed by using each of the 4 parts of the forearm BMD as an independent variable.

MATERIAL AND METHOD

Patients

115 peri and post senile menopausal patients, aged between 41-79 years, (mean age 55.97±8.34 years) were scanned by both Panasonic (DXA-70) and Hologic (QDR 4500) DEXA. In each patient, the right and left forearm were

Table 1. Baseline characteristics of the patients.

Variables	Mean	SD	Minimum	Maximum	n
Age (years)	55.9	8.34	41	79	115
Weight (kg)	58.0	8.41	43	92	115
Height (cm)	155.3	5.48	146	172	115
Menarche (years)	13.9	1.67	9	18	115
Menopause (years)	48.6	3.64	40	59	84

Table 2. Mean, SD and range of the forearm and non forearm BMD (g/cm^2).

Variables	Mean	SD	Minimum	Maximum	n
Right Radius					
supradistal	0.409	0.053	0.256	0.560	115
1/10	0.484	0.059	0.287	0.625	115
1/6	0.536	0.060	0.352	0.721	115
1/3	0.610	0.062	0.372	0.733	115
Right ulna					
supradistal	0.352	0.052	0.184	0.515	115
1/10	0.443	0.067	0.242	0.597	115
1/6	0.495	0.066	0.299	0.667	115
1/3	0.611	0.064	0.388	0.779	115
Left radius					
supradistal	0.410	0.061	0.236	0.585	115
1/10	0.491	0.060	0.293	0.647	115
1/6	0.541	0.063	0.324	0.709	115
1/3	0.604	0.072	0.238	0.839	115
Left ulna					
supradistal	0.364	0.054	0.213	0.534	115
1/10	0.451	0.072	0.221	0.885	115
1/6	0.496	0.065	0.281	0.713	115
1/3	0.605	0.054	0.371	0.789	115
L-spine	0.874	0.141	0.443	1.277	115
Total hip	0.843	0.117	0.512	1..139	115
Femoral neck	0.707	0.106	0.476	1.031	115
Ward's triangle	0.551	0.139	0.214	0.888	115

scanned by Panasonic DEXA while the antero-posterior (AP) lumbar spine, hip and proximal femur were scanned by Hologic DEXA. Scanning was performed on the same day. Measurement of the forearm was performed over the entire length of the forearm and analysis was carried out at 4 regions of interest (ROI) including supradistal, distal 1/10, distal 1/6 and distal 1/3 of the forearm. Each of the ROIs, bone mineral content (g), area (cm^2) and areal BMD (g/cm^2) were computed.

The non forearm included L1-L4 spine, total hip region and Ward's triangle. The total hip region was the sum of the femoral neck, trochanter and intertrochanter regions. The non forearm was scanned, then total area, BMC and BMD were calculated.

Equipment

The Panasonic bone densitometer (DXA-70) was manufactured by Matsushita Industrial equipment (Osaka, Japan). The Hologic DEXA (QDR-4500) was manufactured by Hologic INC (USA). Routine machine calibration was performed beforehand.

Statistics

SPSS-PC version 7.5 was used to calculate the mean, standard deviation (SD) and range. Scatter plots were constructed to evaluate the correlation of BMD between each of the forearm and non forearm regions. Linear regression analysis was carried out and Pearson correlation coefficients were determined.

RESULTS

115 peri and post senile menopausal women from the menopausal clinic, Phramongkutklao Hospital, with a mean age of 55.97±8.34 years (range from 41-79 years) were scanned by both Panasonic and Hologic DEXA. The baseline characteristics of the patients were demonstrated by subclass analysis as mean, SD and range (Table 1). For forearm BMD, the lowest mean BMD occurred at supradistal of the right ulna (Table 2). When considering non forearm BMD (Table 2), mean BMD at Ward's triangle significantly declined more rapidly than that of L1-L4 spine, total hip and femoral neck (P<0.05 for all). The BMD of all parts of both radius and ulna had positive correlation to that of L1-L4 spine, total hip, femoral neck and Ward's triangle with a

Table 3. Correlation and R square of BMD at 4 parts of both forearms and non-forearm.

	Right radius				Right ulna			
	supradistal	1/10	1/6	1/3	supradistal	1/10	1/6	1/3
L1-L4 spine	0.7032 (0.4946)	0.6841 (0.4681)	0.6269 (0.3930)	0.5640 (0.3180)	0.6247 (0.3902)	0.6197 (0.3840)	0.6123 (0.3749)	0.4012 (0.1610)
Total hip	0.6432 (0.4137)	0.5267 (0.2774)	0.5022 (0.2522)	0.4352 (0.1894)	0.6035 (0.3642)	0.5438 (0.2958)	0.5113 (0.2614)	0.4593 (0.2109)
Femoral neck	0.6473 (0.4190)	0.5182 (0.2685)	0.5024 (0.2524)	0.4566 (0.2085)	0.5716 (0.3267)	0.5449 (0.2969)	0.4916 (0.2417)	0.4612 (0.2127)
Ward's triangle	0.6870 (0.4720)	0.5381 (0.2896)	0.5022 (0.2522)	0.4693 (0.2202)	0.5809 (0.3374)	0.5720 (0.3272)	0.5471 (0.2993)	0.4277 (0.1829)
	Left radius				**Left ulna**			
	supradistal	1/10	1/6	1/3	supradistal	1/10	1/6	1/3
L1-L4 spine	0.6814 (0.4643)	0.6472 (0.4188)	0.5942 (0.3530)	0.4323 (0.1869)	0.6164 (0.3800)	0.6160 (0.3794)	0.6158 (0.3792)	0.4935 (0.2436)
Total hip	0.6223 (0.3873)	0.5556 (0.3086)	0.4588 (0.2104)	0.4151 (0.1723)	0.5762 (0.3320)	0.5336 (0.2847)	0.5256 (0.2762)	0.4968 (0.2468)
Femoral neck	0.6036 (0.3644)	0.5464 (0.2985)	0.4393 (0.1929)	0.4126 (0.1702)	0.5214 (0.2718)	0.4868 (0.2370)	0.4599 (0.2115)	0.4800 (0.2304)
Ward's triangle	0.6663 (0.4440)	0.6158 (0.3792)	0.5425 (0.2943)	0.5044 (0.2544)	0.6711 (0.4503)	0.6385 (0.4076)	0.6090 (0.3709)	0.5353 (0.2866)

$p < 0.001$ for all

Table 4. Constant and regression coefficient of 64 simple linear regression equations.

BMD of independent variables (g/cm^2)	BMD of dependent variables (g/cm^2)							
	L1-L4 spine		Total hip		Femoral neck		Ward's triangle	
	Constantx10^{-3}	β*	Constantx10^{-3}	β*	Constantx10^{-3}	β*	Constantx10^{-3}	β*
Right radius								
supradistal	95.4678	1.9100	259.1214	1.4217	176.7609	1.2908	-169.4442	1.7608
1/10	73.0074	1.6612	337.0933	1.0408	257.8344	0.9238	-74.0798	1.2901
1/6	68.3031	1.5081	313.5816	0.9833	229.1033	0.8874	-85.5972	1.1885
1/3	71.4542	1.3195	334.9025	0.8288	226.0875	0.7844	-90.9350	1.0544
Right ulna								
supradistal	265.1351	1.7352	359.7712	1.3643	293.8482	1.1658	-17.5515	1.6082
1/10	291.2782	1.3201	415.6815	0.9582	320.6226	0.8661	13.9965	1.2114
1/6	202.0670	1.3634	389.5624	0.9116	313.4601	0.7908	-26.8876	1.1689
1/3	327.1784	0.8988	328.6532	0.8373	240.9404	0.7585	-20.4864	0.9376
Left radius								
supradistal	227.7956	1.5761	353.4171	1.1956	277.3124	1.0496	-89.4159	1.5609
1/10	183.0934	1.4015	407.1315	0.8881	320.5749	0.7875	-45.6010	1.2171
1/6	152.8605	1.3326	381.1824	0.8546	306.8961	0.7406	-128.1833	1.2621
1/3	364.6670	0.8430	437.4349	0.6723	342.2272	0.6048	-45.8147	0.9981
Left ulna								
supradistal	293.2067	1.5964	392.6875	1.2395	338.3837	1.0150	18.3725	1.4522
1/10	349.0479	1.1643	482.5495	0.8009	385.3683	0.7148	-98.1474	1.4476
1/6	215.3691	1.3279	376.8151	0.9412	337.9677	0.7454	-105.1708	1.3264
1/3	102.5608	1.2736	198.6245	1.0648	143.5524	0.9312	-275.4482	1.3719

* $p<0.001$

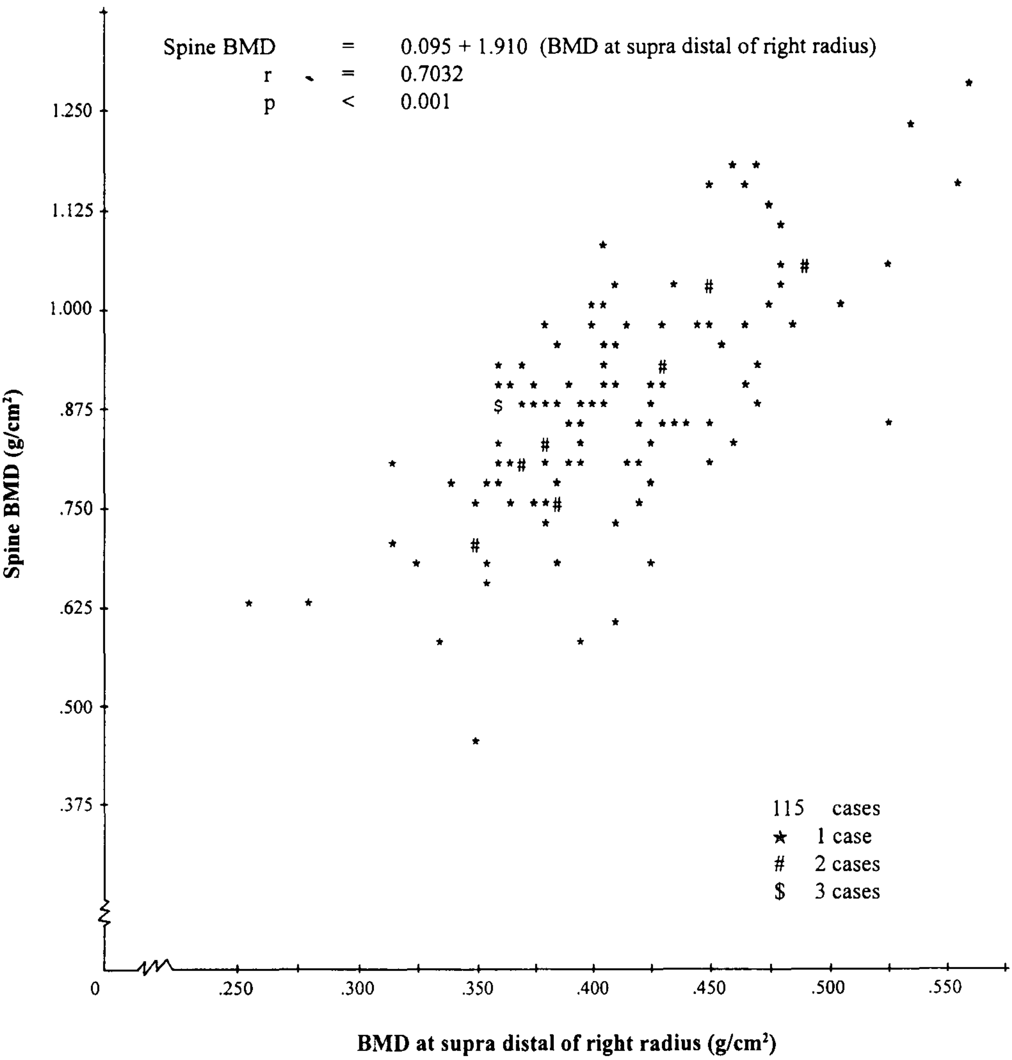

Fig. 1. Scatter plot between spine BMD and BMD at supradistal of right radius.

correlation coefficient ranging from 0.4012 to 0.7032 (p<0.001 for all) as shown in Table 3. However, BMD at supradistal and 1/10 of both radius and ulna showed a stronger correlation with non-forearm BMD than distal 1/6 and 1/3.

The scatter plot between spinal BMD and BMD at supradistal of right radius showed a positive correlation (Fig. 1). The correlation of BMD of other parts of the forearm and non forearm BMD showed a similar trend as shown in Fig. 1 but the degree of correlation (slope) was different depending on the regression coefficient (Table 4). From 64 simple regression analysis, the BMD at the supradistal, 1/10, 1/6 and 1/3 of both radius and ulna can predict that at L1-L4 spine, total hip, femoral neck and Ward's triangle with constant value and regression coefficient ranging from -0.275 to 0.482 and 0.6048 to 1.9100 (P<0.001 for all), respectively as shown in Table 4.

DISCUSSION

Correlation of Z-scores of ultradistal radius BMD with Z-scores for lumbar spine (L2- L4) and femoral neck were high(4). A single BMD measurement at the forearm has a predictive ability for fragility fractures, including hip fractures, on a 25-year perspective(3). BMD declined slowly in the trochanter and total hip but more rapidly in the forearm, femoral neck and Ward's triangle(5). It was found that, BMD at Ward's triangle declined more rapidly than that of spine, hip and neck of femur. It indicated that there was an early change of BMD at Ward's triangle. However, this change followed forearm BMD. Distal forearm BMD is an early sign of bone loss. Because patients with distal radius fracture who are otherwise healthy have not only preferential bone loss at the distal forearm but also a generally low bone mass, patients with fracture of the distal radius fracture should be considered for prophylactic measures against osteoporosis(6).

BMD measurements of lumbar spine, femoral neck and forearm are widely used to detect osteopenia and osteoporosis and to monitor the efficacy of treatment(7). DEXA is the best method to measure bone density(8,9) and measurement of the lumbar spine and femoral neck is standardized. Our data indicated that BMD at radius and ulna can predict that of lumbar spine, femoral neck, hip and Ward's triangle. There was positive correlation between the forearm BMD and that of the spine, hip, femoral neck and Ward's triangle ($r=0.4012$ to 0.7032, $p<0.001$ for all) in peri and postmenopausal women. This is the same conclusion as the measurement in young healthy subjects(6). DEXA provides adequate reliability for *in vivo* determinations of bone mineral content and areal BMD in the distal and shaft sides of the forearm(10).

The peripheral DEXA has the potential for a rapid scanning of patients and is not affected by calcification and degenerative changes that can corrupt DEXA measurements on the antero-posterior spine in older women. The patient motion may occur during femoral scanning (11). Furthermore, the BMD of radius and ulna, especially at supradistal and distal 1/10, showed a strong association between that of lumbar spine, hip, femoral neck and Ward's triangle. So non forearm BMD can be predicted by supradistal and distal 1/10 of forearm BMD. Forearm DEXA measurement is simpler, more suitable and more comfortable method than non forearm measurement. Forearm scanning should be considered to detect bone loss in the general population.

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REFERENCES

1. Augat P, Lida H, Jiang Y, et al. Distal radius fracture: mechanisms of injury and strength prediction by bone mineral assessment. J Orthop Res 1998; 16: 629-35.
2. Augat P, Fuerst T, Genant HK. Quantitative bone mineral assessment at forearm : a review. Osteoporos Int 1998; 8: 299-310.
3. Duppe H, Gardsell P, Nilsson B, Johnell O. A single bone density measurement can predict fractures over 25 years. Calcif Tissue Int 1997; 60: 171-4.
4. Mole PA, McMurdo MET, Paterson CR. Evaluation of peripheral dual energy X-ray absorptiometry : comparison with SPA of the forearm and DEXA of the spine or femur. Br J Radiol 1998; 71: 427-32.
5. Lofman O, Larsson L, Ross I, et al. Bone mineral density in normal Swedish women. Bone 1997; 20: 167-74.
6. Mallmin H, Ljunghall S. Distal radius fracture in an early sign of general osteoporosis : bone mass measurements in a population-based study. Osteoporos Int 1994; 4: 357-61.
7. Horner K, Devlin H, Alsop CW, et al. Mandibular bone mineral density as a predictor of skeletal osteoporosis. Br J Radiol 1996; 69: 1019-25.
8. Sturtridge W, Lentle B, Hanley DA. Prevention and management of osteoporosis : Consensus statements from the Scientific Advisory Board of the Osteoporosis Society of Canada. 2. the use of bone density measurement in the diagnosis and

management of osteoporosis (review). Canad Med Assoc J 1996; 155: 924-9.
9. Adams E. Osteoporosis and bone mineral density. Cur Opinion Radiol 1992; 4: 11-20.
10. Sievanen H, Backstrom MC, Kuusela AL, et al. Dual energy X-ray absorptiometry of the forearm in preterm and term infants : evaluation of the methodology. Pediatr Res 1999; 45: 100-5.
11. Wahner HW, Looker A, Dunn WL, et al. Quality control of bone densitometry in a national health survey using three mobile examination centers. J Bone Miner Res 1994; 9: 951-60.

การทำนายความหนาแน่นของกระดูกสันหลังส่วนเอว, สะโพก, ส่วนคอของกระดูกต้นขาและสามเหลี่ยม Ward's ด้วยความหนาแน่นของกระดูกปลายแขน

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ได้ทำการวัดความหนาแน่นของกระดูกปลายแขนอันนอกและอันในทั้ง 2 ข้าง ด้วยเครื่อง Panasonic (DXA-70) เพื่อหาค่าความสัมพันธ์ กับความหนาแน่นของกระดูกสันหลังส่วนเอว สะโพก ส่วนคอของกระดูกต้นขา และสามเหลี่ยม Ward's ด้วยเครื่อง Hologic (QDR-4500) และคำนวณสมการถดถอยเชิงเส้น 64 สมการ เพื่อใช้เป็นสมการทำนาย โดยมีตัวแปรอิสระคือ ความหนาแน่นที่กระดูกปลายแขนส่วนปลายสุด ส่วนปลาย 1/10 ส่วนปลาย 1/6 และส่วนปลาย 1/3 ตัวแปรตามคือ ความหนาแน่นของกระดูกสันหลังส่วนเอว (ระดับ 1-4) สะโพกทั้งหมด ส่วนคอของกระดูกต้นขา และสามเหลี่ยม Ward's ในผู้ป่วย 115 ราย ช่วงอายุ 41-79 ปี อายุเฉลี่ย 55.97±8.34 ปี จากคลินิกวัยทอง โรงพยาบาลพระมงกุฎเกล้า ผลการวิจัยพบว่า ความหนาแน่นของกระดูกปลายแขนอันนอกและอันในทั้ง 4 ตำแหน่ง มีความสัมพันธ์เชิงบวกกับความหนาแน่นของกระดูกสันหลัง สะโพก ส่วนคอของกระดูกต้นขา และสามเหลี่ยม Ward's ด้วยค่าสหสัมพันธ์เท่ากับ 0.4012 ถึง 0.7032 ($p<0.001$ ทุกค่า) กระดูกปลายแขนตำแหน่งยิ่งอยู่ปลายเท่าใดจะมีความสัมพันธ์กับความหนาแน่นของกระดูกส่วนอื่น ๆ ข้างต้นมากขึ้นเท่านั้น ค่าสัมประสิทธิ์ถดถอยของสมการถดถอยเชิงเส้น 64 สมการ มีค่าเท่ากับ 0.6048 ถึง 1.9011 ($p<0.001$ ทุกค่า) เมื่อพิจารณาความหนาแน่นของกระดูกส่วนอื่น ๆ ที่ไม่ใช่กระดูกปลายแขน ค่าความหนาแน่นเฉลี่ยที่สามเหลี่ยม Ward's ลดลงอย่างรวดเร็วมากกว่าความหนาแน่นเฉลี่ยที่กระดูกสันหลัง สะโพก ส่วนคอของกระดูกต้นขา ($p<0.05$ ทุกค่า) ซึ่งชี้ให้เห็นว่า ความหนาแน่นของกระดูกเริ่มต้นเกิดการเปลี่ยนแปลงที่สามเหลี่ยม Ward's อย่างไรก็ตามการเปลี่ยนแปลงข้างต้นเกิดตามหลังการเปลี่ยนแปลงความหนาแน่นของกระดูกปลายแขน ดังนั้น กระดูกปลายแขนมีการสูญเสียเนื้อกระดูกเร็วที่สุด นอกจากนี้ยังสามารถใช้ความหนาแน่นของกระดูกปลายแขนที่ส่วนปลายสุด และส่วนปลาย 1/10 เป็นตัวทำนายความหนาแน่นของกระดูกส่วนอื่น ๆ ได้

คำสำคัญ : การทำนายค่า, ความหนาแน่นของกระดูก

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