Predicting Osteopenia and Osteoporosis with a Simple Test: A Preliminary Work

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ABSTRACT

Objective: *The occurrence of osteopenia and osteoporosis is a major problem of ageing. For assessing the severity of bone loss, bone mineral density (BMD) measurement is the gold standard. Because of the limitations of BMD, use of simpler serum-based tests to classify osteoporosis/osteopenia patients is gaining interest. In this preliminary work, we aimed to discriminate between healthy individuals and osteoporosis/osteopenia patients through a simple serum-based equation.*

Methods: *In this study, blood from 84 elderly persons were collected and levels of vitamin D, calcium (Ca), phosphorus (P), copper (Cu) and strontium (Sr) were analysed. Additionally, all persons included in the study underwent BMD measurement.*

Results: *Bone mineral density showed that 28 persons had osteoporosis, 28 persons suffered from osteopenia and 28 persons were classified as normal. Using the above-mentioned parameters and major determinants of bone loss disorders, ie age and body mass index (BMI), we suggested various equations. The "Osteo-Pars" equation that is derived from the formula [(Sr × Age)/BMI] showed the best diagnostic accuracy in receiver operating characteristic analysis.*

Conclusion: *The suggested equation is a simple model that obtains reasonable results in discriminating healthy individuals from patients with osteopenia/osteoporosis. More study is needed to reach an exact, conclusive statement about the potential clinical application of this equation in the assessment of bone loss severity.*

Keyword: Age, body mass index, BMI, bone mineral density, osteoporosis, strontium

Predicción de la Osteopenia y Osteoporosis con una Prueba Sencilla: Un Trabajo Preliminar

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RESUMEN

Objetivo: *La aparición de osteopenia y osteoporosis es un grave problema de envejecimiento. Para evaluar la severidad de la pérdida de masa ósea, la medición de la densidad mineral ósea (DMO) es el estándar de oro. Debido a las limitaciones de la DMO, el uso de pruebas más simples basadas en el suero para clasificar a los pacientes de osteoporosis/osteopenia está ganando interés. En este trabajo preliminar, nos propusimos discriminar entre individuos sanos y pacientes de osteoporosis/osteopenia a través de una sencilla ecuación basada en suero.*

Métodos: *En este estudio, se recogieron muestras de sangre de 84 personas mayores, y se analizaron los niveles de vitamina D, calcio (Ca), fósforo (P), cobre (Cu) y estroncio (Sr). Además, a todas las personas incluidas en el estudio se les practicó una medición de DMO.*

Resultados: *La densidad mineral ósea demostró que 28 personas tenían osteoporosis, 28 personas sufrían de osteopenia, y 28 personas fueron clasificadas como normales. Usando los parámetros antes mencionados y los principales determinantes de los trastornos de pérdida de hueso, es decir la edad y el índice de masa corporal (IMC), sugerimos diversas ecuaciones. La ecuación "Osteo-Pars" que se deriva de la fórmula [(Sr × Edad)/IMC] mostró poseer la mejor exactitud diagnóstica en el análisis de las características operativas del receptor.*

Conclusión: *La ecuación sugerida es un modelo simple que obtiene resultados razonables a la hora de diferenciar los individuos sanos de los pacientes con osteopenia/osteoporosis. Se necesitan más estudios*

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para llegar a un planteamiento concluyente y exacto acerca de la potencial aplicación clínica de esta ecuación en la evaluación de la severidad de la pérdida ósea.

Palabras claves: Edad, índice de masa corporal, IMC, densidad mineral ósea, osteoporosis, estroncio

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INTRODUCTION

Because of the silent, progressive nature and relatively high prevalence rate of osteopenia and osteoporosis, these diseases are major health problems worldwide. In these diseases, attenuation in bone strength occurs and susceptibility to bone fractures increases. Low bone mass and micro-architectural deterioration of bone tissue are the most important characteristics of osteopenia and osteoporosis (1). Various reports have shown a higher rate of osteoporosis in postmenopausal women than in men of the same age. After menopause, the decrease in a woman's oestrogen level and the ultimate lack of its inhibitory effects on bone resorption lead to a rapid loss of bone (2, 3). Osteoclasts and osteoblasts are the main cells involved in bone remodelling in which old bone tissue is replaced by new tissue. In this process that occurs in sequential phases, osteoclasts produce a resorption pit or groove, and osteoblasts are responsible for the deposition of osteoids in these pits. After the osteoids are mineralized, the pit will close and the old bone will be replaced by new tissue. During a human's life, bone remodelling is a constant process. It is estimated that in adolescence, bone is replaced every ten years. It has been proposed that as age increases, bone loss occurs at an even faster rate in women than in men. Various risk factors are known for osteopenia and osteoporosis. The main ones include: female gender, age > 70 years, early onset of menopause, inactivity, cigarette smoking, alcohol abuse, excessive caffeine consumption, lack of dietary calcium and/or sunlight exposure, demographic characteristics such as weight, height, and genetic factors, medications, medical disorders and previous fractures (4, 5).

To assess osteoporosis and osteopenia today, physicians are relying on bone mineral density (BMD) measurement, which is a static measurement of bone mineralization. This test is performed by dual energy X-ray [DXA] (4, 6–8) and is interpreted by the World Health Organization (WHO) diagnostic criteria (9, 10). Bone mineral density measurement is the golden method for the diagnosis of osteopenia and osteoporosis, yet it has some major limitations that make it unfavourable for both physicians and patients: a) it is costly, b) the related equipment is expensive, c) trained personnel must perform the test, d) this method is not applicable for people with a spine deformity and e) the accuracy of the test results are compromised by osteoarthritis and vertebral fractures (6–8, 11).

There is a growing interest in classifying patients with osteopenia and osteoporosis through simpler serum-based tests. The main aim of this study was to find a probable equation based on serum levels of some important minerals and trace elements for estimating the severity of bone loss in patients with osteopenia and osteoporosis.

SUBJECTS AND METHODS

Study population

We selected eighty-four elderly persons from Amirkola Health and Ageing Project [AHAP] (12). Inclusion criteria for selecting the persons were age over 60 years, living at home, walking without the help of another person, having the ability to give written consent and answer the questionnaire themselves. Exclusion criteria were having a current or past illness or taking medications which would affect bone metabolism (*eg* uncontrolled hyperthyroidism, parathyroidism, Type 1 diabetes mellitus, connective tissue disease, gastrectomy due to cancer or ulcer, prostate cancer with anti-androgen therapy, glucocorticoid therapy ≥ 5 mg/day for more than three months, treatment with bisphonate for > 6 months, use of vitamin D for > 2 years, and current warfarin use or vitamin K supplementation) and prolonged bed rest (12).

The local ethics committee approved the study and written informed consent was obtained from each individual.

Bone mineral density

On all included persons, BMD was measured by DXA absorptiometry using a Lexxos densitometer. Bone mineral density results were expressed in absolute values (g/cm^2) and T-score for lumbar spine and proximal femur. According to the WHO criteria, osteoporosis is defined as a BMD that lies 2.5 standard deviations or more below the average value for young healthy adults (T-score of < -2.5 SD) and a T-score between -1.0 and -2.5 is considered indicative of osteopenia (9, 10).

Laboratory measurements

Fasting blood samples for the analysis of biochemical parameters were obtained in the morning after an overnight fast, and the serum was divided into 0.2 mL microtubes and stored frozen at -80 ˚C until analysis.

Serum vitamin D concentration was measured by the enzyme-linked immunosorbent assay (ELISA) method (immunodiagnostic systems) and related commercial kits (Jahesh Teb Co. Ltd Kits, Iran). The serum calcium (Ca) and phosphorus (P) concentrations were determined by colorimetric methods and corresponding kits (Ziestchem Diagnostics Kits, Iran).

To analyse the serum levels of copper (Cu) and strontium (Sr), we used the atomic absorption spectrophotometry method (PG 990) equipped with a graphite furnace. In this method, the samples were first diluted with HNO and Triton

X100, and then 10 µL of the diluted samples was injected into the graphite furnace. Serum was diluted ten-fold with 1 ml/L each HNO_3 and Triton X100 for analysis of Cu and four-fold in a 0.5 ml/L Triton X100 – 1 ml/L HNO_3 solution for Sr. We used working standard solutions that were prepared from stock standards (1000 mg/L, Merck) of Cu and Sr**.**

Statistical analysis

All statistical analysis was performed with SPSS® (version 18.0; SPSS Inc., Chicago, IL, USA), and a p-value < 0.05 was considered significant. Data regarding the three study groups were analysed by one-way analysis of variance (ANOVA) followed by the Scheffe post hoc test. By using four parameters, *ie* age, BMI, serum Cu and Sr levels, various equations were calculated and the proposed equations were compared by ANOVA, Scheffe's method. The validity of the equations was assessed by receiver operating characteristic (ROC) analysis. The area under the curve (AUC) was used to evaluate the diagnostic performance of each equation. From the ROC curves, the optimal cut-off points were selected according to the maximum value of sensitivity and specificity. Finally, positive predictive value (PPV), negative predictive value (NPV) and positive and negative likelihood ratios (LR^+ and LR^-) were calculated by CAT Maker software.

RESULTS

In this cross-sectional study, 84 elderly persons participated, including 42 females with a mean age ± SD of 65.5 ± 4.9 years and 42 males (69.3 ± 6.57 years). Bone mineral density results by DXA showed that among these persons, 28 persons had osteoporosis, 28 persons suffered from osteopenia and 28 persons were classified as normal. The results of demographic characteristics, the BMD results according to the mean of BMD in spinal (BMD-S) and/or femoral (BMD-F), and related Z- and T-score (Z-S and Z-F, T-S and T-F) are presented in Table 1. According to the results, the normal individuals had greater BMI measurements than those in the other groups, and the differences were statistically significant ($p < 0.001$). The BMD measurements in healthy individuals were greater than in the two other groups, and the differences were statistically significant ($p < 0.001$). This trend matches the WHO criteria for classifying osteoporosis and osteopenia patients. The results of the laboratory analysis are also presented in Table 1.

Evaluation of the impact of age and BMI for probable discrimination of healthy individuals from patient groups

We tried to find a new equation for discriminating between healthy individuals and the patient groups by focussing on the serum levels of two important elements *ie* Cu and Sr. In the first step, we calculated the sum of these two elements as a new factor (serum Cu levels + serum Sr levels (µg/L)). As is clear from Table 2, although a gradual decreasing trend was observed on the level of this equation from patients with osteoporosis toward the healthy individuals, the differences were not statistically significant ($p > 0.563$).

Because of the great influence of two important factors, *ie* age and BMI in the aetiology of osteoporosis and osteopenia disorders, we used more equations for probable discrimination between healthy individuals and patients using these two variables. In this manner, the first equation resulted from the mean serum levels of Sr (µg/L) divided by BMI. Although significant differences were observed among the participating groups in this equation ($p = 0.040$), the trend was not decreasing or increasing. The next equation resulted from the mean serum levels of Cu (µg/L) divided by BMI, and a decreasing trend from osteoporosis patients toward healthy individuals was observed ($p = 0.023$). The next equation resulted from the sum of mean serum levels of Cu and Sr (µg/L) divided by BMI [(Cu + Sr)/BMI]. Using this equation, we also observed a decreasing trend from osteoporosis patients toward healthy individuals. The normal persons had the lowest levels and the differences were statistically significant ($p = 0.021$). In another equation that was derived from the impact of serum Cu levels, age (years) and BMI [(Cu × Age)/BMI], we observed a decreasing trend and statistically significant differences at the level of this equation from osteoporosis patients toward healthy individuals ($p = 0.010$). When a serum Sr level replaced serum Cu levels in this equation, we observed similar results. In the next two equations, we used serum Cu or Sr levels multiplied by BMI and the result was divided by age [(Cu or Sr × BMI)/Age]. The results in using these two equations did not differ statistically and were not in a decreasing or increasing order. Finally, we calculated the result of the final equation, *ie* [((Cu + Sr) × age)/BMI]. As is clear in Table 2, a decreasing trend and statistically significant differences ($p = 0.009$) were observed on the level of the results from this equation from osteoporotic patients and healthy individuals.

Results of ROC analysis

According to the results presented in Table 2, six equations produced some reasonable results. To compare the diagnostic accuracies of these equations, we performed an ROC analysis on three categories, *ie* for discrimination of a) healthy individuals from all patients (*ie* osteopenia and osteoporosis sufferers), b) healthy persons from patients with osteopenia and c) normal individuals from patients with osteoporosis.

As can be seen in Table 3, the first equation, *ie* Sr/BMI, had only a reasonable AUC for discriminating normal persons from osteopenic patients (AUC = 0.719). The next equation, derived from the formula Cu/BMI, had an accurate AUC for discriminating normal persons from those with osteoporosis. A similar pattern was observed for the next two equations, *ie* [(Cu + Sr)/BMI] and [(Cu × Age)/BMI]. Furthermore, the final equation, [((Cu + Sr) × age)/BMI], showed a trend similar to the two previously described.

The equation [(Sr × Age)/BMI] had a reasonable AUC and statistically significant p-value for discriminating healthy individuals from patients (osteopenia and osteoporosis sufferers), healthy persons from osteopenic patients and normal individuals from patients with osteoporosis. We named this

Table 1: Age, body mass index, bone mineral density parameters and biochemical characteristics of included persons

Variables/Study groups	Osteoporosis patients (n = 28)	Osteopenia patients (n = 28)	Normal persons (n = 28)	*P*-value (between groups)
Age (years)	70.2 ± 6.7	66.3 ± 5.2	65.8 ± 5.4	0.011
BMI, Kg/m^2	24.4 ± 4.8	26.8 ± 4.4	29.7 ± 3.9	< 0.001
BMD-S, g/cm^2	0.630 ± 0.0863	0.857 ± 0.038	1.129± 0.130	< 0.001
BMD-F, g/cm^2	0.659 ± 0.0811	0.846 ± 0.054	1.064 ± 0.114	< 0.001
Z-S	-2.060 ± 0.865	-0.564 ± 0.539	1.346 ± 0.762	< 0.001
Z-F	-1.642 ± 0.855	-0.628 ± 0.438	0.882 ± 0.644	< 0.001
T-S	-3.528 ± 0.8401	0.345 ± 0.065	0.884 ± 0.167	< 0.001
T-F	-2.846 ± 0.579	-1.442 ± 0.354	0.142 ± 0.737	< 0.001
Vitamin D, IU/mL	36.5 ± 27.8	29.0 ± 30.0	34.4 ± 31.3	0.711
Ca, mg/dL	9.1 ± 0.3	9.3 ± 0.4	9.2 ± 0.4	0.221
P, mg/dL	3.9 ± 0.5	3.9 ± 0.7	3.8 ± 0.5	0.639
Sr, µg/L	20.9 ± 6.4	23.9 ± 7.2	20.6 ± 8.2	0.196
Cu, µg/L	644.8 ± 211.8	602.05 ± 193.3	586.4 ± 219.3	0.561

Data are presented as mean ± SD and compared by analysis of variance (ANOVA), Scheffe model. BMD-S and BMD-F; bone mineral density of spine and femur; Z-S and Z-F; Z-score related to spine and femur; T-S and T-F: T -score related to spine and femur; Ca: calcium; P: phosphorus; Sr: strontium; Cu: copper

Table 2: Comparison of various suggested equations in osteoporosis, osteopenia and normal subjects by ANOVA, Scheffe model. The units of variables are: Cu and Sr (µg/L), age (years) and BMI (kg/m^2)

Equation/Study groups	Osteoporosis patients	Osteopenia patients	Normal persons	*P*-value
Cu + Sr	665.7 ± 2.11	622.2 ± 198.4	607.0 ± 220.2	0.563
$\frac{Sr}{BMI}$	0.89 ± 0.3	27.5 ± 11	23.0 ± 9.1	0.040
$\frac{Cu}{BMI}$	27.5 ± 11	25.0 ± 9.1	20.1 ± 8.6	0.023
$\frac{Cu + Sr}{BMI}$	28.4 ± 11.2	24 ± 0.09	20.9 ± 8.7	0.021
$\frac{Cu \times Age}{BMI}$	1934.1 ± 873.6	1566.1 ± 677.8	1332.1 ± 585.1	0.010
$\frac{Sr \times Age}{BMI}$	63.5 ± 25.6	60.2 ± 22.6	47.0 ± 24.4	0.035
$\frac{Cu \times BMI}{BMI}$	229.0 ± 93.5	242.6 ± 90.5	266.5 ± 105.4	0.352
$\frac{Sr \times BMI}{Age}$	7.3 ± 2.9	9.8 ± 3.5	9.3 ± 3.5	0.016
$\frac{(Cu + Sr) \times Age}{BMI}$	1997.6 ± 881.8	1595.6 ± 685.6	1379.2 ± 769.3	0.009

ANOVA: analysis of variance; Cu: copper; Sr: strontium; BMI: body mass index

equation "Osteo-Pars". The detailed results of ROC analysis, *ie p*-value, cut-off point, sensitivity, specificity, PPV, NPV and positive and negative LR are also presented in Table 3. The ROC detail of the Osteo-Pars equation showed good accuracy in classifying the included groups, but it seems that between selected cut points, it had a great specificity in categorizing the normal from the persons with osteoporosis. In addition, the positive LR result is enough to discriminate the above-mentioned groups.

Table 3: Comparison of diagnostic accuracies of various suggested equations by receiver operating characteristic analysis

Equation status	Discrimination point	AUC (CI)	*P*-value	Cut	Sensitivity	Specificity	PPV	NPV	LR^+	LR^-
$\frac{Sr}{BMI}$	Normal than patient	0.698 (0.570, 0.826)	0.004	0.670	77.8	59.3	79	57	1.91	0.38
	Normal than osteopenia	0.719 (0.579, 0.860)	0.006	0.670	80.8	59.3	66	76	1.98	0.32
	Normal than osteoporosis	0.679 (0.532, 0.825)	0.023	0.672	75	59.3	66	70	1.84	0.42
$\frac{Cu}{BMI}$	Normal than patient	0.652 (0.524, 0.780)	0.025	19.4	71.4	55.6	77	48	1.61	0.51
	Normal than osteopenia	0.604 (0.453, 0.756)	0.184	19.4	67.9	55.6	61	63	1.53	0.58
	Normal than osteoporosis	0.700 (0.560, 0.839)	0.011	21.5	75	63	68	71	2.02	0.40
$\frac{Cu + Sr}{BMI}$	Normal than patient	0.665 (0.527, 0.782)	0.024	20.7	70.9	55.6	76	48	1.58	0.53
	Normal than osteopenia	0.606 (0.453, 0.759)	0.180	20.7	66.7	55.6	59	63	1.47	0.62
	Normal than osteoporosis	0.701 (0.566, 0.840)	0.010	23.3	71.4	63	67	68	1.93	0.45
$\frac{Cu \times Age}{BMI}$	Normal than patient	0.661 (0.537, 0.786)	0.018	1296.5	69.6	55.6	76	47	1.57	0.55
	Normal than osteopenia	0.597 (0.445, 0.748)	0.219	1332.5	60.7	55.6	59	58	1.37	0.71
	Normal than osteoporosis	0.726 (0.592, 0.860)	0.004	1546.7	71.4	66.7	69	69	2.14	0.43
$\frac{Sr \times Age}{BMI}$	Normal than patient	0.719 (0.596, 0.843)	0.001	43.7	75.9	66.7	82	58	2.28	0.36
	Normal than osteopenia	0.729 (0.590, 0.869)	0.004	42.3	84.6	55.6	65	79	1.90	0.28
	Normal than osteoporosis	0.710 (0.569, 0.852)	0.007	47.9	71.4	77.8	77	72	3.21	0.37
$\frac{(Cu + Sr) \times Age}{BMI}$	Normal than patient	0.664 (0.538, 0.790)	0.017	1270.8	79.6	51.9	77	56	1.65	0.39
	Normal than osteopenia	0.594 (0.439, 0.749)	0.240	1270.8	73.1	51.9	59	67	1.52	0.52
	Normal than osteoporosis	0.729 (0.596, 0.862)	0.004	1392.3	75	55.6	64	68	1.69	0.45

ROC: receiver operating characteristic; AUC: area under the curve; CI: confidence interval; PPV: positive predictive value; NPV: negative predictive value; LR^+ and LR^-: positive and negative likelihood ratio

DISCUSSION

According to the cohort study previously reported, it seems that in the city of Amirkola in northern Iran, osteopenia and osteoporosis are serious health problems (12). In an attempt to find an easy, noninvasive, cost-effective and simple method to discriminate between healthy individuals and patients, we used demographic data (age and BMI) and serum levels of two important elements (Cu and Sr). We did not focus on the serum levels of two other important elements, *ie* Ca and P, or even vitamin D levels, because the importance of these factors in bone problems has been frequently tested and reported (13–15). We found an equation that was named "Osteo-Pars". It seems that this equation is a useful tool for distinguishing patients with osteopathy from healthy individuals. As is presented in Table 3, the cut-off point of 43.7 of this equation showed a sensitivity of 75.9%. This means that by using this equation, we were able to classify 75.9% of the studied individuals accurately in the patient group. It seems that the power of this equation for distinguishing healthy persons from among the included persons is not as sensitive (specificity = 66.7%). The sensitivity of this equation for discriminating osteopenic persons from others was higher (84.6%), and, finally, the value for discriminating people with osteoporosis from among the included persons was 71.4%. According to these results, it seems that this equation is a relatively powerful tool for discriminating patients from healthy individuals.

We did not find a similar study with which to compare and cross-validate our results. The studies that we found only reported the serum, plasma, and/or urine levels of Cu and/or Sr. It seems that the reported studies related to the level of Sr in patients with osteopenia and osteoporosis are more limited.

Unfer *et al* determined the blood Sr concentrations in premenopausal and postmenopausal women with or without hormone replacement therapy (HRT). That cross-sectional study involved the participation of 72 healthy women in three groups, namely, premenopausal women, postmenopausal women without HRT and postmenopausal women with HRT. The researchers observed no significant differences in whole blood Sr concentrations among these three groups. In addition, they observed no significant correlation between whole blood Sr concentrations and BMD (16). In another study reported by Mir *et al* on six hundred healthy women, the authors reported a mean serum Cu concentration equal to 105.85 ± 40.15 µg/dL. They also observed a 12.9% prevalence of osteoporosis in postmenopausal women with copper deficiency *vs* 11.3% in those with normal serum Cu values. They concluded that Cu has an independent role on bone density in all healthy women (17). Odabasi *et al* measured the Cu in plasma and red blood cell content in 77 postmenopausal women with osteoporosis and 61 healthy postmenopausal women. They found no significant differences in Cu levels in plasma and red blood cells in the patient and control groups (18).

Strontium is one of the minerals that, when absorbed, is distributed throughout the body and deposited in the bone. Studies revealed that Sr may have either beneficial or toxic effects on bone, directly or indirectly, at low and high doses. The direct effects of low doses of Sr are increases in the amount of osteoid and no changes in bone resorption, BMD, or bone apatite crystals. The main indirect effects of low doses of Sr are a small decrease in serum Ca and no changes in intact parathyroid hormone (iPTH) levels and, ultimately, vitamin D status. Strontium in high dose had some direct effects, the main ones being increased amounts of osteoid, decreased bone resorption, hypomineralization of bones, a reduction in the size of bone apatite crystals, decreased Ca levels, a decrease in the rate of iPTH secretion, and, ultimately, decreased vitamin D levels (19).

Age and BMI are the major determinants of osteopenia and osteoporosis. In elderly persons, we observed a loss in the amount of bone mass as a result of increased bone resorption rate, thinning of the endocortical, and, ultimately, an increased rate of cortical porosity (3, 4). It seems that bone loss with ageing occurs in both genders. According to the longitudinal studies, it is suggested that this loss may reach 5–10% in each decade. In a study published by Scholtissen *et al*, a statistically significant association between age and the presence of osteoporosis was reported (20). There are other studies that confirm this finding. Furthermore, there are reports that indicate lower BMI scores are associated with BMD loss (21–25). Tanaka *et al* showed that a decrease in the BMI score was an independent risk factor for osteoporosis (26). Scholtissen *et al* also concluded that ageing and a decrease in the BMI score are associated with a decrease in the femoral neck T-score (20).

CONCLUSION

Our suggested equation, Osteo-Pars, is derived from two important bone determinants, age and BMI score, and the serum levels of Sr. It seems that after approval of the diagnostic accuracy of this equation in other studies with a larger sample size, we will be able to use this equation as a probable clinical tool in the evaluation of bone loss severity. The number of subjects that enrolled in this study was relatively small, because this study was only a preliminary work. We intend to analyse the diagnostic accuracy of this equation in a cohort study. Because of the limitations and high cost of the complicated techniques such as DXA for evaluating the severity of bone loss, a simpler and more cost-effective methods for the assessment of the bone loss severity are needed. With more studies, we will be able to reach an exact conclusive statement for the potential clinical application of this equation in the assessment of the severity of bone loss.

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REFERENCES

1. Consensus Development Conference: diagnosis, prophylaxis and treatment of osteoporosis. Am J Med 1993; **94:** 646–50.
2. Harper KD, Weber TJ. Secondary osteoporosis diagnostic considerations. Endocrinol Metab Clin North Am 1998; **27:** 328–48.
3. Ross PD. Osteoporosis frequency, consensus and risk factors. Arch Intern Med 1996; **156:** 1399–411.
4. WHO Study Group. Assessment of fracture risk and its application to screening for postmenopausal osteoporosis. Report of a WHO Study Group. World Health Organ 1994; **843:** 1–129.
5. Kanis JA; on behalf of the World Health Organization Scientific Group. Assessment of osteoporosis at the primary health care level. Sheffield, UK: WHO Collaborating Centre for Metabolic Bone Diseases, University of Sheffield Medical School; 2008.
6. Lentle BC, Prior JC. Osteoporosis: what a clinician expects to learn from a patient's bone density examination. Radiology 2003; **228:** 620–8.
7. Dasher LG, Newton CD, Lenchik L. Dual X-ray absorptiometry in today's clinical practice. Radiol Clin North Am 2010; **48:** 541–60.
8. Lorente-Ramos R, Azpeitia-Armán J, Muñoz-Hernández A, García-Gómez JM, Díez-Martínez P, Grande-Bárez M. Dual-energy X-ray absorptiometry in the diagnosis of osteoporosis: a practical guide. AJR Am J Roentgenol 2011; **196:** 897–904.
9. Kanis JA, McCloskey EV, Johansson H, Oden A, Melton LJ, Khaltaev N. A reference standard for the description of osteoporosis. Bone 2008; **42:** 467–75.
10. Kanis JA, Melton LJ, Christiansen C, Johnston C, Khaltaev N. The diagnosis of osteoporosis. J Bone Miner Res 1994; **9:** 1137–41.
11. Damilakis J, Maris TG, Karantanas AH. An update on the assessment of osteoporosis using radiologic techniques. Eur Radiol 2007; **17:** 1591–602.
12. Hosseini SR, Cumming RG, Kheirkhah F, Nooreddini H, Baiani M, Mikaniki E et al. Cohort profile: the Amirkola Health and Ageing Project (AHAP). Int J Epidemiol 2014; **43:** 1393–400. doi: 10.1093/ije/dyt089.
13. Warensjö E, Byberg L, Melhus H, Gedeborg R, Mallmin H, Wolk A et al. Dietary calcium intake and risk of fracture and osteoporosis: prospective longitudinal cohort study. BMJ 2011; **24:** 342.
14. Hanley DA, Cranney A, Jones G, Whiting SJ, Leslie WD, Cole DE et al; Guidelines Committee of the Scientific Advisory Council of Osteoporosis Canada. Vitamin D in adult health and disease: a review and guideline statement from Osteoporosis Canada. CMAJ 2010; **7:** E610–8. doi: 10.1503/cmaj.080663.
15. Meng J, Ohlsson C, Laughlin GA, Chonchol M, Wassel CL, Ljunggren O et al; Osteoporotic Fractures in Men (MrOs) Study Group. Associations of estradiol and testosterone with serum phosphorus in older men: the Osteoporotic Fractures in Men study. Kidney Int 2010; **78:** 415–22. doi: 10.1038/ki.2010.161.
16. Unfer TC, Müller EI, de Moraes Flores EM, Dressler VL, da Silva JC, Duarte MM et al. Sr and Fe relationship with hormone replacement therapy and bone mineral density. Clin Chim Acta 2007; **384:** 113–7.
17. Mir E, Hossein-nezhad A, Bahrami A, Bekheirnia MR, Javadi E, Afshar A et al. Adequate serum copper concentration could improve bone density, postpone bone loss and protect osteoporosis in women. Iran J Public Health 2007; **Suppl:** 24–9.
18. Odabasi E, Turan M, Aydin A, Akay C, Kutlu M. Magnesium, zinc, copper, manganese, and selenium levels in postmenopausal women with osteoporosis. Can magnesium play a key role in osteoporosis? Ann Acad Med Singapore 2008; **37:** 564–7.
19. Cabrera WE, Schrooten I, De Broe ME, D'haese PC. Strontium and bone. J Bone Miner Res 1999; **14:** 661–8.
20. Scholtissen S, Guillemin F, Bruyère O, Collette J, Dousset B, Kemmeret C al. Assessment of determinants for osteoporosis in elderly men. Osteoporos Int 2009; **20:** 1157–66.
21. Meier DE, Orwoll ES, Jones JM. Marked disparity between trabecular and cortical bone loss with age in healthy men. Measurement by vertebral computed tomography and radial photon absorptiometry. Ann Intern Med 1984; **101:** 605–12.
22. Jones G, Nguyen T, Sambrook P, Kelly PJ, Eisman JA. Progressive loss of bone in the femoral neck in elderly people: longitudinal findings from the Dubbo osteoporosis epidemiology study. BMJ 1994; **309:** 691–5.
23. Nguyen TV, Kelly PJ, Sambrook PN, Gilbert C, Pocock NA, Eisman JA. Lifestyle factors and bone density in the elderly: implications for osteoporosis prevention. J Bone Miner Res 1994; **9:** 1339–46.
24. Hannan MT, Felson DT, Anderson JJ. Bone mineral density in elderly men and women: results from the Framingham osteoporosis study. J Bone Miner Res 1992; **7:** 547–53.
25. van der Klift M, de Laet CD, Pols HA. Assessment of fracture risk: who should be treated for osteoporosis? Best Pract Res Clin Rheumatol 2005; **19:** 937–50.
26. Tanaka T, Latorre MR, Jaime PC, Florindo AA, Pippa MG, Zerbini CA. Risk factors for proximal femur osteoporosis in men aged 50 years or older. Osteoporos Int 2001; **12:** 942–9.