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Original Article

Ultrasound Measurement of Proximal Phalanges in a Normal Polish Female Population

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Abstract. In this cross-sectional study 954 Polish healthy women aged 30–80 years were evaluated (mean age 50.8 ± 8.9 years). Among them were 460 premenopausal (mean age 44.4 ± 5.5 years) and 494 postmenopausal women (mean age 56.8 ± 7.2 years). Women suffering from diseases known to affect bone metabolism and/or treated with drugs that affect bone tissue were excluded. All women were volunteers from six towns in the south of Poland, who underwent bone measurements for screening purposes. Bone status was assessed using an ultrasound device (DBM Sonic 1200, Igea, Italy) that measures amplitude-dependent speed of sound (AD-SoS) in metres per second. Phalanges (II–V) of the non-dominant hand were measured and an average value was computed. In vivo short-term precision was 0.49% for intraobserver, and 0.42% for interobserver measurements. Mean AD-SoS values were: in the whole group, 1974.6 ± 90.7 m/s; in premenopausal women, 2032.1 ± 50.0 m/s; and in postmenopausal women, 1921.0 ± 87.3 m/s (p <0.0001). The mean decrease in AD-SoS value in the studied population was 6.1 m/s per year. Simple linear regression analysis showed significant, negative correlations between age and AD-SoS: in the whole group $r = -0.70$ (p <0.0001); in pre- and postmenopausal women, $r = -0.29$ (p <0.0001) and $r = -0.58$ (p <0.0001), respectively. Years since menopause (YSM) showed a significant influence on AD-SoS: linear correlation in the whole group resulted in a value of $r = -0.59$ (p <0.0001) and in the group of postmenopausal women in a value of $r = -0.57$ (p<0.0001). AD-SoS decreased in the first 8 YSM by 5.1% (0.63%/year) and in the next 15 YSM by 5.44% (0.36%/year). In postmenopausal women mean AD-SoS was regressed simultaneously on age and YSM, resulting in AD-SoS = 2181.0 – 4.031 × Age – 3.911 × YSM. In conclusion, ultrasound measurements of proximal phalanges were found to enable detection of age- and YSM-related skeletal changes in a Polish healthy female population. Results obtained in this study showed a premenopausal decrease in the ultrasound parameter (not observed by other authors) and an AD-SoS value lower than those in French, Italian and Spanish populations. The premenopausal decline in AD-SoS, the most important observation, requires further longitudinal investigations to determine factors affecting the skeleton before menopause.

Keywords: Healthy female population; Menopause; Normative data; Phalanges; Quantitative ultrasound

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Introduction

Bone mineral density (BMD) is regarded as the most important parameter in the assessment of osteoporosis and fracture risk [1]. Currently available techniques of bone mass measurement include: single-photon absorptiometry (SPA), dual-energy X-ray absorptiometry (DXA) and quantitative computed tomography (QCT). However, none of them enables a qualitative evaluation of bone tissue. These techniques reflect bone mass only quantitatively. Low bone mass may be only one of several factors contributing to bone fragility; damaged microarchitecture or loss of elasticity are examples of the importance of qualitative features of bone tissue

[2,3]. Qualitative aspects alone may account for up to 30% of a bone's capability to resist an applied force [4]. Indirect and in vitro experiments have shown that quantitative ultrasound (QUS) may provide information not only about the bone mass but also about bone tissue architecture and elasticity [5–8]. QUS is free from ionizing radiation and relatively cost-effective. Several studies have shown that QUS can discriminate between osteoporotic and normal individuals [9–11].

In most studies that have used ultrasound methods the os calcis has been chosen as the measurement site [9–13]. Researchers have found age-related and years since menopause (YSM)-related changes in ultrasound parameters within the heel in women [12–14]). The only commercially available ultrasound device that can be used for measurements of the proximal phalanges is the DBM Sonic 1200 (Igea, Italy). Several recent studies have shown that such measurements are able to detect bone changes due to aging and the menopause [15–19]. In these studies correlations, ranging from 0.43 to 0.69, between amplitude-dependent speed of sound (AD-SoS) and BMD measurement of spine, distal and ultradistal radius, metacarpals and total body were reported.

The aim of the present study was to evaluate bone status in a healthy Polish female population by using ultrasound at the proximal phalanges. On the basis of the data collected, a normal curve for the Polish healthy female population was established.

Materials and Methods

Nine hundred and fifty-four healthy women aged 30–80 years were studied: 460 in premenopause and 494 in postmenopause. Women were recruited after public announcements in six towns in the south of Poland. The majority of them were hospital staff. All were volunteers who underwent bone measurements for screening purposes. Each woman gave her consent prior to the study and was interviewed by a physician in order to exclude those with a present or past history of conditions affecting bone metabolism. None of the subjects was on hormone replacement therapy or taking calcitionin, bisphosphonates, fluoride, calcium or vitamin D. The study was approved by the local ethics committee.

The subjects were divided into subgroups to discriminate the skeletal changes due to age and to menopause. To evaluate the effect of aging on ultrasound parameters, women were divided into 5-year age groups: 30–34 years, 35–39 years, etc. Because rapid bone changes were expected during the first year after the menopause, the following subgroups were created according to time since menopause: from 6 to 12 months (1 YSM), from 13 to 36 months (2–3 YSM) and then every 3 years (4–6 YSM, 7–9 YSM, etc.). Time since the postmenopause was established on the basis of interviews with the subjects. The characteristics of the women studied are presented in Table 1.

Bone status was assessed by DBM Sonic 1200, consisting of two probes mounted on an electronic caliper. The emitting probe positioned on the medial surface of the phalanx generates a single pulse at 1.25 MHz every 128 ms. The receiving probe is positioned on the lateral surface of the phalanx and records the ultrasound that has crossed the phalanx. We determined the speed of sound in the distal metaphyses of the proximal phalanges of the second through fifth fingers of the non-dominant hand. The time interval between emission and reception of the ultrasound signal is recorded and used to calculate the speed of sound. In addition, the device automatically takes into account the amplitude (2 mV) of the signal present at the receiving probe, and hence an amplitude-dependent speed of sound (AD-SoS; in m/s) is calculated. Acoustic coupling was achieved using a standard ultrasound gel [15–17]. All measurements were done by the same technician.

In vivo short-term precision was assessed based on standard error of estimation (SEE) for 15 measurements taken in each of four healthy persons by the same operator. CV% was 0.49%. Interobserver precision was 0.42% as assessed by comparing the results of 40 measurements obtained by two independent operators in two healthy persons.

Statistical Analyses

Student's *t*-test was used for comparison of differences between subgroups. Simple and multiple regression

Table 1. Characteristics of the population studied

	Whole group *n*=954	Premenopausal women *n*=460	Postmenopausal women *n*=494
Age (years)	50.87 ± 8.94	44.4 ± 5.5	56.8 ± 7.2
Weight (kg)	67.1 ± 11.0	65.3 ± 10.5	68.7 ± 11.2
Height (m)	1.61 ± 0.05	1.62 ± 0.05	1.61 ± 0.05
BMI (kg/m^2)	25.74 ± 4.09	24.9 ± 3.8	26.5 ± 4.2
Age at menopause (years)			48.9 ± 4.26
Years since menopause (years)			7.4 ± 6.9

All parameters are given as mean value ± SD.
BMI, body mass index.

analyses were used to evaluate the relation between AD-SoS, age and YSM. All calculations were made using the Statistica program run on an IBM PC.

Results

Table 2 shows age-related changes in AD-SoS values in the whole group. Table 3 shows ultrasound values according to YSM. Groups of fewer than 8 persons are not included. Mean values of AD-SoS were: 2032.1 ± 50.0 m/s in premenopausal women, 1921 ± 87.3 m/s in postmenopausal women and 1974.6 ± 90.7 m/s in all women. AD-SoS was significantly different in pre- and postmenopausal women (p <0.001).

Results of simple linear regression analysis between AD-SoS and age, AD-SoS and YSM for the whole group, and for pre- and postmenopausal women are listed in Table 4. The AD-SoS decline with aging was present in premenopausal women (r = –0.29, p <0.00001), a larger decline was observed in postmenopausal women (r = –0.58, p <0.0001). Annual changes in Ad-SoS value in meters per second per year or in per cent (%/year) can be calculated. The value of AD-SoS in the youngest group studied (aged 30–34 years) was established as 100%; between the youngest (aged 30–34 years) and the oldest group (aged 70–74 years) AD-SoS dropped by 244 m/s, i.e. 11.86% of the young AD-SoS value. Mean decrease was 6.1 m/s per year (0.29% each year). In premenopausal women AD-SoS decreased 44 m/s (2.18%), i.e. 2.58 m/s per year (0.12% each year). After the menopause the AD-SoS decline was as follows: during the first 8 YSM, 104 m/s (5.16%), or 13.0 m/s per year (0.64% each year); during the following 15 YSM, 104 m/s (5.44%), or 6.93 m/s per year (0.36% each year). During the 23 postmenopausal years AD-SoS decreased by 208 m/s (9.07%), or 9.04 m/s per year (0.39% each year).

Figures 1–4 show the relationship between AD-SoS and age and YSM in the different groups considered. All

Table 2. Age-related changes in the whole group (n = 944)

Age (years)	n	Mean AD-SoS (m/s)	± SD
30–34	12	2058	39.0
35–39	58	2048	37.4
40–44	160	2038	43.8
45–49	224	2020	50.8
50–54	210	1972	74.0
55–59	138	1917	76.7
60–64	69	1876	77.2
65–69	43	1870	60.9
70–74	30	1814	85.9
Average		1974.6	90.8

Table 3. AD-SoS changes according to years since menopause (n = 487)

YSM (years)	n	AD-SoS (m/s)	± SD
1	58	2000.5	57.0
2–3	111	1961.1	69.3
4–6	99	1941.3	71.8
7–9	52	1910.3	76.0
10–12	64	1886.4	78.0
13–15	36	1862.2	67.3
16–18	31	1869.9	73.9
19–21	15	1824.7	73.6
22–24	13	1806.5	68.0
25–27	8	1808.0	61.8

Table 4. Correlations and regressions between AD-SoS and age and YSM in the whole group and in pre- and postmenopausal women

Regression equation	r	p-value
Whole group		
AD-SoS = – 7.16 × Age + 2338.8	–0.70	<0.00001
AD-SoS = – 7.6 × YSM + 1983.7	–0.59	<0.00001
Premenopausal women		
AD-SoS = – 5.4 × Age + 2266.3	–0.29	<0.00001
Postmenopausal women		
AD-SoS = – 6.99 × Age + 2318.7	–0.58	<0.00001
AD-SoS = – 7.4 × YSM + 1980.5	–0.57	<0.00001

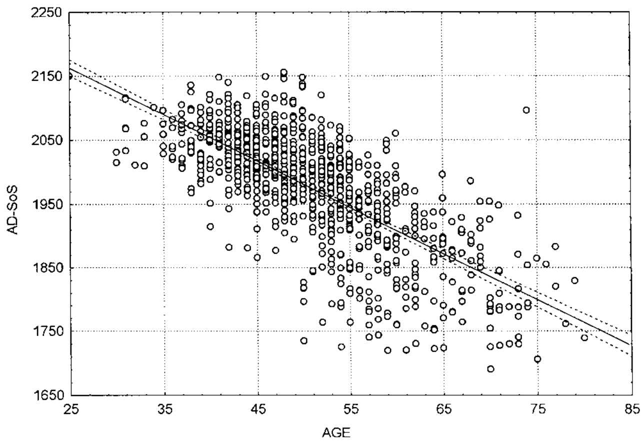

Fig. 1. Simple regression between AD-SoS and age in the whole group.

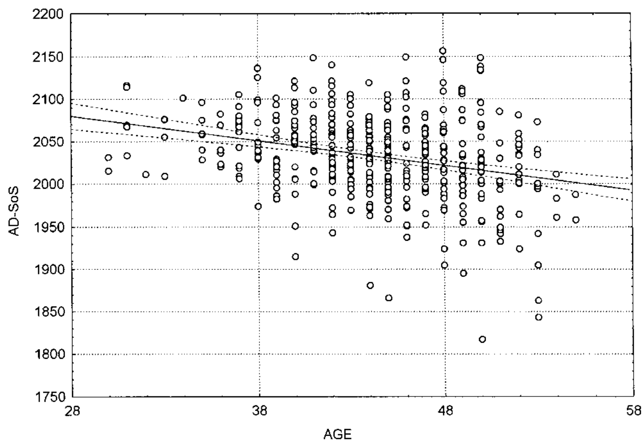

Fig. 2. Simple regression between AD-SoS and age in premenopausal women.

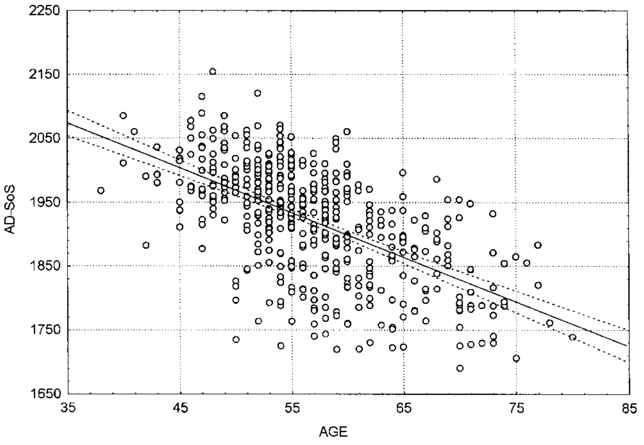

Fig. 3. Simple regression between AD-SoS and age in postmenopausal women.

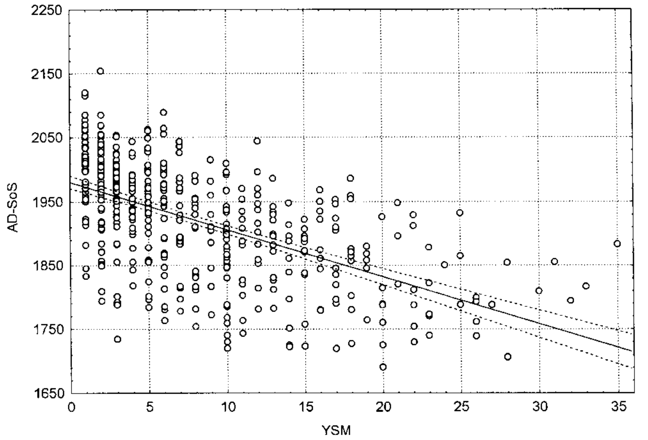

Fig. 4. Simple regression between AD-SoS and YSM in postmenopausal women.

correlations are highly significant. AD-SoS was regressed simultaneously on age and YSM in postmenopausal women resulting in AD-SoS = 2181 –4.031 × Age –3.911 × YSM.

Discussion

A longitudinal study has shown that radiogrammetry of the metacarpals can predict hip fractures [20]), and a cross-sectional trial has demonstrated that radiographic absorptiometry of the phalanges discriminates between osteoporotic and healthy postmenopausal women [21]. The above findings suggest that the phalanges may be an appropriate measurement site for the assessment of skeletal status. The present study has shown age- and YSM-related skeletal changes within phalanges as monitored by ultrasound.

Correlation between age and AD-SoS in the whole group of Polish healthy women studied was higher than that reported in an Italian study by Ventura et al. [15] (r = –0.70 vs –0.47). The age-related decrease in AD-SoS value was greater in our population in comparison with the decrease reported in a French study, Duboeuf et al. [16], in simple linear regression analysis, obtaining the following equation: AD-SoS = –2.87 × Age + 2150.25 (r = –0.61, p <0.0001). The regression equation obtained in our study is given in Table 4. In Polish premenopausal women a significant, age-related decrease in AD-SoS was observed (simple linear regression equation: AD-SoS = –5.4 × x Age + 2266.3, r = –0.29, p <0.00001; also shown in Fig. 2). No such findings have been reported by other authors [15–17]. The correlation coefficient between AD-SoS and age in Polish postmenopausal women was –0.58 (p <0.0001), similar to that given by Sili Scavalli et al. [19] r = –0.63 and higher than the value obtained by Duboeuf et al. [16] r = –0.39. A decrease in AD-SoS related to YSM was also reported by the abovementioned authors. In the study by Ventura et al. [15], YSM caused a smaller decrease in AD-SoS (simple linear regression analysis equation: AD-SoS = –0.5 × YSM + 2050.5, r = –0.42, p <0.0001) in comparison with our results (Table 4). Murgia et al. [17] reported the correlation coefficient between AD-SoS and YSM to be r = –0.52, and Sili Scavalli et al. [19] found it to be r = –0.58.

Multiple regression calculated in postmenopausal women showed almost the same influence of age and YSM on AD-SoS. This finding is different from the results obtained in studies on spinal bone loss assessed by densitometric measurements [22–24]. Gambacciani et al. [22] and Richelson et al. [23] have shown that menopausal (hormonal) bone loss is a major factor in spinal osteopenia in postmenopausal women. In a large study by Gambacciani et al. [22] age-related bone loss was also observed. In a study by Nordin et al. [24] performed with QCT of the spine no age-related bone loss was noted. It can be argued that age and menopausal components of bone loss may be related to trabecular/cortical ratio in the measured bone. Measurements of the phalanges consisting of both cortical and trabecular bone tissue reveal both age- and YSM-related changes as shown by multiple regression. Spine seems to be more sensitive to menopausal bone loss due to its high trabecular content, while cortical bone loss is more age-dependent.

A general tendency towards a decrease in phalangeal AD-SoS was similar in all studies when comparing postmenopausal women and pre- and postmenopausal women together, but only in Polish premenopausal population was a significant decrease in AD-SoS noted. The decline observed is the most important finding of the study.

Direct comparisons of various populations are possible if we use a decrease in AD-SoS expressed in per cent. In the French study by Duboeuf et al. [16] a 9.6% decrease was noted between 30 and 80 years of age, which is clearly less than the 11.86% decrease between women aged 30–34 years and 70–74 years obtained in our study. Especially interesting is a comparison of our reference curve with those given by Mele [25] and Palacios et al. [26]. Measurements were made in women aged 35–65 years. AD-SoS was found to be decreased by 9.6% (our study), 8.6% (Mele), 6.8% (Palacios) and 7.2% (Duboeuf). The comparison shows that the greatest decrease in AD-SoS was observed in the Polish population. Comparison of our AD-SoS values with those given by other authors provides further interesting information. For example, in 55-year-old women Murgia et al. [17] observed an AD-SoS value of 2007 ± 74 m/s, while in our study it was 1942 ± 72 m/s. In 60-year-old women Sili Scavalli et al. [19] reported 1962 ± 71 m/s, Aguado et al. [18] 2006 ± 68 m/s, and in our study it was only 1903 ± 84 m/s. The differences were also observed in the younger age range: 39-year-old women had an AD-SoS value of 2114 ± 73 m/s in Aguado et al.'s study [18] compared with 2035 ± 38 m/s in ours. In the study by Ventura et al. [15], postmenopausal women aged 54 years had an AD-SoS of 2026 ± 50 m/s; in our study this value was achieved at about 44 years of age. It is difficult to explain the lower values obtained in our study in comparison with other studies. Probably social, dietetic and other unknown factors difficult to detect in a cross-sectional study were responsible for our results. All the studies quoted above were carried out in women from the south of Europe, which may also account for the differences. Moreover, it should be stressed that Polish women are the only population in which a premenopausal decrease in AD-SoS is observed. This fact is especially difficult to explain. In our study women with clinical features of irregular bleeding were excluded. Ventura et al. [15] examined women with regular and irregular bleeding and noted values significantly lower in women with irregular menstruation. Thus, we suspect that in Polish premenopausal women with irregular menstruation, AD-SoS may be even lower than that obtained in our study. In order to explain factors affecting skeletal status before menopause some other aspects (beside bone measurement) ought to be taken into consideration in further studies, such as the endocrine system, physical activity, calcium intake and genetics.

In conclusion, the study demonstrated the ability of ultrasound measurements of the proximal phalanges to detect bone changes due to aging and time since menopause. It also revealed unexpectedly large differences between our Polish women and French, Italian and Spanish healthy female populations. The premenopausal decrease in the ultrasound parameter studied (not observed by other authors) and generally lower values of AD-SoS in the Polish female healthy population require further, longitudinal investigation.

References

1. Kanis JA, and the WHO study group. Assessment of fracture risk and its application to screening for postmenopausal osteoprosis: synopsis of WHO report. Osteoporos Int 1994;4:368–81.
2. Cummings SR, Kelsey JL, Nevitt MC, O'Dowd KJ. Epidemiology of osteoporosis and osteoporotic fractures. Epidemiol Rev 1985;7:178–208.
3. Melton LJ, Riggs BL. Risk factors for injury after a fall. Clin Geriatr Med 1986;1:525–36.
4. Einhorn TA. Bone strength: the bottom line. Calcif Tissue Int 1992;51:331–9.
5. Langton CM, Palmer SB, Porter RW. The assessment of broadband ultrasound attenuation in cancellous bone. Eng Med 1984;13:89–91.
6. Langton CM, Evans GP. Dependence of ultrasonic velocity and attenuation on the material properties of cancellous bone. Osteoporos Int 1994;1:194. [abstract]
7. Kaufman JJ, Einhorn TA. Ultrasound assessment of bone. J Bone Miner Res 1993;8:517–25.
8. Njeh CF, Boivin CM, Langton CM. The role of ultrasound in the assessment of osteoporosis: a review. Osteoporos Int 1997;7:7–22.
9. Turner CH, Peacock M, Timmerman L, Neal JM, Johnston CC. Calcaneal ultrasonic measurements discriminate hip fracture independently of bone mass. Osteoporos Int 1995;5:130–5.
10. Scott AM, Weill-Engerer S, Hans D, Duboeuf F, Delmas PD, Meunier PJ. Ultrasound discriminates patients with hip fracture equally well as dual energy X-ray absorptiometry and independently of bone mineral density. J Bone Miner Res 1995; 10:243–9.
11. Mautalen C, Vega E, Gonzales D. Ultrasound and dual X-ray absorptiometry densitometry in women with hip fracture. Calcif Tissue Int 1995;57:165–8.
12. Yamazaki K, Kushida K, Ohmura A, Sano M, Inoue T. Ultrasound bone densitometry of the os calcis in Japanese women. Osteoporos Int 1994;4:220–5.
13. Cepollaro C, Agnusdei D, Gonnelli S. Ultrasonographic assessment of bone in normal Italian males and females. Br J Radiol 1995;68:910–4.
14. Schott AM, Hans D, Sornay-Rendu E, Delmas PD, Meunier PJ. Ultrasound measurement on os calcis: precision and age-related changes in normal female population. Osteoporos Int 1993; 3:249–54.
15. Ventura V, Mauloni M, Mura M, Paltrinieri F, de Aloysio D. Ultrasound velocity changes at the proximal phalanges of the hand in pre-, peri- and postmenopausal women. Osteoporos Int 1996;6:368–75.
16. Duboeuf F, Hans D, Schott AM, Giraud S, Delmas PD, Meunier PJ. Ultrasound velocity measured at proximal phalanges: precision and age-related changes in normal females. Rev Rhum 1996;63:427–34.
17. Murgia C, Cagnacci A, Paoletti AM, Pilia I, Meloni A, Melis GB. Comparison between a new ultrasound densitometer and single-photon absorptiometry. Menopause 1996;3:149–53.
18. Aguado F, Revilla M, Hernandez ER, Villa VL, Rico H. Dual energy X-ray absorptiometry, total body mineral content, ultrasound bone velocity, and computed metacarpal radiogrammetry with age, gonadal status, and weight in healthy women. Invest Radiol 1996;31:218–22.
19. Sili Scavalli AS, Marini M, Spadaro A, Riccieri V, Cremona A, Zoppini A. Comparison of ultrasound transmission velocity with computed metacarpal radiogrammetry and dual-photon absorptiometry. Eur Radiol 1996;6:192–5.
20. Jergas M, San Valentin R, Black M, Nevitt L, Palermo L, Genant HK, Cummings SR. Radiogrammetry of the metacarpals predicts future hip fracture: a prospective study. Seventeenth Annual Meeting of the American Society for Bone and Mineral Research. J Bone Miner Res 1995; 10 (Suppl 1):475.
21. Takada M, Engelke S, Hagiwara S, Grampp M, Jergas M, Gluer CC, Genant HK. Radiographic absorptiometry of phalanges: in vivo study. Seventeenth Annual Meeting of the American Society for Bone and Mineral Research. J Bone Miner Res 1995; 10 (Suppl 1):489.
22. Gambacciani M, Spinetti A, Simone L, Cappagli B, Maffei S, Taponeco F, Fioretti P. The relative contributions of menopause and ageing to postmenopausal vertebral osteopenia. J Clin Endocrinol Metab 1993;77:1148–51.
23. Richelson RS, Wahner HW, Melton LJ, Riggs BL. Relative contributions of ageing and estrogen deficiency to postmenopausal bone loss. N Engl J Med 1984;311:1273–5.

24. Nordin BEC, Need AG, Bridges A, Horowitz M. Relative contributions of years since menopause, age and weight to vertebral density in postmenopausal women. J Clin Endocrinol Metab 1992;74:20–3.
25. Mele R. Determinazione delle charateristiche structuralle densitometriche del tessuto osseo mediante ultrasuoni. Atti della Societa Emiliana Romagnola Triveneta di Ortopedia e Traumatologia 1993:35.
26. Palacios S, Jurado AR, Menendez C. Curva de normalida en mujeres Espanolas para un densitometro DBM Sonic 1200 [abstract]. Congresso National de Menopausia, Sarragosa, 10–12 Nov 1994.

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