

Original Article

Ultrasound Measurements at the Calcaneus in Men: Differences Between Healthy and Fractured Persons and the Influence of Age and Anthropometric Features on Ultrasound Parameters

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Abstract. The aim of this cross-sectional study was to assess the ability of quantitative ultrasound at the calcaneus to discriminate between fractured and unfractured men, fracture probability, and the relationship of ultrasonic parameters to age and body size. The study included 224 men (age range 36–86 years) with no history of diseases or therapy affecting bone metabolism. The subjects were divided into two groups (unfractured, $n = 148$; fractured, $n = 76$) matched for age and body size. Bone status was assessed by ultrasound measurements at the calcaneus. Long-term in vitro CV% values were 0.88% for speed of sound (SOS) and 0.54% for broadband ultrasound attenuation (BUA). In vivo CV% values were 0.33% for SOS and 2.48% for BUA, while sCV% values were 4.66% and 6.58%, respectively. The following SOS/BUA values were obtained: in unfractured men, $\text{SOS} = 1517.5 \pm 35.3 \text{ m/s}$ and $\text{BUA} = 114.0 \pm 13.3 \text{ dB/MHz}$; in fractured men, $\text{SOS} = 1492.6 \pm 24.6 \text{ m/s}$ and $\text{BUA} = 106.1 \pm 11.6 \text{ dB/MHz}$. The differences were significant ($p < 0.0001$). The odds ratio for BUA for all fractures was 1.05 (95% CI, 0.03–2.07) and for SOS 2.13 (95% CI, 0.77–3.49). Only the age-related decrease in SOS in unfractured men was significant ($r = -0.17$, $p < 0.05$). In fractured men, weight and body mass index (BMI) were found to correlate significantly with BUA ($r = 0.31$, $p = 0.007$, $r = 0.31$, $p = 0.007$, respectively). The areas under receiver operating characteristics (ROC) curves were 0.706 for SOS and 0.665 for BUA. Ultrasound measurements at

the calcaneus thus enable discrimination between fractured and healthy males. Different patterns of the relationship between age and body size in the two groups suggest the presence of other, unknown factors affecting bone status. Their identification requires further prospective studies.

Keywords: Age; Body size; Fracture discrimination; Male; Osteoporotic fracture; Quantitative ultrasound

Introduction

Ultrasound measurement of the skeleton has recently been proposed as an alternative method of evaluating bone status [1–3]. There are several sites of ultrasonic measurement (calcaneus, phalanges, patella, tibia, etc.), the most common being the calcaneus because of its high trabecular content [4]. Cancellous bone, due to its high turnover rate, shows changes within the tissue earlier than compact bone. The majority of previous studies were carried out in women [5–7] and provided data on discrimination between healthy and fractured women [1,8,9], as well as on correlations of ultrasound parameters with age, years since menopause [5,7,10], height, weight and body mass index (BMI) [5,7]. There are only a few reports in the literature of similar measurements in men [11–14]. Moris et al. [13] used quantitative ultrasound to discriminate between healthy men and those with foot algodystrophy. Some data are also available on a correlation between age and ultrasonic parameters [11–14]. The small number of studies in men makes every new observation an

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important contribution to our knowledge of bone status in men. The multifactorial pathophysiology of involutional bone loss in men includes a reduction in osteoblast function with age, hypogonadism, decreased physical activity, negative calcium balance and secondary hyperparathyroidism [15]. The female-to-male ratio is about 1.5:1 for Colles' fracture, 7:1 for vertebral fracture and 2:1 for hip fracture [16]. Most studies of bone mass and density in aging men have shown a gradual decline in bone mineral content at cortical sites (3–4% loss per decade after age 40 years) and greater rate of fall at cancellous sites (7–12% loss per decade after ages 30–35 years). These changes are similar to but occur at a slower rate than those in women [16].

In the current study a group of Polish men was studied using quantitative ultrasound (QUS) measurements. The study was undertaken to assess: (1) the ability of QUS measurements at the calcaneus to discriminate fractured from unfractured individuals, (2) the odds ratio for SOS and BUA, and (3) correlations between ultrasonic parameters and age, height, weight and BMI.

Materials and Methods

Subjects

The study included 255 men who underwent ultrasonic measurements at the Outpatient Osteoporosis Clinic in the years 1993–1997 and had no history of diseases (hyperparathyroidism, thyroid gland diseases, chronic liver or kidney diseases, stomach surgery, prolonged immobilization, etc.) or medications (corticosteroids, thyroid hormones, anticonvulsants, antacids, etc.) affecting bone metabolism or current treatment for osteoporosis. Two hundred and twenty-four men (age range 36–86 years) were divided into two groups matched for age, height, weight and BMI: Group 1 consisted of 148 men without fractures and group 2 consisted of 76 men with nontraumatic fractures. Thirty-one men were excluded in order to obtain comparable groups. The clinical characteristics of the population studied are given in Table 1.

The subjects were interviewed by a physician with regard to factors influencing bone metabolism (calcium intake, type of job, family history of fractures). Due to the retrospective design of the study we were unable to assess physical activity, smoking, alcohol intake and

caffeine intake accurately, and this information is not included. All the fractures ($n = 120$) were the result of minimal trauma: a fall from standing height or less during daily normal activity (23 spine, 23 feet, 21 ankle, 19 wrist, 17 rib, 11 clavicle, 4 hip, 2 humerus). All spine fractures were confirmed on radiographs. The study was approved by the local ethics committee and informed consent was obtained.

Method

Evaluation of the skeletal status was based on ultrasound measurements of the calcaneus at the right (dominant) heel. In the case of a previous fracture within the lower extremity, the contralateral calcaneus was measured. The speed of sound (SOS, m/s) and broadband ultrasound attenuation (BUA, dB/MHz) were measured with the Achilles system (Lunar, Madison, WI), which was calibrated daily in accordance with the manufacturer's recommendations. All measurements were done by the same operator. Reproducibility was assessed using a polyurethane phantom and on the basis of in vivo measurements. Fifteen phantom measurements in 15 days enabled the calculation of short-term in vitro CV% values: 0.12% for SOS and 1.23% for BUA. Long-term in vitro CV% values obtained from 20 measurements of the phantom over a period of 4 years were 0.88% for SOS and 0.54% for BUA. Short-term in vivo precision was established on the basis of 60 measurements, 5 in each of 12 healthy men aged 23–66 years. The CV% values were: BUA 2.48% and SOS 0.33%, and the sCV% values were 6.58% and 4.66%, respectively ($SCV = CV\%/4 \text{ SD/mean}$).

Statistical Analysis

Student's *t*-test was used to compare the mean values. The patterns of age-related SOS and BUA changes were processed by applying different curve-fitting functions (linear, quadratic and cubic models). All calculations were done using the Statistica program run on an IBM PC. Receiver operating characteristic (ROC) analysis was performed. The age-adjusted odds ratio was calculated using logistic regression (SPSS software).

Table 1. Clinical characteristics of the men studied

	Total ($n = 224$)	Group 1 ($n = 148$)	Group 2 ($n = 76$)	<i>p</i> value (between groups)
Age (years)	56.3 \pm 10.3	56.2 \pm 10.2	56.5 \pm 10.6	NS
Weight (kg)	78.9 \pm 11.8	79.7 \pm 11.4	77.2 \pm 12.5	NS
Height (m)	1.72 \pm 0.07	1.72 \pm 0.066	1.71 \pm 0.076	NS
BMI (kg/m ²)	26.6 \pm 3.4	26.7 \pm 3.4	26.4 \pm 3.5	NS

Results

The following SOS/BUA values were obtained: in unfractured men, $\text{SOS} = 1517.5 \pm 35.3$ m/s and $\text{BUA} = 114.0 \pm 13.3$ dB/MHz; in fractured men, $\text{SOS} = 1492.6 \pm 24.6$ m/s and $\text{BUA} = 106.1 \pm 11.6$ dB/MHz. The differences were significant ($p < 0.0001$). The odds ratio for BUA value for all fractures was 1.05 (95% CI, 0.03–2.07) and for SOS was 2.13 (95% CI, 0.77–3.49). Age-related changes expressed by linear regression are shown in Table 2. Only the age-related decrease in SOS in unfractured men was significant. These relationships in healthy men are presented graphically in Figs 1 and 2. There was no evidence for a quadratic or cubic age-related decrease in SOS and BUA (data not shown).

Table 2. The correlations and regressions between ultrasound values and age

Linear regression equation	r	p value
<i>Group 1: unfractured men</i>		
$\text{SOS} = 1551.4 - 0.60 \times \text{age}$	-0.17	0.033
$\text{BUA} = 124.0 - 0.18 \times \text{age}$	-0.14	0.09
<i>Group 2: fractured men</i>		
$\text{SOS} = 1505.7 - 0.23 \times \text{age}$	-0.10	NS
$\text{BUA} = 104.9 + 0.02 \times \text{age}$	0.02	NS

Using simple linear regression, correlations between ultrasound parameters and body size (height, weight, BMI) were calculated. In unfractured men no significant

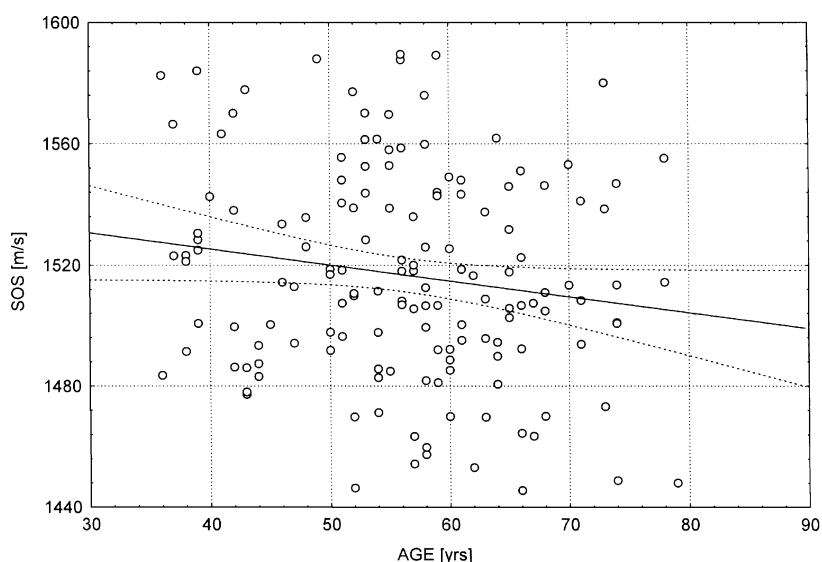


Fig. 1. Simple linear regression between age and SOS in healthy men.

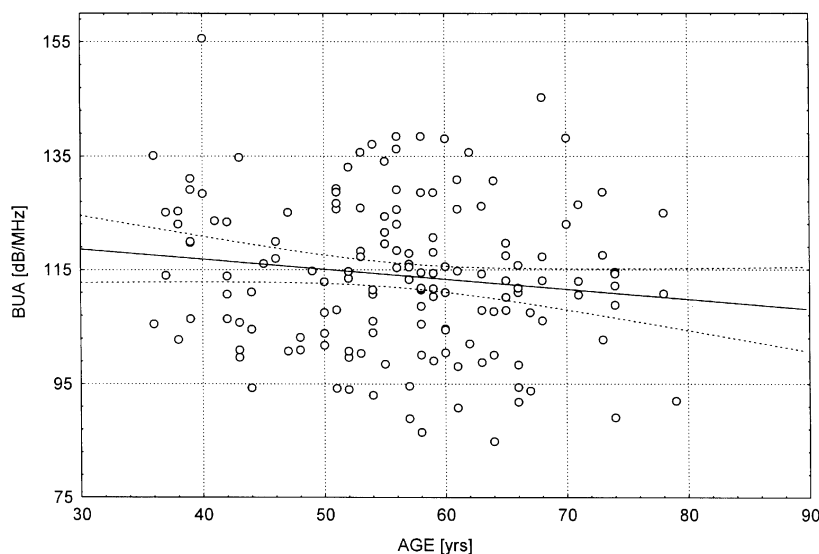


Fig. 2. Simple linear regression between age and BUA in healthy men.

correlations with body size were reported, while in fractured men some weak but significant correlations were obtained: BUA (dB/MHz) = $84.3 + 0.28 \times \text{weight}$ ($p=0.007$), BUA (dB/MHz) = $79.0 + 1.02 \times \text{BMI}$ ($p=0.007$), SOS (m/s) = $1453.8 + 1.47 \times \text{BMI}$ ($p=0.07$). ROC curves are presented in Figs 3 and 4. The areas under fitted curves were 0.706 for SOS and 0.665 for BUA.

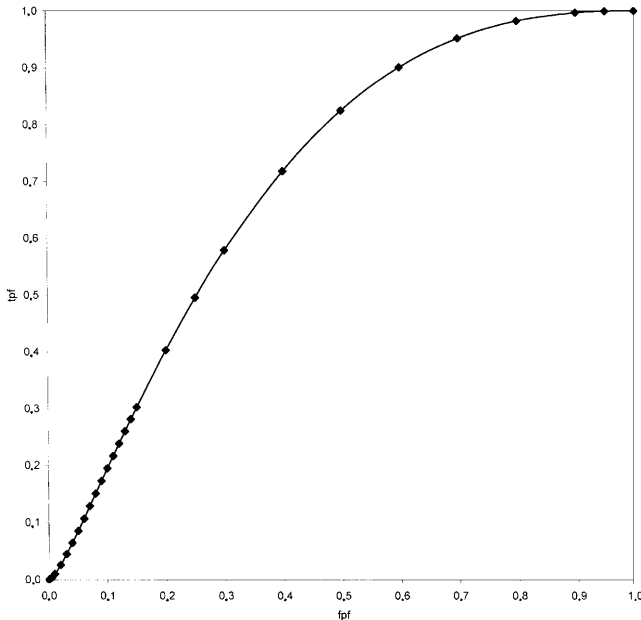


Fig. 3. ROC curve for SOS. *tpr*, true positive fraction; *fpr*, false positive fraction.

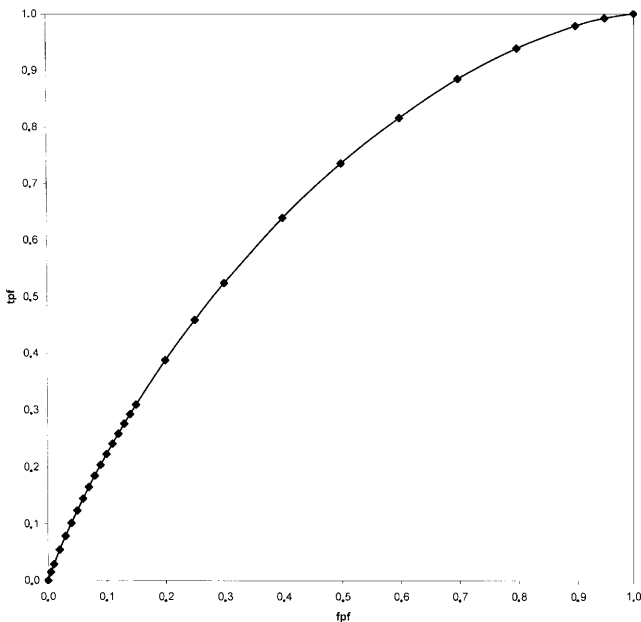


Fig. 4. ROC curve for BUA. *tpr*, true positive fraction; *fpr*, false positive fraction.

Discussion

Osteoporosis in men has received much less attention than its counterpart in women. One-seventh of all osteoporotic vertebral compression fractures and one-fourth to one-fifth of all hip fractures occur in men [15]. The lower incidence of osteoporosis in the male population is due to higher peak bone mass, shorter life expectancy, and the absence of a distinct menopause-equivalent with associated marked acceleration of bone loss [15]. In contrast to the large number of studies on changes in ultrasound parameters in women [2–10], there are only a few reports of such measurements in men [11–14]. In some cross-sectional studies it was possible to discriminate between fractured and unfractured men [17–19], whereas a retrospective study by Stewart et al. [20] failed to detect male vertebral deformations or fractures using BUA. To our knowledge, no prospective studies on fracture discrimination in men have been published. In our study we were able to discriminate between healthy and fractured men by both SOS and BUA measurements at the calcaneus. Our odds ratio for the BUA and SOS values for all fractures was comparable with odds ratio (1.65; 1.31–2.06) obtained by Stegman et al. [18] in a cross-sectional study in men, the only one previously published.

In all male studies [11–14], negative age-related changes were observed. In the Rotterdam study age-related decreases in SOS ($r = -0.11$) and BUA ($r = -0.09$) were noted [14], which is comparable to our results. Our sCV% values were also very close to those obtained in the Rotterdam study (2.48% vs 2.28% and 0.33% vs 0.45%). Moris et al. [13] reported higher rates of decrease in SOS ($r = -0.64$) and BUA ($r = -0.70$). In our study, decreases in ultrasound parameters in healthy men were found to be more pronounced than those in fractured men. This may suggest that in the latter group the decrease occurred earlier or/and peak values of SOS and BUA were lower. As no other data on correlations between age and ultrasound parameters in fractured men are available in the literature, our findings cannot be compared with results obtained elsewhere. These results can be fully confirmed only in longitudinal studies.

Studies in female populations have demonstrated significant correlations between body size and ultrasound values, ranging from 0.09 to 0.51 [5,7]. In the Rotterdam study [14] no correlations of BUA and SOS with BMI were observed; however, in multiple regression analysis BMI revealed a negative influence on SOS and a positive influence on BUA. In our study we regressed SOS and BUA for height, weight and BMI. In fractured men weak, significant correlations of weight and BMI with BUA, and a borderline correlation of BMI with SOS were noted. No significant correlations were found in healthy men. The results obtained suggest the presence of other pathophysiologic factors affecting bone status in fractured and healthy men.

It is concluded that ultrasound measurements at the calcaneus can discriminate between fractured and

healthy men. Different patterns of correlation between age and body size in the two groups suggest the presence of some unknown factors that have an influence on bone status. Their identification requires further prospective studies.

References

1. Hans D, Dargent-Molina P, Schott AM, et al. Ultrasonographic heel measurements to predict hip fracture in elderly women: the EPIDOS prospective study. *Lancet* 1996;348:511–4.
2. Njeh CF, Boivin CM, Langton CM. The role of ultrasound in the assessment of osteoporosis: a review. *Osteoporos Int* 1997;7:7–22.
3. Gregg EW, Kriska AM, Salamone LM, et al. The epidemiology of quantitative ultrasound: a review of the relationships with bone mass, osteoporosis and fracture risk. *Osteoporos Int* 1997;7:89–99.
4. Vogel J, Wasnich R, Ross P. Clinical relevance of calcaneus bone mineral measurement: a review. *Bone Miner* 1988;5:35–58.
5. Yamazaki K, Kushida K, Ohmura A. Ultrasound bone densitometry of the os calcis in Japanese women. *Osteoporos Int* 1994;4:220–5.
6. Massie A, Reid DM, Porter RW. Screening for osteoporosis: comparison between dual energy X-ray absorptiometry and broadband ultrasound attenuation in 1000 perimenopausal women. *Osteoporos Int* 1991;49:107–11.
7. Pluskiewicz W. Bone status assessed by quantitative ultrasound in Polish healthy postmenopausal women: a normative data. *Clin Rheumatol* 1998;17:40–3.
8. Porter RW, Johnson K, McCutchan JDS. Wrist fracture, heel bone density and thoracic kyphosis: a case control study. *Bone* 1990;11:211–4.
9. Gluer CC, Cummings SR, Bauer DC, et al. Osteoporosis: association of recent fractures with quantitative US findings. *Radiology* 1996;199:725–32.
10. Schott AM, Hans D, Sornay-Rendu E, et al. Ultrasound measurements on os calcis: precision and age-related changes in a normal female population. *Osteoporos Int* 1993;3:249–54.
11. Cepollaro C, Agnusdei D, Gonnelli S, et al. Ultrasonographic assessment of bone in normal Italian males and females. *Br J Radiol* 1995;68:910–4.
12. Langton CM, Langton DK. Male and female normative data for ultrasound measurement of the os calcaneus within the UK adult population. *Br J Radiol* 1997;70:580–5.
13. Moris M, Peretz A, Tjeka R, et al. Quantitative ultrasound bone measurements: normal values and comparison with bone mineral density by dual X-ray absorptiometry. *Calcif Tissue Int* 1995;57:6–10.
14. Van Daele PLA, Burger H, Algra D, et al. Age-associated changes in ultrasound measurements of the calcaneus in men and women: the Rotterdam Study. *J Bone Miner Res* 1994;9:1751–7.
15. Jackson JA. Osteoporosis in men. In: *Primer on the metabolic bone diseases and disorders of mineral metabolism*. New York: Raven Press, 1993:255–8.
16. Kleerekoper M, Avioli LV. Evaluation and treatment of postmenopausal osteoporosis. In: *Primer on the metabolic bone diseases and disorders of mineral metabolism*. New York: Raven Press, 1993:223–9.
17. Stegman MR, Heaney RP, Recker RR, et al. Velocity of ultrasound and its association with fracture history in a rural population. *Am J Epidemiol* 1994;139:1027–34.
18. Stegman MR, Heaney RP, Recker RR. Comparison of speed of sound ultrasound with single photon absorptiometry for determining fracture odds ratios. *J Bone Miner Res* 1995;10:346–52.
19. Stegman MR, Heaney RP, Travers-Gustafson D, et al. Cortical ultrasound velocity as an indicator of bone status. *Osteoporos Int* 1995;5:349–53.
20. Stewart A, Felsenberg D, Kalidis L, et al. Vertebral fractures in men and women: how discriminative are bone mass measurements? *Br J Radiol* 1995;68:614–20.

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