Quantitative Ultrasound Measurements at the Calcaneus in a Population of Urban Senegalese Women: Least Significant Difference and T-Score

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Abstract

Background: Bone ultrasound measurements can be used to evaluate osteoporosis in clinical practice. As with DXA, ultrasonography shows marked variations across racial groups. In the USA, quantitative ultrasound measures were higher in African-American women than in Caucasian women. Few data are available on these measures in African women, and there are no normative data for Senegalese women.

Our objectives were to evaluate the least significant difference (LSD) and to establish reference values of quantitative ultrasound measures at the calcaneus in Senegalese women.

Methods: Reference values were obtained in 50 healthy women aged 25-35 years. A UBIS 5000 ultrasound sonometer was used to determine speed of sound (SOS), broadband ultrasound attenuation (BUA), and the Strength Index (STI) at both heels.

Results: In the 50 healthy controls (mean age, 29.8 ± 3.7 years, mean height, 167.3 ± 5.8 cm, mean weight 68.1 ± 13.2 kg; 38 right-handed), BUA (mean of the two sides) was 72.24 ± 6.83 dB/MHz. BUA values were higher in women with regular sporting activities (n=10) and in those with higher body weight values, indicating an increase in bone mass associated with greater loads through the calcaneus.

Conclusion: Quantitative ultrasound parameters measured at the calcaneus using a UBIS 5000 sonometer in Senegalese women showed similar reproducibility to that reported previously in Caucasian women examined using the same sonometer or a comparable sonometer. The mean BUA values in our reference population can be used to compute T-scores in individual female patients in Senegal. Our data support a link between greater mechanical loads and higher bone mass.

Keywords: Bone density measurement; Quantitative ultrasonography; Calcaneus; Reference population, Black African women; Senegal

Abbreviations: BMI: Body Mass Index; BUA: Broadband Ultrasound Attenuation; CV: Coefficient of Variation; LSD: Least Significant Difference; N: Number of participants; sCV: Standardized Coefficient of Variation; SD: Standard Deviation; SOS: Speed of Sound; STI: Strength Index

Introduction

Ultrasound sonometers can be used to measure the speed of a sound wave and its attenuation as it travels through a peripheral bone. Sound wave attenuation varies not only with bone mass, but also with bone mechanical properties, which depend on various factors such as bone micro-architecture, mineralization, and elasticity. Bone ultrasound measurements can be used to evaluate osteoporosis in clinical practice [1-4]. Many studies have established that ultrasonography is effective in separating osteoporotic from healthy individuals [5-7] and in predicting the fracture risk [8-12]. Ultrasound sonometers are compact, portable, and inexpensive; and ultrasonography does not require radiation exposure. Thus, ultrasonography is valuable when dual-energy X-ray absorptiometry (DXA) is unavailable, as is often the case in Africa.

As with DXA, ultrasonography shows marked variations across racial groups. In the USA, quantitative ultrasound measures were higher in African-American women than in Caucasian women [13,14]. However, few data are available on these measures in African women [15-18], and there are no normative data for Senegalese women.

The objectives of this cross-sectional study were to evaluate the

least significant difference (LSD) and to establish reference values of quantitative ultrasound measures at the calcaneus in Senegalese women. The reference values were used to compute the T-score, a crucial parameter for bone status evaluation. Factors potentially associated with variability of quantitative ultrasound measures (e.g., age, height, weight, physical activity, dominant side, and measured side) were also identified.

Methods

Ultrasound sonometer and measures

A UBIS 5000 sonometer (DMS, Montpellier, France) with two fixedfocused transducers immersed in a temperature-controlled water-bath at $30 \pm 2°C$ was used. The measurements are made in a 60 mm x 60 mm scanning area with 1 x 1 pixel size. A circular region of interest of 14 mm in diameter is automatically selected within the scanning area. The following variables are measured in the region of interest: speed of

sound (SOS) in m/s, broadband ultrasound attenuation (BUA, in dB/mHz), and the strength index (STI, a composite index computed from SOS and BUA). The relative risk of fracture (RRF), which theoretically reflects the fracture risk, was not studied, since its relevance to the study population has not been established.

Reference population

Fifty 50 healthy women aged 25 to 35 years old who lived near our hospital in Dakar, Senegal were recruited. Ultrasound measurements were made during ten sessions, each in 5 women. In each woman, measurements were obtained on both sides, after cleansing the heels with 70% alcohol. Women with a history of calcaneal fracture, amenorrhoea, glucocorticoid use, smoking or use of other substances with adverse health effects, musculoskeletal disease, inflammatory disease, cancer, or other chronic diseases were not included.

Statistical Analysis

Means, standard deviations (SDs), and medians were computed to describe our data. Groups were compared using ANOVA for multiple comparisons and the Student t test. Pearson's test was used to assess correlations (SYSTAT® software, Chicago, IL, USA). Values of p smaller than 0.05 were considered significant.

The SD and LSD were determined using ANOVA. The LSD at the 5% significance level was computed as $1.96\sqrt{2}$ x [mean SD]. The coefficient of variation (CV) in % was obtained by dividing the SD by the mean. To enable comparisons of CVs of variables with widely differing variabilities, the standardized CV (sCV) or intraclass correlation coefficient as CV(%)/(4SD/mean)were computed, where the SD and mean were from the reference population [19,20].

Results

Mean age was 29.8 ± 3.7 years (range, 25-35 years); mean height, 167.3 ± 5.8 cm (range, 149-183 cm); mean weight, 68.1 ± 13.2 kg (range, 46-100 kg); and mean body mass index (BMI), 24.26 ± 4.38 kg/m² (range, 16.42 à 35.01 kg/m²). Of the 50 participants, 38 were right-handed and 12 left-handed. Only 10 women engaged regularly in sporting activities. The distribution of ethnic groups (Table 1) was consistent with previously published data [21].

Speed of sound

The difference between the right and left sides (-0.10%) was not statistically significant, and the values on the two sides were closely correlated. Compared to the 48 women with a right-left difference smaller than 1.33%, the remaining 2 women had considerably larger differences of -9.16% and +6.02%, respectively. After excluding these 2 women, the right-left difference was trivial (-0.03% ± 0.59%). The cause of the large right-left difference in these 2 women was not identified (Table 2).

Broadband ultrasound attenuation

No statistically significant right-left difference in BUA values was found, and the values on the two sides were closely correlated. In 14 participants, however, the absolute right-left difference was greater than 4% (from -17.56% to +7.47%). BUA correlated well with SOS, with an r² value of 0.51 (Table 2).

Strength index

There was no statistically significant difference between values on the right and left sides. However, 24 women had an absolute right-left difference greater than 4% (from -43.27% to +15.35%) (Table 2).

T-score

The T-score data are reported in Table 3.

Factors associated with ultrasound parameter values in the reference population

For this evaluation, we used the mean of the values obtained on both sides (Table 4). Table 5 shows the correlation coefficient matrix (linear, Pearson's) between mean ultrasound parameter values and mean values of patient age, height, weight, and BMI, with the p values. BUA was inversely correlated with age and positively correlated with weight and BMI. No other statistically significant correlations were found.

No correlations were found between ultrasound parameter values on each side and handedness. For instance, in the 38 right-handed women, BUA was 72.74 ± 6.84 dB/mHz at the right calcaneus and 69.99 ± 6.20 dB/mHz at the left calcaneus (nonsignificant difference).

Ultrasound parameter values were significantly higher in the 10 women who engaged regularly in sporting activities than in the 40 other women (Table 5), although no differences were found between these two groups in terms of age or weight (ANOVA).

Ethnic group	Number	Percentage	Estimated percentage in the general population of Senegal [3]
Lebou	24	48%	41.1%
Wolof	9	18%	
Toucouleur	5	10%	10.6%
Serere	4	8%	14.3%
Fulani	3	6%	12.5%
Mandinka (Sose, Bambara)	4	8%	5.4%
Dyula	1	2%	6.8%

Table 1: Distribution of ethnic groups in the 50 women of the reference population.

	SOS right heel	SOS left heel	Mean SOS	BUA right heel	BUA left heel	Mean BUA	STI right heel	STI left heel	Mean STI
Mean	1536	1538	1537	72.1	72.4	72.2	105.2	106.3	105.7
SD	34	44	37	6.7	7.4	6.8	19.3	24.3	21.1
Median	1532	1534	1536	71.4	71.6	71.2	100.5	101.3	102.7
Variability	2.2%	2.9%	2.4%	9.3%	10.2%	9.5%	18.4%	22.8%	20.0%

SOS: Speed of Sound in m/s; BUA: Broadband Ultrasound Attenuation; STI: Strength Index; SD: Standard Deviation; LSD: Least Significant Difference; CV: Coefficient of Variation; sCV: Standardized Coefficient of Variation

Table 2: Speed of sound (m/s), Broadband ultrasound attenuation (dB/MHz) and Strength Index in the reference population.

	SOS	BUA	STI
Mean	1 537.0	72.2	105.7
SD	37.1	6.8	21.1
T-score	(m-1536.5)/37.1	(m-72.2)/6.8	(m-105.7)/21.1

Table 3: T-score values in the reference population.

	Mean SOS	Mean BUA	Mean STI
Age	NS	- 0.337 (*)	NS
Height	NS	NS	NS
Weight	NS	+ 0.384 (**)	NS
BMI	NS	+ 0.337 (*)	NS

*$p<0.05$; **$p<0.01$

Table 4: Correlations between ultrasound parameters and the age and physical characteristics of the patients.

	N	Age, years	Weight, kg	Height, cm	BMI, kg/m²	BUA, dB/MHz	SOS, m/s	STI
Regular sporting activities	10	29.0 ± 3.5	69.6 ± 6.3	170.5 ± 5.1	23.98 ± 2.34	76.2 ± 8.0	1557.7 ± 49.3	118.6 ± 18.1
No regular sporting activities	40	29.9 ± 3.7	67.7 ± 14.5	166.6 ± 5.8	24.33 ± 4.77	71.3 ± 6.3	1531.9 ± 32.2	102.5 ± 18.1

The data are mean ± SD.*$p<0.05$; **$p<0.01$

Table 5: Correlations between ultrasound parameters and sporting activities.

Discussion

This study allowed us to determine among Senegalese women for measurements of the ultrasonic parameters to the calcaneus: LSD and reference values of quantitative ultrasound measures.

The reproducibility and LSD of quantitative ultrasound measurements at the calcaneus obtained in Senegalese women (data not showed ou additional file) using a UBIS 5000 sonometer were consistent with data from in Caucasian women examined using the same sonometer [22] or a similar sonometer [23]. Furthermore, reference values from a population of healthy controls that can be used to compute the T-scores of quantitative ultrasound measures in Senegalese women were collected. The sCV, which takes into account parameter variability in the healthy controls and patients, indicates greater reproducibility of the STI compared to SOS and BUA in both groups for women, in keeping with earlier data [22]. Therefore, the STI may deserve preference in everyday clinical practice. BUA was the most useful measure for identifying factors associated with bone status (age, weight, and physical activity). Both higher weight and participation in sports are associated with increased mechanical loads through the calcaneus and were associated with higher quantitative ultrasound parameter values. Similarly, physical activity was associated with bone mineral density in a study of South African adults [15].

Quantitative ultrasound parameters varied somewhat between the right and left sides. Side-to-side differences, although substantial for BUA, were greatest for STI. Therefore, measurements should be made routinely on both sides and the mean of the two values used. This precaution is particularly important as we identified no factors associated with a larger side-to-side difference. An unusually large side-to-side difference may indicate a technical problem and should prompt repetition of the measurements.

The mean T-score value determined automatically by the ultrasound sonometer using the manufacturer's data from healthy young French women was 0.9 ± 1.2. Of our 50 healthy young Senegalese women, only 11 had values smaller than the mean in healthy young French women. These 11 women with negative T-score values had a mean BUA of 64.3 ± 2.3 dB/MHz compared to 74.5 ± 5.9 dB/MHz in the other 39 women.

They were significantly shorter (164.1 ± 8.6 cm versus 168.3 ± 4.5 cm, $p<0.05$) but had no statistically significant differences for weight, BMI, or age compared to the women with positive T-scores. Similar results were obtained for SOS and the STI.

Conclusion

Quantitative ultrasound parameter measurement at the calcaneus performed using a UBIS 5000 sonometer in Senegalese women shows similar reproducibility to that in Caucasian women examined using the same sonometer or a comparable sonometer. The mean BUA values in healthy young Senegalese women reported here can be used to compute T-scores in individual patients. Finally, these data indicate that greater mechanical loads through the calcaneus are associated with higher calcaneal bone mass.

Key Message

Quantitative ultrasound parameters measured at the calcaneus using a UBIS 5000 sonometer in Senegalese women showed similar reproducibility to that reported previously in Caucasian women examined using the same sonometer or a comparable sonometer. The mean BUA values in our reference population can be used to compute T-scores in individual female patients in Senegal. Our data support a link between greater mechanical loads and higher bone mass.

Quantitative ultrasound parameters at the calcaneus in Senegalese women showed similar reproducibility to that reported previously in Caucasian women. Our data can serve to compute T-scores in Senegalese women.

Conflict of Interest Statement

No conflict of interest has been declared by the authors.

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