Calcif Tissue Int (2001) 68:277–284
DOI: 10.1007/s002230010028

Calcified Tissue International

Assessment of the Bone Status of Nigerian Women by Ultrasound and Biochemical Markers

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Received: 9 October 2001 / Accepted: 10 January 2001 / Online publication: 27 April 2001

Abstract. Ultrasound analysis of the calcaneus and serum markers of bone turnover were used to examine the bone status of healthy Nigerian women who reside in an area of the world where dietary calcium intake is generally low and estrogen replacement therapy is not widely available. A total of 218 women (108 premenopausal and 110 postmenopausal) between the ages of 16 and 95 years were enrolled in the study. Broadband ultrasound attenuation (BUA) and speed of sound velocity (SOS) were measured and used to calculate the stiffness index (SI) of the calcaneus. In this cross-sectional study, the Nigerian women exhibited a marked age-dependent decline in SI that was defined by the regression equation $SI = 105.9 - 6.62E\text{-}3 \times Age^2$. SI was significantly correlated with age ($r = -0.41$, $P < 0.001$) and with serum NTx concentrations ($r = -0.26$, $P < 0.001$), but not with serum levels of bone-specific alkaline phosphatase (BSAP). Years since menopause was also significantly correlated with SI ($r = 0.40$, $P < 0.001$). A significant increase in serum NTx concentration occurred at least a decade before a significant decline in SI was evident. In the total study group, 24% of the women had T-scores indicative of osteopenia and 9% had T-scores indicative of osteoporosis, based on US reference data. Although the reported current incidence of fracture is low in women in sub-Saharan West Africa, these data show that after menopause Nigerian women have a decline in bone quality and increase in bone turnover similar to North American Caucasian women.

Key words: Calcaneal ultrasound — Stiffness index — Serum NTx — Premenopausal women — Postmenopausal women — Nigeria — Sub-Saharan Africa

Although loss of bone mass and increasing fracture risk are universal attributes of aging, the rate of bone loss and the accompanying incidence of bone fractures vary greatly among different populations and ethnic groups [1]. At present, the majority of hip fractures worldwide occur in Caucasian women in North America and Europe with low incidence rates being reported in other parts of the world. However, using current fracture rates and the demographic changes expected to occur over the next 50 years, Cooper et al. [2] predicted that by the year 2050 three-fourths of the world's elderly will reside in Latin America, Asia, and Africa. This would result in steep increases in the incidence of fractures in these regions of the world and will necessitate the introduction of preventive measures in countries where they are not currently considered necessary.

There is a considerable amount of literature regarding the age-related changes in bone and fracture risks for Caucasian women in North America and Europe [3–6], and African-American [7, 8] and Asian women [9–11]. However, much remains to be learned about the age-dependent changes in bone mass and bone turnover in African women, particularly those in sub-Saharan Africa.

An individual's peak bone mass is usually achieved during the third decade of life and is determined not only by genetic factors [12] but also by hormonal and nutritional status [13]. Adequate dietary calcium (Ca) intake over a lifetime is important in the attainment of peak bone mass during growth and the conservation of bone mass with aging [14]. Women in West Africa commonly consume diets that are not only low in Ca [15] but which are also based on cereal staples such as millet and sorghum that contain divalent cation chelators, such as phytates and oxalates, that interfere with intestinal Ca absorption [16].

In addition, women in sub-Saharan West Africa are commonly of high parity and breast-feed their infants for 2 years or more, thereby increasing the Ca requirements of women for extended periods during their adult life. After menopause, estrogen replacement therapy is not widely available in most parts of Africa, primarily because of economic reasons. Collectively, these various cultural, nutritional, and socioeconomic factors place many African women at an increased risk for osteoporosis and bone fracture after menopause.

In a previous study of Nigerian women, we found significantly higher levels of serum bone collagen N-telopeptide (NTx) and bone-specific alkaline phosphatase (BSAP), markers of bone turnover, compared with healthy Caucasian women matched for age and body mass index [17]. A high rate of bone remodeling is associated with increased risk for osteoporotic fracture in women [18].

However, there is a dearth of information regarding the

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bone density of African women and changes in their bone quality after menopause. For this reason, we used quantitative ultrasound (QUS) of the calcaneus to assess the bone status of healthy Nigerian women between the ages of 16 and 95 years. QUS parameters have been shown to be as good a predictor of osteoporotic fractures as bone mineral density (BMD) and can predict fracture risk independent of BMD [19–22]. QUS instrumentation is relatively inexpensive, does not use ionizing radiation, and is portable. These properties allow the use of QUS in areas of the world where DXA is not widely available. Correlations between QUS parameters and serum concentrations of NTx and BSAP were also determined.

Materials and Methods

Experimental Subjects

Women were recruited from among the patients presenting at the outpatient clinic of the Department of Obstetrics and Gynaecology at the Jos University Teaching Hospital in Jos, Nigeria. Jos is a metropolitan city of about 800,000 inhabitants and is located on the 2500-meter high plateau of Nigeria. Information on the age, height, weight, occupation, parity and menstrual status for each subject was obtained. Other anthropometric measurements made were mid-arm circumference and triceps skinfold. Exclusion criteria included pregnancy, immobility, malignancy, and recent surgery or fracture. Informed consent was obtained from each subject. This study was approved by the Ethics Review Committee of the Jos University Teaching Hospital, Jos, Nigeria and by the Human Research Review Committee of the University of New Mexico, Albuquerque, New Mexico, USA.

Bone Ultrasound Measurements

The calcaneus stiffness index (SI) of subjects was measured using the Achilles$^+$ ultrasound (Lunar Corporation, Madison, WI, USA) according to the manufacturer's instructions. Each subject was seated with her right foot placed in the heel bath of the instrument. After the introduction of water containing surfactant into the heel bath, measurements of the speed of sound transmission (SOS, m/sec) and the broadband ultrasound attenuation (BUA) were made. BUA is defined as the slope of the regression line derived from the ratio of the signal amplitude of the calcaneus to that of water (reference) at each frequency of ultrasound (dB/MHZ). SI was calculated with the aid of the instrument software using the equation SI = (0.67 × BUA) + (0.28 × SOS) − 420. The calibration of the instrument was checked using a phantom heel and the reproducibility was monitored by measuring the same control subject on the same day that measurements were made on the study subjects.

The data for the reference population provided in the instrument software was generated using a healthy Caucasian population. T- and Z-scores for SI were calculated as follows: T-score = (subject SI − mean SI for the young reference group)/standard deviation of the SI for the young reference group. Z-score = (subject SI − mean SI for the age-matched reference group)/standard deviation of the SI for the age-matched reference group. A separate T-score was calculated using SI data for the young African women in the study group who were between the ages of 20 and 35 years.

Biochemical Analyses

N- Telopeptide of Type 1 Collagen in Serum

The concentration of the N-telopeptide of Type 1 collagen (NTx) in serum was measured using a competitive enzyme-labeled immunoassay (Osteomark NTx assay, Ostex International, Inc., Seattle WA, USA) as described previously [17]. Absorbance at 450 nm was measured using an automated plate reader and the concentration in the sample was calculated with a calibration curve constructed from NTx standards. NTx concentration is reported as nanomoles bone collagen equivalents (nmole BCE) per liter serum.

Bone-Specific Alkaline Phosphatase.

The level of BSAP in serum was determined using an enzyme immunoassay (Alkphase-B® Metra Biosystems, Mountain View, CA, USA). This assay is highly specific for bone alkaline phosphatase (AP), cross-reacting less than 8% with liver AP and not significantly with other AP isoenzymes. The color developed during the reaction of the BSAP and the substrate p-nitrophenylphosphate (pNPP) was measured at 405 nm using an automated plate reader. BSAP concentrations in unknowns were calculated using a calibration curve fitted with a quadratic equation and are expressed in U/l. Each unit represents one mole of pNPP hydrolyzed per minute at 25°C. The BSAP reference interval established by the manufacturer for healthy women is 11.6– 30.6 U/l.

Statistical Analyses

Results are expressed as the mean ± standard deviation. Statistical analyses were performed using the Number Crunching Statistical Software program (NCSS 2000, Kaysville, UT). Comparison of parameters among decades of age were made using one-way ANOVA. Comparisons of pre- and postmenopausal women were made using the two-sample *t*-test. Spearman rank correlation coefficients were calculated to describe the relationships among anthropometric characteristics, serum concentrations of bone turnover markers, and ultrasound parameters. The regression equation of SI on age was determined using the Table Curve 2D version of SPSS (SPSS 4.0, SPSS, Inc, Chicago, IL). A *P*-value of 0.05 was considered statistically significant.

Results

Subjects

A total of 218 women between the ages of 16 and 95 years were enrolled in the study which included 108 premenopausal and 110 postmenopausal women. A summary of the subjects by decade of age is given in Table 1. The majority of the women we studied were between 20 and 59 years of age, with the lowest number of subjects in the 16–19 and the 80–89 year age groups. There was a steady increase in weight, bone mineral index (BMI), and mid-arm circumference with age for the Nigerian women after 40 years of age; however, after 70 years these parameters returned to values comparable to those of the 20–29 year-old group (Table 1).

Thirty of the 66 women in the 40–49 year age group were postmenopausal and four of the women in the 50–59 year age group were premenopausal. When the study population was divided into pre- and postmenopausal groups, the mean age of premenopausal women was 35 years; the mean age of postmenopausal women was 50 years and ranged from 31 to 95 years. The postmenopausal women were shorter than the premenopausal subjects ($P = 0.02$); however, there was no significant difference in weight, BMI, mid-arm circumference, and skin-fold measurements be-

Table 1. Anthropometric characteristics of the Nigerian women by decades of age

Age interval (years)	n	Age (years)	Weight (kg)	Height (cm)	BMI (kg/m^2)	Midarm circumference (cm)	Triceps skinfold (mm)
16–19	7	18.0 ± 1.2	48.6 ± 9.7	158.7 ± 4.1	19.3 ± 3.5	23.4 ± 2.6	20.9 ± 4.6
20–29	29	24.4 ± 3.0	56.9 ± 13.4	161.5 ± 7.6	21.7 ± 4.4	25.6 ± 4.1	20.9 ± 6.5
30–39	43	33.8 ± 2.9	64.4 ± 12.3	162.7 ± 6.1	24.4 ± 4.7	29.1 ± 4.5	27.1 ± 6.9[a]
40–49	66	43.8 ± 3.0	66.8 ± 14.4[c]	160.0 ± 5.8	25.9 ± 5.6[a]	30.4 ± 5.7[a]	26.9 ± 7.9[a]
50–59	52	51.3 ± 2.2	66.9 ± 13.8[c]	158.9 ± 5.9	26.4 ± 5.1[a]	30.5 ± 5.2[a]	27.0 ± 8.5[b]
60–69	13	62.3 ± 2.9	70.1 ± 14.2[c]	160.0 ± 5.4	27.4 ± 5.4[b]	31.6 ± 4.5[a]	27.9 ± 9.4[d]
70–79	13	71.5 ± 2.3	52.1 ± 16.3	159.0 ± 3.7	20.5 ± 6.4	25.9 ± 5.1	20.7 ± 9.8
80–89	6	81.7 ± 2.6	51.8 ± 9.7	159.0 ± 2.9	20.5 ± 3.9	24.4 ± 4.9	16.7 ± 11.1
90–99	1	95	45	149	20.3	24.7	20.0

Significantly different from 20 to 29-year-old group
[a] $P < 0.001$, [b] $P = 0.001$, [c] $P = 0.002$, [d] $P = 0.01$

tween the two groups. A significant correlation between BMI and age ($P < 0.001$) was obtained only for the postmenopausal subjects, with age accounting for 11% of the variation in BMI. The median length of time since menopause was 6 years and ranged from 0.25 to 30 years.

Ultrasound Parameters

BUA, SOS, and SI parameters by decade of age are given in Table 2. Compared with the 20 to 20-year-old age group, a significant difference in SI was obtained for the women beginning with the 50–59-year-old age group (Table 2). The regression of SI on age for all 230 subjects was determined by fitting over 8000 possible regression equations that were then ranked by the F-statistic. The equation best describing the relationship was determined to be SI = 105.9 – 6.62E-3 × (age)^2 (Fig. 1).

When the study population was divided into pre- and postmenopausal groups, no significant relationships were found between age and any one of the three ultrasound parameters (SI, BUA, SOS) for the premenopausal women. However, significant negative correlations between age and BUA and SOS were found for the postmenopausal women. A significant negative correlation was also observed for SI and length of time since menopause ($P < 0.001$) (Fig. 2).

T- and Z-scores for the subjects are summarized in Table 3. Because reference data were not available for African women at the time our study was performed, it was necessary to calculate the T- and Z-scores using US reference values. A second T-score for the subjects was calculated using the mean and standard deviation of SI for the young African women in the present study and the data are shown in Table 3. The mean SI for women between 20 and 35 years of age (n = 55) in this study was 99.2 ± 16.7. When subjected to a paired *t*-test, we found no significant difference between the T-scores of the postmenopausal African subjects calculated using the US and African reference values. Therefore, all comparisons were made using the American reference values.

The T-scores for the Nigerian women became progressively more negative by decade of age; however, only the 70 to 79-year-old and the 80 to 89-year-old groups were significantly different from the 20 to 29-year-old young reference group. The Z-scores, which are based on age-matched reference values, ranged between –0.35 and 0.13. This indicates that the elderly Nigerian women had similar SI values when compared to Caucasian American women when matched for age.

T-scores between –1 and –2.5 are considered to be indicative of osteopenia and T-scores more negative than –2.5 are indicative of osteoporosis [26]. The percent of the Nigerian women in this study with T-scores in these categories are given in Table 3. When the mean T-scores of the Nigerian women were plotted vs decade of age, the mean T-score reached a value of –1 for the 60 to 69-year-old women and declined to –2.5 by the ninth decade of age. These results are similar to those reported by Faulkner et al. [23] for the age-related decline in mean T-scores for a Caucasian reference population obtained using US measurement of the heel. Of the total Nigerian study group, 24% of the subjects had T-scores between –1.1 and –2.5 and 9% had T-scores more negative than –2.5. When the study population was divided into pre- and postmenopausal groups, 18.2% of the postmenopausal subjects had T-scores less than –2.5, whereas no premenopausal subject had a T-score in that category.

Biochemical Markers of Bone Turnover

The serum concentrations of NTx and BSAP by decade of age are given in Table 2. There was a significant difference in serum NTx concentrations for subjects 50 years and older compared with the 20 to 29-year-old age group. Serum NTx was significantly correlated with age for the whole study group ($P < 0.001$). However, when the subjects were divided into pre- and postmenopausal groups, there was a significant correlation between serum NTx and age only for the postmenopausal subjects ($P = 0.003$, r = 0.30). Of the

Table 2. Ultrasound parameters and serum markers of bone turnover by decade of age for the Nigerian study population

Age interval (years)	n	BUA (dB/MHz)	SOS (m/sec)	SI	BSAP (U/l)	NTx (nmol BCE/l)
16–19	7	126 ± 12	1579 ± 39	106 ± 14	30.5 ± 8.6	8.6 ± 4.3
20–29	29	124 ± 13	1557 ± 31	99 ± 16	26.1 ± 12.1	8.9 ± 4.2
30–39	43	126 ± 15	1555 ± 35	100 ± 18	22.0 ± 9.4	7.8 ± 4.8
40–49	66	122 ± 14	1550 ± 35	96 ± 18	22.1 ± 8.9	10.1 ± 9.5
50–59	52	116 ± 20	1536 ± 39	81 ± 23[c]	25.8 ± 7.7	12.7 ± 5.9[a]
60–69	13	115 ± 24	1520 ± 40[b]	83 ± 25[c]	32.6 ± 12.1	15.0 ± 5.0[a]
70–79	13	99 ± 14[a]	1489 ± 27[a]	63 ± 16[a]	28.8 ± 9.8	17.7 ± 7.1[a]
80–89	6	93 ± 14[a]	1492 ± 25[a]	60 ± 15[a]	31.8 ± 16.6	20.9 ± 13.2[a]
90–99	1	80	1480	47	29.7	32.9

NA, not available; significantly different compared with 20 to 29-year-old group
[a] $P < 0.001$, [b] $P < 0.01$, [c] $P = 0.05$
BUA, broadband ultrasound attenuation; SOS, speed of sound; SI, stiffness index; BSAP, bone-specific alkaline phosphatase; NTx, N-telopeptide of bone collagen; BCE, bone collagen equivalents

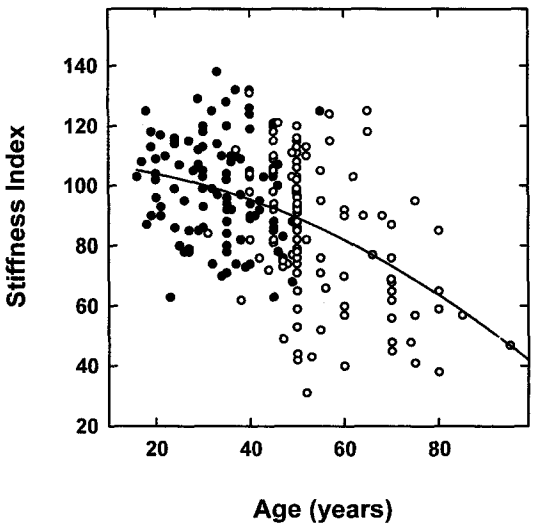

Fig. 1. The relationship between calcaneal stiffness index (SI) and age for Nigerian women. SI = 105.9 − 6.62E-3 × $(Age)^2$. ●, premenopausal subjects ○, postmenopausal subjects.

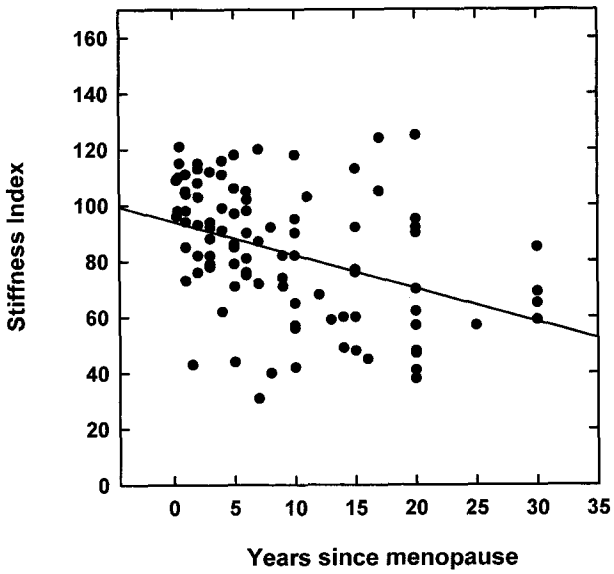

Fig. 2. The effect of length of menopause (yrs) on calcaneal stiffness index (SI) for Nigerian women (r = 0.40, $P < 0.001$).

two serum bone turnover markers, only the serum NTx value was significantly correlated with the US parameters BUA, SOS, and SI (Table 5).

There was no significant difference in serum BSAP concentrations for the women by decade of age (Table 2). When the subjects were divided into pre- and postmenopausal groups, there was a significant difference in BSAP (20.8 U/L vs 25.8 U/L, $P = 0.002$). The serum BSAP was significantly correlated with age for both the premenopausal and postmenopausal subjects ($P = 0.004$, r = −0.27, and $P = 0.02$, r = 0.23, respectively).

Discussion

Using ultrasound analysis of the calcaneus and biochemical markers of bone turnover in serum, we have shown that healthy Nigerian women exhibit a steady and marked decline in bone quality that begins after age 30. The two main factors contributing to this decline in bone quality in these women are most likely the low intakes of dietary Ca over their lifetime and the lack of hormone replacement therapy after menopause.

The decline in SI we observed in this population is similar to that of the US reference population [24] for whom the incidence of hip fracture after menopause is high. Also notable was the high percentage (24%) of Nigerian women who had T-scores indicative of osteopenea (−1.1 to −2.5). In addition, 9% of the total study group had a T-score more negative than −2.5, a score that indicates osteoporosis based on data from a healthy U.S. Caucasian population.

Although SI has been shown to be predictive of fracture risk independently of bone mineral density [19–22], the use of the T-score value of −2.5 for osteoporosis assessment using ultrasound methodologies may not be valid. In a com-

Table 3. T-scores and Z-scores by decade of age for the Nigerian study population

Age interval (years)	n	T-score[a]	T-score[b]	Z-score[a]
16–19	7	0.5 (−0.8, 1.6)	—	NA
20–29	29	0.1 (−2.3, 1.8)	—	0.1 (−2.3,1.9)
30–39	43	−0.5 (−2.4, 2.3)	—	0.1 (−2.2,2.5)
40–49	66	−0.3 (−3.2, 2.0)	−0.31 (−3.0, 1.96)	0.0 (−2.8,2.2)
50–59	52	−0.6 (−4.3, 1.6)	−0.43 (−4.1, 1.5)	0.1 (−3.6,2.5)
60–69	13	−1.05 (−2.7, 1.6)	−0.55 (−2.5, 1.5)	0.65 (−1.5,3.1)
70–79	13	−2.2 (−3.7, 0.7)	−2.2 (−3.5,−0.25)	0.50 (−1.6,1.0)
80–89	6	−2.6 (−3.9,−0.9)	−2.5 (−3.6,−0.85)	0.10 (−1.4,1.6)
90–99	1	−3.3		0.20

[a] T-score and Z-score based on young Caucasian reference population
[b] T-score based on stiffness index data for Nigerian women between 20 and 35 years of age in the present study group

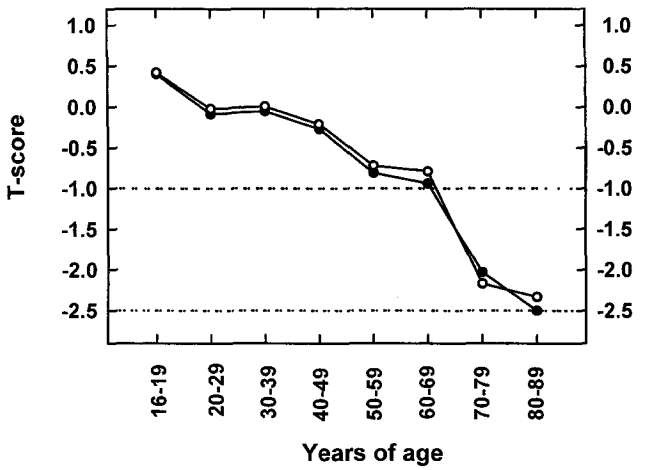

Fig. 3. The decline in mean heel ultrasound T-score by decade of age for Nigerian women. ●, *t*-scores based on Caucasian reference data; ○, *t*-scores based on SI values for the young Nigerian women between 20 and 35 years of age.; ------, cutoff values of −1 and −2.5 indicative of osteopenia and osteoporosis, respectively.

parison of T-score values for a female Caucasian population, Faulkner et al. [23] found a variation in the relationship between age and T-scores depending on the methodology and the site measured. The spine bone density showed the greatest T-score decline with age, whereas the hip and heel measurements declined the least. They suggested that different cut-off criteria for osteoporosis and fracture risk should be used that are method- and site-specific.

Based on the comparable SI values of Nigerian and US women at old age, one would expect a high incidence of fracture among elderly Nigerian women. However, the little data of this sort that exists for African women suggest that bone fractures in postmenopausal African women are rare. Adebajo et al. [25] compared the rate of hip and forearm fractures for women in Nigeria to women in two urban centers in England and reported that the rates for the Nigerian women were significantly lower than their European counterparts. For example, the incidence rate for hip fractures in women between 65 and 74 years of age was 2.0/100,000/year for Nigerian women compared with 172.3/100,000/year for women in England. Fracture rates were also found to be rare in elderly rural Gambian women despite low bone mineral content [26].

Genetics are thought to account for approximately 75–80% of peak bone mass [12]. The fracture risk for African-American women in North America, with whom Nigerian women share considerable ancestry [27, 28], is half that for Caucasian women [29–31]. The lower fracture rate in African-American women has been attributed to their greater peak bone mass [32, 33] and their ability to maintain bone mass with age.

Using calcaneal broad-band ultrasonic attenuation and DXA, a study of elderly African-American and Caucasian women [34] reported greater BMD at the hip and higher calcaneal BUA values for the African-American women. However, the difference was not evident after adjusting for calcaneal BMD. Aloia et al. [35] also reported less difference in ultrasound-based estimates of bone quality for African-American women vs Caucasian women than for BMD determined by DXA. These results indicate that ultrasound analysis of the calcaneus, although predictive of fracture risk, measures properties of bone that are different from bone density. They also pointed out the need for specific reference values for different ethnic groups.

In addition to genetics, other factors play a role in determining susceptibility to fracture; these include an individual's nutrition, level of physical activity, and hip geometry. Hip axis-length has been shown to vary among African-American, Caucasian, and Asian women [36], populations in which there is great variability in hip fracture rates. African-American and Asian women who are at lower risk of fracture also have shorter hip-axis lengths than Caucasians. Theobald et al. [37] found that Nigerian women have thicker cortical bone in the hip, a shorter hip-axis length, and smaller intertrochanteric widths than Caucasians and concluded that these differences could account for the relatively low fracture incidence in Nigerian women.

Table 4. Distribution of T-scores for Nigerian women

	Total subjects n = 218		Premenopausal women n = 108		Postmenopausal women n = 110	
T-Score	(n)	(%)	(n)	(%)	(n)	(%)
Greater than 0	85	39	57	53	28	25.5
−0.1 to −1	60	28	32	30	28	25.5
−1.1 to −2.5	53	24	19	17	34	31
Less than −2.5	20	9	0		20	18

T-scores between −1.1 and −2.5 are indicative of osteopenia and T-scores less than −2.5 are indicative of osteoporosis based on reference data for healthy American Caucasian women.

Table 5. Spearman rank correlation coefficients for the relationships among anthropometric parameters, serum bone marker concentrations, and ultrasound parameters for Nigerian women

	Age	BMI	BUA	SOS	SI	NTx	BSAP
Age	—	0.16[b]	−0.35[a]	−0.43[a]	−0.41[a]	0.42[a]	0.13[e]
BMI	0.065	—	0.005	0.031	0.01	−0.15[c]	−0.13[d]
BUA	−0.45[a]	0.01	—	0.79[a]	0.94[a]	−0.23[a]	−0.05
SOS	−0.47[a]	0.03	0.79[a]	—	0.95[a]	−0.26[a]	−0.06
SI	−0.49[a]	0.01	0.95[a]	0.94[a]	—	−0.26[a]	−0.06
NTx	0.45[a]	−0.15	−0.23[a]	−0.26	−0.26[a]	—	0.41[a]
BSAP	0.11	−0.13[e]	−0.05	−0.06	−0.06	0.41[a]	—

BMI, body mass index; BUA, broadband ultrasound attenuation; SOS, speed of sound; SI, stiffness index; NTx, N-telopeptide of collagen; BSAP, bone-specific alkaline phosphatase

[a] $P < 0.001$; [b] $P = 0.01$; [c] $P = 0.02$; [d] $P = 0.04$; [e] $P = 0.05$; the remainder of the correlations were not significant, $P > 0.05$

The rate of bone remodeling also plays a crucial role in determining bone fragility and fracture risk. It is well known that the normal decrease in endogenous estrogen with menopause results in accelerated bone loss. After menopause, osteoclast activity generally exceeds osteoblast activity [38], such that the amount of new bone formed during remodeling decreases with age [39]. Therefore, the rate of new bone formation cannot keep pace with the rate of bone removal during resorption [40]. The telopeptide NTx is produced by osteoclasts during normal degradation of bone collagen and is a highly specific index of the rate of bone resorption [41–43]. BSAP reflects osteoblast activity and is used to monitor patients with osteoporosis or other metabolic bone diseases [44, 45].

The range of serum NTx concentrations we observed in this study were similar to those obtained for other populations. The median serum NTx concentration in the serum of the premenopausal Nigerian women (6.7 nmol BCE/l) was slightly higher than the mean value of 4.7 nmol BCE/l, reported for a group of healthy Caucasian premenopausal women with normal rates of bone resorption [41], but was considerably lower than the average serum NTx concentration of 16.2 nmol BCE/l reported in our previous study of Nigerian women [17]. For the postmenopausal women in the present study, the median serum NTx concentration of 13.3 nmol BCE/l is similar to the value reported for healthy elderly Caucasian women (14.1 nmol BCE/l) by Scariano et al. [3] and lower than the value of 16.0 nmol BCE/l obtained for women with lumbar spine *t*-scores indicative of osteopenia, described by the same authors (3). We also found a significant negative correlation between serum NTx levels and SI values for the entire study population ($r = 0.26$, $P = 0.001$); however, serum NTx accounted for only 7% of the variation in SI. Noteworthy is the observation that serum NTx values increased significantly at the same age as marked decreases in SI were obtained (Table 2).

Because the 40 to 49-year-old age group in our study contained both pre- and postmenopausal women (n = 36 and 30, respectively), we compared the NTx values for women of the same age who differed only by their hormonal status. The NTx concentration for the postmenopausal women in the 40–49 age group was 1.8-fold higher than the median NTx concentration for the premenopausal women in that age group (6.63 vs 11.8 nmol BCE/l, respectively). Similarly, the serum NTx concentration for the four postmenopausal women in the 50–59 age group (12.9 nmol BCE/l) was approximately double that of the premenopausal women in that age group (5.38 nmol BCE/l), demonstrating the marked effect of estrogen loss on the bone turnover in these women. Because the serum NTx concentrations increased steadily with age without a parallel increase in the serum BSAP level, we conclude that the age-dependent deterioration in the ultrasound parameters BUA, SOS, and SI were the result of an imbalance in bone remodeling in the elderly Nigerian women.

Dietary Ca intake is an important nutritional factor in the

formation of peak bone mass and maintenance of skeletal integrity after menopause. The dietary intake of Ca for women in many African populations may be as low as 350–400 mg/day [15] compared with the recommended intake of 800–1000 mg/day. Because the efficiency of Ca absorption decreases after menopause, it is recommended that postmenopausal women increase their Ca intake to 1200–1500 mg/day [46]. Dairy products such as milk and cheese are excellent sources of dietary calcium. Unfortunately, the consumption of dairy products and the use of Ca supplements are low among African women because of economic reasons. Therefore, alternate dietary sources of Ca that are affordable and locally available must be identified in order to provide Nigerian women with an acceptable intake. In a survey of locally available foods, we reported that baobab leaf (*Adansonia digitata L.*) contains significant amounts of Ca (approximately 3 mg/g dry weight [47]. Baobab leaves are a staple in many parts of Africa and are used to make soups and sauces. However, the bioavailablity of Ca from the baobab leaves has not been determined.

One of the limitations of this study is the lack of dietary information for the women we studied. However, they reside in a region in Africa where the food staples are low in Ca and calcium-deficiency rickets is prevalent. The estrogen status of the women, which is a factor in bone turnover, was not determined. In addition, this study was cross-sectional in design and the results may have been influenced by factors that were dependent on the conditions experienced by different cohorts of women during their lifetime (e.g., nutrient availability). Future longitudinal studies following the changes in the bone status of women over time need to be undertaken.

In summary, women in Nigeria exhibit calcaneal ultrasound changes with age that are similar to US Caucasian women. Although the current rate of fracture for women is reported to be low in this region of Africa, future population increases in this region of the world will most probably raise the prevalence of fractures in these populations. Knowledge of the bone status and changes with age in African women is of increasing importance.

Acknowledgments. This study was funded by a Minority International Research Training (MIRT) grant from the Fogarty International Center of the National Institutes of Health.

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