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Original Article

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Age-associated changes in quantitative ultrasonometry (QUS) of the os calcis in Lebanese women – assessment of a Lebanese reference population

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Abstract

Objective: This study was aimed to assess age changes in quantitative ultrasonometry (QUS) in a large sample of Lebanese women to determine a Lebanese reference population. **Design:** Cross-sectional study. **Subjects and methods:** Broadband ultrasound attenuation (BUA) and speed of sound (SOS) and the stiffness index (SI) of the os calcaneus was measured in 4,320 women with a mean age of 52.5 years (age range 20 to 79 years) using three identical Achilles Express (GE/Lunar) and one Achilles Plus (GE/Lunar) ultrasonometry devices. Women were randomly selected and asked to participate in a nation-wide screening program using the media, conferences, telephone calls etc. Measurements were performed at Red Cross centers located all over the country. No inclusion or exclusion criteria were used. **Results:** There was an overall decline of 19.2% for BUA, 3.1% for SOS and 30.3% for SI between late adolescence and old age. In premenopausal women, BUA decreased only slightly by 3%, while postmenopausal women showed a significant decline of 16.2%. In contrast, SOS continuously decreased from the age of 42; there was a decline of 0.8% from adolescence to the menopause; postmenopausal women showed a larger decline of 2.4%. The SI of premenopausal women decreased by 6%, while postmenopausal women showed a significantly larger decline of 24.3%. SI value for the female Lebanese young adult reference is 8% lower than that of the American and European women (92 SI units compared to 100). At the age of 42, SI value for the Lebanese women is 10.4% lower than the American women and 7.5% lower than the European women (86 SI units compared to 96 and 93, respectively). At the age of 75, SI values for the Lebanese women is 4.4% lower than the American women and the European women (65 SI units compared to 68). The decline in stiffness index for the Lebanese women between age 20 and 75 years is about 30.3% compared to 32% for the American or European reference curves. The rate of decrease for the Lebanese women was 0.2 SI units per year for the premenopausal period, and 0.7 SI units per year for the postmenopausal period. **Conclusion:** The age-related female, Lebanese reference curve was significantly different from the American and the European reference curves used by the manufacturer. Therefore, the use of our standardized reference data instead of the proposed US or European database reduces the risk of overestimating osteoporosis in the Lebanese population. The impact of our results on the prevalence of osteoporotic fracture in Lebanon has to be evaluated later on.

Keywords: Osteoporosis, Ultrasonometry, Aging, Calcaneus, Lebanese, Ultrasound

Introduction

Osteoporosis is a metabolic bone disease associated with low bone mineral density and micro-architectural changes of the bone leading to decreased bone strength and increased incidence of fragility fractures[1]. The diagnosis of osteoporosis has focused on the assessment of bone mass and bone mineral density (BMD), leading to the refinement of dual

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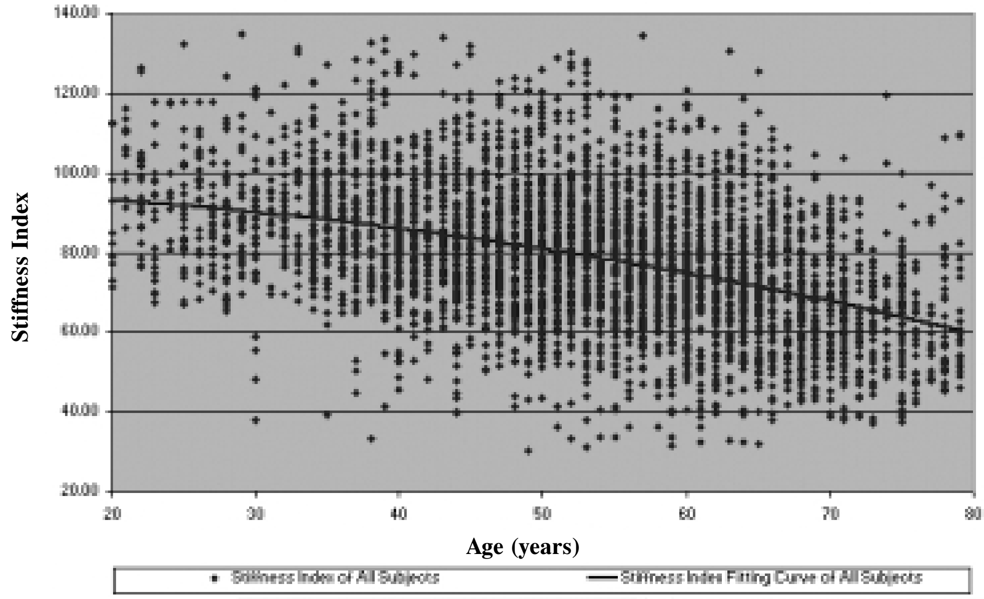

Figure 1. Stiffness index of all population subjects.

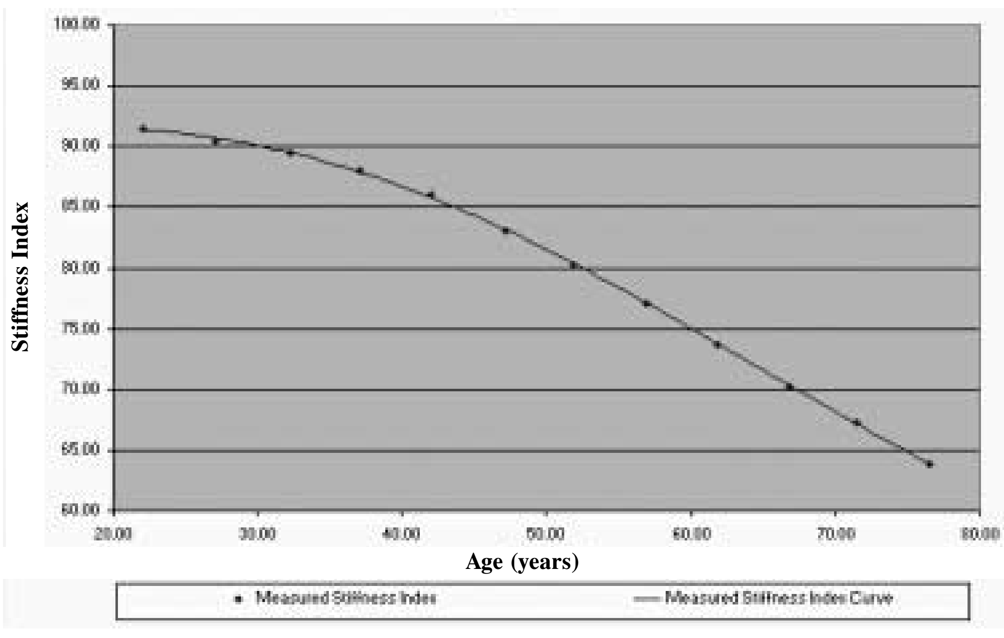

Figure 2. Selected stiffness index values 5 years age bracket.

energy X-ray absorptiometry (DXA)[2]. Although DXA has proven to be a reliable predictor of future fracture, the high costs and their availability cross country limits its application[3]. Additionally the assessment of local reference values is essential in order to avoid misclassifications in different populations[4-6]. The measurement of BMD still fails to explain a considerable portion of the overlap between healthy women and those with osteoporotic fracture. Since the pathophysiology of osteoporosis is known to include both a loss of bone mass and alteration of trabecular microstructure, it has been suggested that the assessment of both would improve the prediction of future fracture.

This has led to the evaluation of quantitative ultrasonometry of bone (QUS). It is an inexpensive, radiation-free

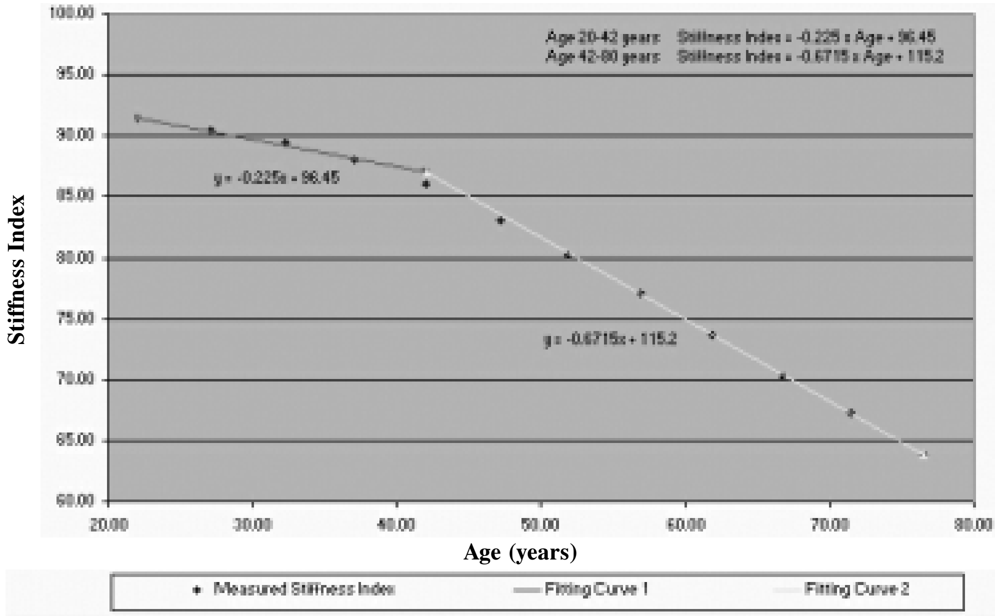

Figure 3. Selected stiffness index values 5 years age bracket.

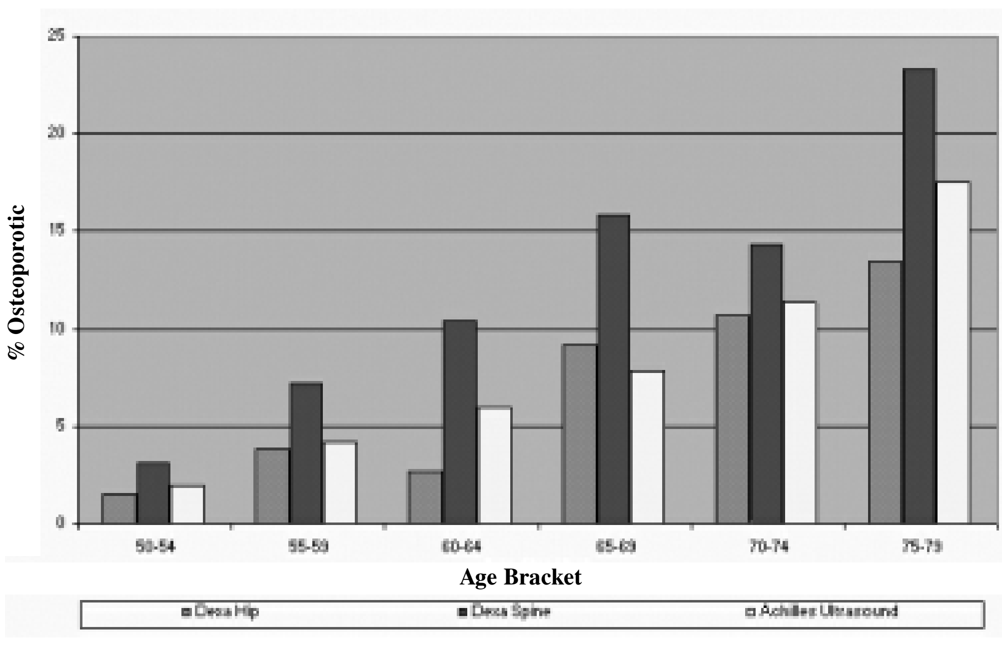

Figure 4. Prevalence chart for achilles population vs Dexa hip and Dexa spine.

method which provides information on BMD, and perhaps on bone quality as well[7-10]. Quantitative ultrasonometry variables at the heel were reported to correlate highly (r=0.8 to 0.9) with bone mineral density at the same site, and even more highly with biomechanical properties of bone[11-14]. Furthermore, ultrasonometry measurement may be a better indicator of bone fragility and the risk of fracture than peripheral bone mineral density[15]. Cross-sectional and prospective studies have shown that QUS variables are as good as bone mineral density determined by DXA in predicting hip and vertebral fracture, and provide additional information that is independent of bone mineral density[16-26], though there is no unanimity about this point.

A number of recent studies have shown age-dependent

Age Bracket	Number	Mean Age	Stiffness Index	SD
20-24	77	22.00	91.50	14.21
25-29	144	27.09	90.50	14.02
30-34	185	32.30	89.40	14.29
35-39	312	37.06	88.00	15.97
40-44	436	41.99	86.00	14.91
45-49	500	47.18	83.11	16.01
50-54	669	51.88	80.15	16.23
55-59	604	56.89	77.08	15.65
60-64	586	61.90	73.70	15.96
65-69	408	66.74	70.30	15.05
70-74	245	71.52	67.30	13.95
75-79	154	76.55	63.80	15.05

Table 1. Stiffness index as a function of age as calculated from curve in Figure 2.

Age Bracket	50-59 kg (SI)	60-69 kg (SI)	60 - 50 kg Bracket Δ SI	% SI	70-79 kg (SI)	70 - 50 kg Bracket Δ SI	% SI
20-29	91.07	92.03	0.96	1.05	***	***	***
30-39	89.30	88.17	-1.14	-1.29	90.53	1.23	1.36
40-49	82.88	82.13	-0.75	-0.91	84.56	1.68	1.99
50-59	76.37	77.87	1.50	1.93	78.48	2.12	2.70
60-69	68.95	72.05	3.10	4.30	70.08	1.13	1.62
70-79	63.76	65.50	1.74	2.66	65.01	1.25	1.93

*** The sample size for this age bracket and weight is not statistically sufficient

Table 2. Influence of weight on SI. SI variation and % SI variation.

Age Bracket	Number	Average Age	Average. Stiffness	Average T-score	% Normal	% Osteopenic	% Osteoporotic
20-24	77	22.00	94.31	0.17	90.91	9.09	0.00
25-29	144	27.09	89.35	-0.13	85.42	14.58	0.00
30-34	185	32.30	90.38	-0.07	88.11	10.81	1.08
35-39	312	37.06	88.12	-0.20	78.53	20.19	1.28
40-44	436	41.99	83.28	-0.48	71.56	26.61	1.83
45-49	500	47.18	83.11	-0.49	68.20	30.60	1.20
50-54	669	51.88	80.15	-0.67	62.18	35.87	1.94
55-59	604	56.89	77.08	-0.85	53.48	42.38	4.14
60-64	586	61.90	73.70	-1.05	43.00	51.02	5.97
65-69	408	66.74	69.72	-1.28	33.33	58.82	7.84
70-74	245	71.52	65.83	-1.51	23.27	65.31	11.43
75-79	154	76.55	63.68	-1.64	24.03	58.44	17.53

Table 3. Percent of osteopenic and osteoporotic in the Lebanese population.

decreases in calcaneal QUS[27-35]. In a previous study on age-related changes in Lebanese women, normal BMD reference values were found to be different from the US and European values[36]. The aim of the present study was to assess a large, normative Lebanese QUS reference curve and to compare our results with the presently used US and European reference curves.

Additionally, we compared the proportion of osteopenic

Age Bracket	Number	Average Age	Average Stiffness	Average T-score	% Normal	% Osteopenic	% Osteoporotic c
20-24	77	22.00	94.31	-0.38	72.73	27.27	0.00
25-29	144	27.09	89.35	-0.67	57.64	42.36	0.00
30-34	185	32.30	90.38	-0.60	62.70	35.14	2.16
35-39	312	37.06	88.12	-0.74	58.65	38.78	2.56
40-44	436	41.99	83.28	-1.04	43.81	51.38	4.82
45-49	500	47.18	83.11	-1.06	45.20	49.60	5.20
50-54	669	51.88	80.15	-1.24	37.22	53.96	8.82
55-59	604	56.89	77.08	-1.43	31.95	56.13	11.92
60-64	586	61.90	73.70	-1.64	23.04	58.19	18.77
65-69	408	66.74	69.72	-1.89	17.16	56.13	26.72
70-74	245	71.52	65.83	-2.14	11.43	54.29	34.29
75-79	154	76.55	63.68	-2.27	8.44	44.16	47.40

Table 4. Percent of osteopenic and osteoporotic in the Lebanese population. Calculations are made using the American stiffness index reference values.

Age Bracket Years	HIP-BMD (DXA) Prevalence in %	Os Calcaneus (QUS) Prevalence in %
50-54	1.49	1.94
55-59	3.83	4.14
60-64	2.66	5.97
65-69	9.15	7.84
70-74	10.64	11.43
75-79	13.40	17.53

Table 5. Prevalence of osteoporosis in hip (DXA) and os calcaneus (QUS).

and osteoporotic women in comparing DXA and QUS results in this regard.

Materials and methods

Subjects

The sample consisted of 4,320 Lebanese women. Subjects were recruited through Lebanese Red Cross centers, the media, health organizations, and the Lebanese Osteoporosis Society, from all regions of the country and different communities, and randomly without exclusion or inclusion criteria, except that the women had to be ambulatory, ethnic Lebanese with parents and grandparents of Lebanese origin.

Measurements

Quantitative ultrasonometry of the os calcaneus was performed following a standardized, routine procedure and measured by only one operator per machine. Female subjects visited the Red Cross centers distributed all over the country, except for those living in nursing homes, where the machine and the operator were moved to.

Ultrasound devices

Three identical Achilles Express (GE/Lunar) ultrasound devices and one Achilles Plus (GE/Lunar) ultrasound device were used in this study. The Achilles system consists of two unfocused transducers (2.5 cm diameter) mounted approximately 9.5 cm apart. One transducer acts as the transmitter and the other as the receiver. Acoustic coupling is accomplished by submerging the transducers in a surfactant solution in water maintained at 35°C. The quality control procedure using the standard phantom was performed each day before the measurements *in vivo*. Besides daily quality control using phantoms, instrument performance was checked regularly by the operator, as well as by a specialized engineer employed by the manufacturer's agents. These machines were cross calibrated every three months over the project period of one and a half years. Each machine was within ±1.7% of the average result, of the four machines.

Two ultrasound variables on the os calcaneus were measured: broadband ultrasound attenuation (BUA) expressed in decibels per megahertz (db/MHz) and speed of sound (SOS) expressed in meters per second (m/s). A third variable, the stiffness index (SI) (expressed as the percent of young adults) was used to minimize measurement errors caused by variable heel width and water temperature. This index should not be confused with the biomechanical term 'stiffness'. The SI is a linear combination of normalized BUA and SOS as follows:

SI = 0.67 x (BUA) + 0.28 x (SOS) - 420.

Statistical analysis

The effect of age was determined using linear regression and multiple regression analysis. Analysis was carried out on a whole sample basis as well as by age brackets. Results in both cases were comparable. In all cases and in each age bracket the number of subjects was sufficiently high. The point corresponding to the age bracket 80-90 was eliminated as the number of subjects in this bracket was statistically insufficient.

Results

Influence of age

Stiffness index as a function of age for all the population without using age brackets shows that there is a constant decrease with age (Figure 1).

Table I summarizes the influence of age using the age bracket method on stiffness index results. The curve obtained in Figure 2 was approximated by two segments of straight lines (Figure 3) that are expressed by the following formulae:

Age 20-42 Stiffness Index =-0.225 x Age + 96.45
Age 42-79 Stiffness Index=-0.6715 x Age +115.2

The curve shows a slight decrease in stiffness index at the age of 20 and up to the age of 42 of about 0.2 SI units/year, after which the decrease becomes steeper with a value of 0.7 SI units/year. Young adult reference was found to be 92 (normal stiffness index at age 20) and the standard deviation 17. It was also obtained that the mean height of the overall Lebanese women population is 157.6 cm and the mean weight is 68.68 kg.

Effect of weight

The effect of weight was examined by determining the stiffness regression curves for three samples of the population in the weight brackets 50-59, 60-69 and 70 to 79 kg. The effect of weight is negligible on the stiffness index (Table 2).

Prevalence of osteoporosis and osteopenia

The T-score of each Lebanese woman from the sample was recalculated using the obtained Lebanese Normal Stiffness Index curve. The definition used for determining the osteoporotic and osteopenic subjects was the same as that proposed by the WHO for classifying patients according to their BMD T-score. Osteopenia was defined as a T-score between –1 and –2.5 and osteoporosis with a T-score below -2.5. Table 3 gives the detailed results per age bracket of 5 years using the Lebanese reference curve, whereas Table 4 uses the USA reference curve.

Additionally, we compared the results of the prevalence of osteoporosis as determined in this study and the prevalence determined in an earlier report using only DXA[36,40]. Hereby, the mean height and weight of the female, Lebanese QUS reference population that were obtained was 157.6 cm and 68.68 kg compared to 155.8 cm and 65.6 kg from the latter DXA study[36]. We found no statistical significant difference in the proportion of women classified as osteoporotic using DXA or QUS over all age brackets (Figure 4, Table 5).

Discussion

Bone mineral density (BMD) measurements using dual energy X-ray absorptiometry (DXA) have been the standard for diagnosing osteoporosis and evaluating fracture risk. Authors have found differences in BMD among ethnic groups which was not reflected in the incidence of hip fractures[4,34,38]. Therefore, "standardized reference data" were introduced, especially for the femur on a geographical basis[33], because already small differences could affect the classification of patients as osteopenic or osteoporotic. This effect was observed in an earlier report where we determined the Lebanese reference curve for BMD[36]. Hereby, the incidence of osteoporosis would have been overestimated had the US/European database been used instead of the Lebanese.

Several large cross-sectional studies of aging in European women using the QUS including the Achilles device have been reported[13,32,37,39]. Studies have also been done with other ultrasonometers[37], and on Asian populations[29-31]. All reports show that ultrasound values decrease with age. It has been difficult to evaluate the clinical impact of these decreases, because the scaling of BUA and SOS differ from that of BMD. In contrast, the percentage of age changes for SI are very similar to those expected for calcaneal BMD[13,38]. The present study was performed to establish a similar normative database, this time for QUS, as has already been performed in numerous other countries.

Our results indicated that the calcaneal stiffness index of the Lebanese female population curve reflects sufficient differences in values and trends from the American and European curves to warrant separate Lebanese data. Using the American reference curve for determining the prevalence of osteoporosis revealed completely erroneous figures. The calcaneal stiffness index of the Lebanese female population as determined in this study seems to correlate well with the Lebanese female femur BMD results.

Additionally, we have evaluated that the prevalence of osteoporosis using QUS corresponds to the prevalence found using DXA[36]. We have used the limit of T=-2.5 in this process though this definition is established only for the BMD of spine and hip. It is to be noted that the characteristics of both study populations were similar as evidenced by the close height and weight. Hereby, our results indicate that there was no influence of weight on ultrasonometry variables[30,39]. At the same time, the rate of osteoporotic fractures in the Lebanese populations needs to be evaluated.

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