Bone status in healthy Estonian women assessed with quantitative ultrasonometry

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Submitted 01-04-21. Accepted 02-01-20

ABSTRACT – We assessed age-related changes of bone status in healthy Estonian women in various age groups with quantitative ultrasonometry. The speed of sound (SOS), broadband ultrasound attenuation (BUA), and stiffness index (SI) of the calcaneus were measured in 288 women. BUA and SI values peaked at 30–39 years of age while SOS peaked at 20–29 years and decreased thereafter. We detected no statistically significant changes between the age groups of 20–29, 30–39 and 40–49 years. The total age-related decrease was 18% for BUA, 3% for SOS and 29% for SI.

We found a statistically significant correlation between bone status and calcium intake, as well as physical activity in the age group over 40 years.

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Several methods are used to measure bone mass, but they do not measure bone quality. Quantitative ultrasonometry (QUS) is another method for assessing skeletal status. Previous studies have shown that QUS reflects not only the bone mineral density (BMD), but also qualitative aspects of bone tissue such as elasticity, structure and geometry (Langton et al. 1984, Gluer et al. 1994, Njeh et al. 1997). Since ultrasound is safe, non-invasive, relatively cheap, and easy to do, it is suitable for population screening (Hans et al. 1998). Ultrasound measurement seems to be useful for predicting the risk of fracture (Bauer et al. 1995, Schott et al. 1995, Hans et al. 1996). There are several QUS studies have been done, but no reference values from general population samples are available.

The aim of the present epidemiological study was to evaluate the changes in bone status in the healthy Estonian female population, and determine reference values for stiffness index (SI), speed of sound (SOS) and broadband ultrasound attenuation (BUA) measured with calcaneal ultrasound.

Patients and methods

We performed an epidemiological study of the healthy Estonian female population's bone status in three different regions of Estonia. The study was approved by the Ethics Committee of Human Studies at the University of Tartu. The sample consisted of healthy women aged 20-89 years. Persons with possible pathological changes in bone structure or density were excluded as also were those: 1) of other nationalities; 2) with chronic diseases; 3) who were bedridden or could not walk; 4) persons with frequent fractures or previous calcaneal fractures; 5) who used or had regularly used glycocorticosteroids, estrogens, thyroxin, anticonvulsants, bisphosphonates, or metabolites of vitamin D. A selection was made from 3,000 persons separately for the age groups 20–29, 30–39 years, etc., with every tenth person being selected. Thus 288 women were included.

All subjects were informed and consented to participate before the study. They were asked to fill in a questionnaire concerning body height and weight, lifestyle, physical activity, past and present eating habits, gynecological status, previous illnesses and hereditary diseases, medications used, activities at school and at work, various sports and household chores. We determined their calcium intake with a food-frequency questionnaire. Body mass index (BMI) was calculated as body weight divided by height squared. The bone mineral status was measured using the Lunar Achilles Ultrasound system (Lunar Corporation, Madison, WI, USA). This system consists of two unfocused transducers with a diameter of 2.54 cm, mounted coaxially about 9.5 cm apart. Acoustic coupling is cone by submerging the transducer pair and the heel in water kept at 35 °C, containing surfactant to wet the foot. The water is changed for each subject. The heel is then placed between the transducers (one acts as the transmitter and the other as the receiver), with the ultrasound beam propagating laterally through the center of the calcaneus (Mazess et al. 1991). Two ultrasound variables on the calcaneus were measured: BUA (in decibels per megahertz (dB/MHZ)) and SOS (in meters per second (m/s)). A third variable, the mathematical index referred to as the stiffness index, is calculated automatically from the combined data about SOS and BUA. All measurements were made by the same operator using the same ultrasonometer. The quality control procedure with the standard phantom was done each day before the in vivo measurements. The coefficient of variation in the precision of this instrument was 0.2% for SOS and 1.8% for BUA.

Table 1. Age-related changes in height. weight and BMI of 288 healthy Estonian women

		Age (years)		Height (cm)		Weight (kg)		BMI (kg/m^2)	
Age	No.	Mean	SD	Mean	SD	Mean	SD	Mean	SD
20–29	32	25	3	168	6	63	10	22	3
30–39	38	34	3	166	6	65	11	23	4
40–49	66	45	3	165	6	69	16	25	5
50–59	53	54	3	164	5	73	16	27	6
60–69	54	63	3	161	6	75	13	29	5
70–89	45	74	4	160	6	74	11	29	4

Table 2. Age-related changes in BUA, SOS, SI of 288 healthy Estonian women

Age	n	BUA (dB/MHz)		SOS (m/s)		SI (%)	
		Mean	SD	Mean	SD	Mean	SD
20–29	32	116	14	1,556	33	93	16
30–39	38	119	12	1,554	29	94	14
40–49	66	118	13	1,549	33	92	16
50–59	53	113	14	1,539	29	86	16
60–69	54	103	15	1,522	38	75	19
70–89	45	96	15	1,508	35	66	18

Table 3. Linear correlation coefficients (r) between calcaneal ultrasound measurements (SOS, BUA and SI) and age, height and weight of healthy Estonian women

	SI r	P-value	SOS r	P-value	BUA r	P-value
Age	–0.49	0.0001	–0.45	0.0001	–0.47	0.0001
Height	0.26	0.0001	0.23	0.0001	0.27	0.0001
Weight	0.09	0.1	0.05	0.3	0.12	0.03

Results

We found a rise in weight, decline in height and rise of the BMI in the 6 age groups from 20–29 to 70–89 (Table 1). The mean reduction in body height was 7.8 cm, rise in weight 11.7 kg and increase in mean BMI 23%. The differences in ultrasound measurements of bone with age are shown in Table 2. Linear correlations coefficients (r) between calcaneal ultrasound measurements (SOS, BUA and SI) and age, height and weight are presented in Table 3.

Figure 1 reveals a non-linear trend between the changes in bone stiffness and the subjects' age. The relationship between bone stiffness and age can be found with the help of the following formula: bone stiffness = 78.94 + 0.996 age – 0.016 age^2. The model is significant ($p < 0.0001$ and r-square of the model 0.2887). Standard errors and significances of parameters are shown in Table 4. By using this formula, we calculated the age at which bone loss starts as 31 years. The analysis of significant differences in bone stiffness between different age groups showed that age was a significant factor. The highest mean SI and BUA values occurred at

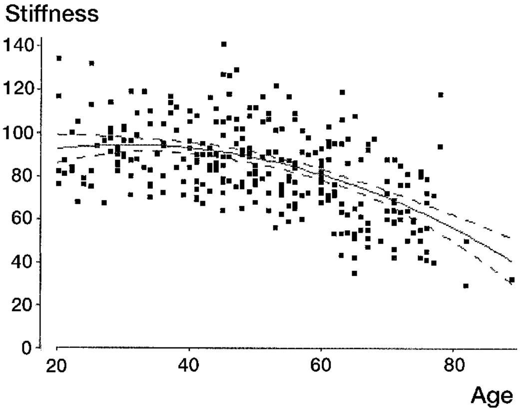

Figure 1. Distribution of bone stiffness in 288 healthy Estonian women.

the age of 30–39 years, but there was no statistically significant change between the age groups of 20–29, 30–39 and 40–49 years. SOS decreased only slightly from 20–49 years, in the age group of 50–59 years, the annual decrease in SOS was 1 m/s and after 60 years ~1.6 m/s. The annual mean decrease in SOS was 0.06% and in BUA 0.4%. The use of the Fisher LSD test yielded statistically significant homogeneous groups: the first three age groups had similar ultrasound values for bone status, but significantly lower characteristics in the oldest age group.

We found no correlations between bone status, calcium intake and physical activity when comparing all subjects or those in various age groups (20–29, 30–39, etc.). Only the subjects in extreme groups were evaluated separately—i.e., those with a large or minimal intake of calcium in food and those with a very inacative or very active way of life. In assessing calcium correlations, the subjects whose daily calcium intake exceeded 1200 mg were considered, as well as those who were mainly vegetarians or whose food contained hardly any calcium. Physical activity was evaluated in the subjects who had never had any interest in sports and those with sedentary jobs, as well as in those who had participated in sports since childhood and whose jobs required physical activity. We concentrated on two age groups (20–39 years old and over 40 years old) and found a correlation between SI and calcium intake ($p = 0.04$), and physical activity ($p = 0.03$) in the age group over 40 years old. In the younger age group, no such relationship was noted.

Table 4. Standard errors and significance of parameters to SI model

Variable	Estimate	SE	T stat	Pr > | t |
Intercept	78.9	9.26	8.53	<0.0001
Age	0.99	0.38	2.59	0.0101
Age x age	–0.016	0.0038	–4.27	>0.0001

Discussion

Several studies about ageing in women have reported changes in BMI, weight and height. In our investigation, similar results were obtained. There was a decline in body height and a rise in body weight. BMI rose a quarter, being lower than 25 in the age group of 20–39 years but starting with the age group of 40–49 years, the mean BMI was higher than 25, which accords with the presence of overweight. Damilakis et al. (1992) found no correlation between body size (height, weight and BMI), and BUA. In several studies, significant correlations have been reported between each of the ultrasound values and body size variables (Yamazaki et al. 1994, Pluskiewicz 1998, Landin-Wilhelmsen et al. 2000). In the current investigation, no correlation was detected between body weight and SOS and SI.

All reports show that the ultrasound values decrease with age, but the age at which the peak bone mass occurs may differ in various populations. In our study of Estonian females BUA and SI values peaked at the age of 30–39 years, while in several other population studies, the ultrasonographic parameter values peaked before the age of 30 years (Yamazaki et al. 1994, Cepollaro et al. 1995, Hadji et al. 1999). The bone stiffness of the subjects in various age groups was compared the mean values of BUA, SOS and SI in German (Hadji et al. 1999) and Swedish (Landin-Wilhelmsen et al. 2000) female populations (Figures 2 and 3). The same Lunar Achilles Ultrasound scanner was used in all the above studies. The total age-related decrease was 18% for BUA, 3% for SOS and 29% for SI in Estonian women; 15% for BUA, 5% for SOS and 31% for SI in German women; 14.8% for BUA, 4% for SOS and 32% for SI in Swedish women. The mean values for BUA, SOS and SI in

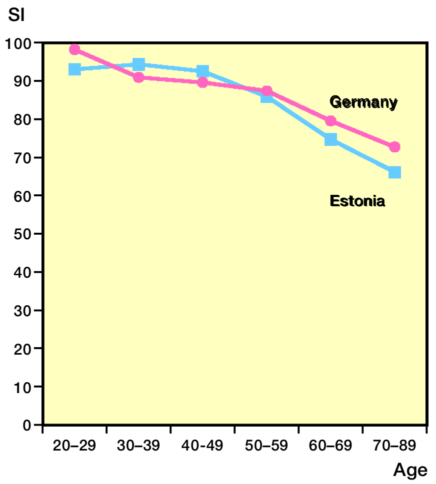

Figure 2. SI values in Estonian and German women.

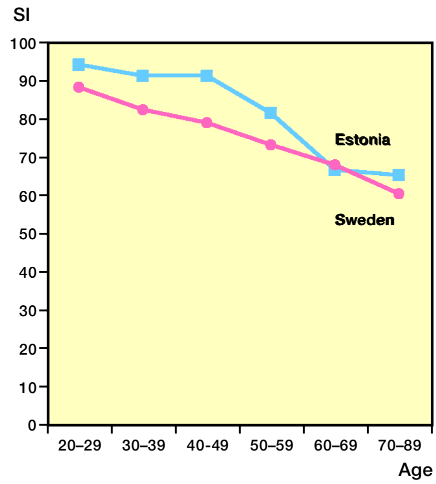

Figure 3. SI values in Estonian and Swedish women.

Estonian women were lower in the young and the old age groups than those of German women, but significantly higher than those of Swedish women. It is hard to explain why our data about bone quality are better than those in the Swedish population, but the fact that Swedes live north of us and that there are fewer sunny days in Sweden than in Estonia may be one of the reasons.

This study was supported by the Estonian Scientific Foundation (grant no. 2423). The assistance of Dr. Katrin Ollikainen, Dr. Maarika Kukk, Dr. Merle Raidoja, Dr. Kersti Pelisaar and Dr. Anu Mõtsar is appreciated.

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