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Impact of anthropometric, lifestyle, and body composition variables on ultrasound measurements in school children

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Abstract

Quantitative ultrasound (QUS) measurement at hand phalanges was demonstrated to be a reliable method to assess skeletal maturation during childhood and adolescence. The aim of the study was to evaluate the influence of age, gender, puberty, lifestyle factors, and body composition on QUS parameters and to provide a normative database for QUS in school children in Lebanon.

Measurements of phalangeal osteosonography were examined in 256 healthy subjects (132 boys and 124 girls) aged 11–18 years using an ultrasound device.

In both genders, amplitude-dependent speed of sound (AD-SoS) and bone transmission time (BTT) increased significantly with age and pubertal stages. Girls had higher AD-SoS values than boys between 11 and 15 years of age and at Tanner stages III and IV; however, no differences were detected in the older age groups. AD-SoS and BTT showed a significant positive correlation with age and height in both genders (R = 0.41–0.66, P < 0.01). There was no correlation between physical activity, calcium intake, sun exposure, and any of the QUS parameters in either gender. Weight showed moderate positive correlation with AD-SoS in boys and with BTT in both genders (R = 0.31–0.47, P < 0.01). Lean mass showed significant positive correlation with AD-SoS and BTT (R = 0.2–0.68, P < 0.01) in both genders. Percentage body fat showed significant negative correlation with BTT and AD-SoS in boys (R = −0.25 to −0.37, P < 0.01). In the linear regression analyses, there was a significant negative correlation between percentage fat mass and both AD-SoS and BTT in both genders.

In conclusion, QUS parameters of the phalanges in Lebanese children are related to growth variables such as height, age, and puberty in healthy children. The impact and magnitude of body composition variables and lifestyle factors on ultrasonometry derived variables differ from their effect on dual energy X-ray absorptiometry derived parameters.

Keywords: Quantitative ultrasound; Puberty; Body composition; Gender; Normative data

Introduction

During the last years, measurement of bone mineral density is becoming increasingly important in children and adolescents. In this population, measurement of bone mineral density (BMD) or content (BMC) should be ideally assessed with a technique that is relatively cost-effective and free of ionizing radiation. Quantitative ultrasound (QUS) is a noninvasive method that is a surrogate estimation of bone density and bone architecture, with specific parameters derived from sound waves passing through both cortical and trabecular bone [1–3]. This technique is safe, easy to use, and radiation-free. The equipment can be transported and the measurement is relatively cheap compared to dual-energy X-ray absorptiometry and quantitative computed tomography.

In addition, ultrasound may have the added advantage of providing information about bone architecture [1]. It measures the properties of bone that depend on trabecular orientation that contributes to mechanical bone strength [4,5]. Ultrasonography, therefore, provides information about the biomechanical properties of bone that is important in assessing fracture risk over and above BMD [6,7].

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The phalangeal QUS method is based on the transmission of ultrasound through the distal diaphysis of the proximal phalanx of the hand. The results obtained show the characteristics of the electrical signaling generated by the US after crossing the phalanx soft tissue and bone. QUS measures are affected not only by bone density but also by bone size and quality features of bone tissue [8–11]. Baroncelli et al [9] demonstrated that phalangeal QUS, in addition to BMD, reflected the architectural organization of growing bone, suggesting that it may be a useful method to assess bone quality in pediatric subjects.

Pediatric studies characterizing bone mass acquisition during childhood and adolescents by means of QUS techniques are in a large part conducted in western populations [7–9,12,13]. Furthermore, most studies in children have expressed ultrasonometry parameters as a function of age rather than pubertal maturation, the latter an important determinant of bone mass accrual. Our group and others demonstrated that both lean mass and fat mass were strong correlates of BMD and BMC in children [14–16]. To our knowledge, no study has investigated the association between body composition parameters and QUS measures in children.

The aims of our study were as follows:

1. To evaluate the pattern of phalangeal US signal transmission in Lebanese school-aged children and relate these values to anthropometric variables such age, gender, and growth variables such as height, weight, and pubertal status; and to lifestyle factors.
2. To investigate the impact of body composition parameters such as lean mass and fat mass on QUS parameters in this study group.

Materials and methods

Subjects

Quantitative ultrasound of the phalanges was performed on 256 subjects (132 boys and 124 girls) ages 11–18 years [17]. Measurements were performed during the period extending between December 2002 and June 2003.

The exclusion criteria included: any medical condition likely to affect bone metabolism, i.e., renal disease, liver disease, chronic diarrhea, gastric or bowel surgery. Also were excluded children who were on high dose vitamins within 6 months of the study and those on medications known to affect bone metabolism such as antiseizure drugs, rifampicin, cholestyramine, or chronic steroid therapy.

The study was approved by the Institutional Review Board of the American University of Beirut. All the participants and/or one of their parents gave written informed consent to participate in the study.

Methods

Each child underwent a physical examination that included height, weight, and pubertal stage assessment. The subject's standing height was recorded in triplicate in centimeters to the nearest 0.1 cm using a wall stadiometer, and the average was used in the analyses. Weight was recorded in kilograms, to the nearest 0.5 kg wearing light clothes, without shoes using a standard clinical balance. Mean height and weight were rounded to the nearest integer. Height and weight percentile were derived using American growth curves published by the U.S. National Center for health statistics [18], as national standards are not available.

Pubertal status was determined by a physician (MN), using breast and pubic hair stages in girls, testicular and pubic hair stages in boys, according to the established criteria of Tanner [19]. Medications and vitamin intake were assessed with a questionnaire. Sun exposure was assessed by asking the children about estimated exposure time to the sun, head and arms uncovered, per week. Veiled girls were considered as not having any sun exposure. Calcium and vitamin D intakes were assessed with a validated food frequency questionnaire [20]. Blood was drawn for serum calcium, phosphorus, and alkaline phosphatase levels, which were measured by standard calorimetric methods using the Hitachi 912 analyzer (Boehringer Mannheim, Mannheim, Germany).

Body compositions, i.e., lean mass, fat mass, and percentage fat mass, were measured by a dual-energy X-ray absorptiometry (DXA) using a Hologic 4500A device (Hologic, Bedford, MA, USA) in the fan beam scanning mode and analyzed using One -Time™ Auto Analysis, a feature of all models in the Discovery Series. In our center, the mean ± SD of precision expressed as coefficient of variation (CV%) for 30 serial duplicate scans performed in vivo were as follows: 0.54 ± 0.36% for lean mass, 1.13 ± 0.79% for fat mass, and 0.96 ± 0.76% for percentage fat mass.

QUS measurements were performed using the DBM-Sonic 1200 (IGEA, Carpi, Italy) on proximal phalanges II to V of the non-dominant hand of children, as recommended by the manufacturer. The DBMSonic 1200 measures the transmission of ultrasound through human phalanges using a hand-held caliper with two opposing transducers, one acting as a transmitter and the other as a receiver. Time-of-flight between the probes and the distance between probes is measured and velocity parameters, amplitude-dependent speed of sound (AD-SoS), are calculated as the ratio between transducer separation and the time when the signal received attains a predefined signal amplitude of 2 mV. Bone transmission time (BTT) is calculated as the difference between the time when the first peak of the signal received attains its maximum and the time that would be measured if no bone but only soft tissue was present between the transducers. This parameter is calculated from phalanges II to IV only. Soft tissue velocity is measured between the base of the thumb and the index finger during each session. Thus, BTT, unlike AD-SoS, is largely independent of ultrasound attenuation and soft tissue bias [10].

All scans were assessed by IgEA (Carpi, Italy), subjects with less than 4 fingers measured were excluded (only one subject was excluded due to this criterion). Furthermore, 17 measurements were not triggered on the first peak and for these subjects only BTT values were used in the analysis. This is because the lack of triggering on the first peak of the ultrasound measure only affects AD-SoS but not BTT.

Precision was calculated on 192 study subjects measured twice by the same operator. Values of intraoperator precision of AD-SoS and BTT obtained in terms of root mean square of coefficient of variation CV% were 0.54 and 2.01, respectively.

Statistical analysis

Analyses were performed for boys and girls separately. Differences between the two groups were assessed by independent *t* test. Children were subdivided into seven age groups of 1-year interval each. The effects of age and puberty on bone parameters, within each gender, were assessed using one-way analysis of variance (ANOVA). The relationship between QUS parameters and continuous variables such as age, height, weight, lean mass, fat mass, percentage fat mass, and Tanner stage was evaluated using a Pearson correlation coefficient or Spearman for non-normally distributed variables. Correlation coefficients between lean and percentage fat mass and QUS parameters were compared between genders using two-tailed *t* test. Multiple regression models were created by entering the specific QUS parameter as a dependent variable, and the independent variables that were significant correlates of BTT and AD-SoS on bivariate analyses. The models were constructed based on all enter selection procedure, where the independent variables were entered by sequential blocks and the cumulative R^2 was determined after adding each block. These blocks were entered in the following order: anthropometric variables (age, height, pubertal stages), and the body composition variables such as lean and percentage fat mass entered as discrete blocks. Percentage fat mass and lean mass were entered last in the models in order to investigate the strength of their association with ultrasound parameters, after correcting for the classical predictors of bone mass in children. Since both lean mass and percentage fat mass are components of body weight, weight was not entered in the models to avoid collinearity.

All results are expressed as mean ± SD; two-sided P values < 0.05 were considered as statistically significant and were not adjusted for multiple testing. All analyses were carried out using SPSS software, version 10.0 (SPSS, Chicago, Illinois).

Results

Clinical characteristics

Clinical characteristics of the study group are shown in Table 1. The mean age of study participants was 13.8 ± 1.9 years. There was balanced representation from both genders. There was no statistical difference in mean age between boys and girls. As anticipated, boys were taller, had higher weight, lean mass, BMI, calcium intake, sun exposure, and muscle strength than girls (Table 1). Serum calcium, phosphorus, and alkaline phosphate levels were normal in all children (data not shown).

Correlates of ultrasound parameters on bivariate analyses

Growth correlates, age, and puberty

Normative values of gender-specific ultrasound parameters by age group and Tanner stages are shown in Tables 2 and 3.

In both genders, AD-SoS and BTT increased with age and pubertal stages. There was a significant effect of age and Tanner stage on QUS parameters within each gender by analysis of variance (Tables 2 and 3). AD-SoS and BTT showed a significant positive correlation with age and height in both genders, R = 0.41–0.66, P < 0.01 (Table 4).

Table 1
Clinical characteristics of the study group

Variables	Boys (n = 132)	Girls (n = 124)	Whole group (n = 256)
Age (years)	13.8 ± 1.8	13.8 ± 1.9	13.8 ± 1.9
Height (cm)*	159.4 ± 12.1	155.6 ± 8.5	157.6 ± 10.6
Height percentile	49 ± 30	45 ± 29	47 ± 30
Weight (kg)**	56.9 ± 17.4	50.8 ± 11.3	54 ± 15.1
Weight percentile	62 ± 32	55 ± 29	58 ± 31
Body mass index (kg/m^2)*	21.9 ± 4.5	20.9 ± 3.6	21.4 ± 4.1
Lean mass (kg)***	37 ± 10.7	29.5 ± 5	33.3 ± 9.2
Fat mass (kg)*	13.8 ± 8.2	16 ± 7.6	14.8 ± 8
Percentage fat mass (%)***	24.9 ± 9.4	32.6 ± 7.6	28.7 ± 9.6
Calcium intake (mg/day)***	667 ± 278	516 ± 229	594 ± 266
Exercise hours/week	5.8 ± 5.9	4.5 ± 5.2	5.2 ± 5.6
Sun exposure (min/week)***	466 ± 260	349 ± 176	410 ± 230
Ultrasound parameters			
AD-SoS (m/s)***	1974 ± 64	2019 ± 62	1997 ± 67
BTT (μs)	1.20 ± 0.27	1.22 ± 0.20	1.21 ± 0.24
Tanner staging			
I	11	6	17
II	35	17	52
III	37	26	63
IV	25	51	76
V	24	24	48

Values are mean ± SD.
* Statistically significant difference between boys and girls at P < 0.05.
** Statistically significant difference between boys and girls at P < 0.01.
*** Statistically significant difference between boys and girls at P < 0.001.

Table 2
Gender-specific values of amplitude-dependent speed of sound (AD-SoS) and bone transmission time (BTT) by age group

Age (years)	Boys				Girls			
	n	AD-SoS (m/s)	*n*	BTT (μs)	*n*	AD-SoS (m/s)	*n*	BTT (μs)
11–11.9	20	1928 ± 46[a]	24	0.98 ± 0.16	23	1965 ± 54	25	1.03 ± 0.18
12–12.9	16	1942 ± 38[a]	22	1.08 ± 0.17	27	1997 ± 60	27	1.14 ± 0.2
13–13.9	24	1951 ± 38[a]	26	1.12 ± 0.15	18	2007 ± 35	18	1.2 ± 0.13
14–14.9	22	1976 ± 57[a]	23	1.29 ± 0.23	15	2035 ± 42	15	1.31 ± 0.14
15–15.9	18	2013 ± 64	19	1.36 ± 0.25	14	2051 ± 54	15	1.35 ± 0.15
16–16.9	9	2022 ± 59	9	1.41 ± 0.25	14	2061 ± 29	14	1.35 ± 0.1
17–17.9	8	2075 ± 49	8	1.64 ± 0.16[a]	10	2091 ± 55	10	1.42 ± 0.13
*P**		<0.001		<0.001		<0.001		<0.001

Values are mean ± SD.
[a] Statistically significant as compared to age matched opposite gender group.
* *P* value for difference between different age groups within each gender by ANOVA.

Weight showed moderate positive correlation with AD-SoS in boys and with BTT in both genders, $R = 0.35–0.47$, $P < 0.01$ (Table 4).

Gender effect

Girls had higher AD-SoS values than boys for the age categories 11–15 years and in Tanner stages III and IV (Tables 2 and 3); however, this gender difference disappeared in the older age groups. No gender difference was found in BTT at any Tanner stage and was only detected in the oldest age category where boys had higher BTT than girls (Tables 2 and 3).

Lifestyle correlates

No significant correlation was found between sun exposure, physical activity, or calcium intake and any of the ultrasonometry parameters in either gender.

Body composition correlates

In both genders, lean mass showed significant positive correlation with AD-SoS and BTT ($P < 0.05$). For both parameters, the coefficients of correlations were larger in boys than girls ($P < 0.01$). These coefficients were 0.54 versus 0.20 for AD-SoS and 0.68 versus 0.46 for BTT for boys and girls, respectively. Percentage body fat showed a significant negative correlation with BTT and with AD-SoS in boys only ($P < 0.01$). No significant correlation was found between total fat mass and ultrasound parameters in either gender (Table 4).

Correlates of QUS parameters on multivariate analyses

In the linear regression analyses, anthropometric variables, such as age, puberty, and height entered as a single block, accounted for 46% and 52% of AD-SoS and BTT variance, respectively, in boys, and 40% and 48% of AD-SoS and BTT variance, respectively, in girls (Table 5).

After adjustment for the above predictors, lean mass showed a marginal albeit significant contribution to BTT variance in boys ($R^2 = 0.1\%$) and a significant contribution to AD-SoS with negative slope in girls ($R^2 = 8.4\%$). Conversely, percentage fat mass showed significant negative contribution to AD-SoS and BTT variance in both genders. This contribution was higher in boys than in girls: $R^2 = 12\%$ in boys versus $R^2 = 6.5\%$ in girls for AD-SoS and $R^2 = 9.4\%$ in boys versus $R^2 = 6\%$ in girls for BTT (Table 5).

Discussion

Our study provided gender-specific values of the quantitative ultrasound (QUS) parameters assessing bone status (AD-SoS and BTT) by age and by Tanner stages of the Lebanese pediatric population. It showed the anticipated

Table 3
Gender-specific values of amplitude-dependent speed of sound (AD-SoS) and bone transmission time (BTT) by Tanner stages

Tanner stage	Boys				Girls			
	n	AD-SoS (m/s)	*n*	BTT (μs)	*n*	AD-SoS (m/s)	*n*	BTT (μs)
I	7	1911 ± 46	11	0.98 ± 0.19	6	1951 ± 50	6	0.95 ± 0.13
II	30	1945 ± 40	35	1.08 ± 0.15	15	1963 ± 46	17	1.00 ± 0.16
III	33	1947 ± 45[a]	36	1.10 ± 0.18	26	2004 ± 55	26	1.18 ± 0.18
IV	2	1994 ± 58[a]	25	1.31 ± 0.23	51	2031 ± 55	51	1.27 ± 0.17
V	23	2050 ± 51	24	1.54 ± 0.27	23	2060 ± 62	24	1.37 ± 0.14
*P**		<0.001		<0.001		<0.001		<0.001

Values are mean ± SD.
[a] Statistically significant as compared to Tanner stage matched opposite gender group.
* *P* value for difference between different Tanner stages within each gender by ANOVA.

Table 4
Correlation coefficients between speed of sound (AD-SoS) and bone transmission time (BTT) and anthropometric variables in boys and girls

	Boys				Girls			
	AD-SoS (m/s)		BTT (μs)		AD-SoS (m/s)		BTT (μs)	
	r	*P*	*r*	*P*	*r*	*P*	*r*	*P*
Age	0.58	<0.01	0.63	<0.01	0.61	<0.01	0.66	<0.01
Height	0.56	<0.01	0.64	<0.01	0.41	<0.01	0.53	<0.01
Weight	0.31	<0.01	0.47	<0.01	0.13	NS	0.35	<0.01
Lean mass	0.54	<0.01	0.68	<0.01	0.20	<0.05	0.46	<0.01
Fat mass	−0.06	NS	0.10	NS	0.01	NS	0.19	<0.05
Percentage fat	−0.37	<0.01	−0.25	<0.01	−0.10	NS	0.01	NS
Sun exposure	0.15	NS	0.18	<0.05	−0.001	NS	−0.02	NS
Exercise	−0.04	NS	−0.04	NS	−0.04	NS	−0.03	NS
Calcium intake	0.04	NS	0.15	NS	−0.03	NS	−0.08	NS

continuous increase in these parameters with age and pubertal stages in both genders. Percent body fat was a consistent negative independent predictor of QUS parameters in both genders. The impact of lean mass on these parameters was less consistent and varied in magnitude and direction between genders and QUS parameter.

The effect of age and puberty on ultrasound parameters was in agreement with the results obtained by dual energy X-ray absorptiometry (DXA) showing an increase of bone mineral content (BMC) and bone mineral density (BMD) with age and a substantial impact of pubertal development on BMC and BMD in both genders [8,9,12,13].

As reported by others [8,9], females had higher mean AD-SoS values than males from the ages of 11–15, but these differences disappeared in the older groups. This has been attributed to the earlier onset of pubertal development in girls as compared to boys [8]. However, in accordance with others [9], these differences were present even in subjects matched for Tanner stages (stages III and IV). The ultrasound device measures the distal portion of proximal phalanges, which are rich in trabecular bone. Our group and others have found that girls have higher mean bone mineral density than boys as measured by DXA, at trabecular sites, suggesting the effect of estrogen on trabecular bone [17,21–25]. Although not as optimal as QCT data, formulas used to calculate volumetric BMD using DXA confirmed these gender differences [17,23]. Between age 11 and 15 years, gender differences were observed in AD-SoS and not in BTT. BTT is relatively a new QUS parameter meant to offer improved performance for ultrasound measurements in children and, unlike AD-SoS, BTT is largely independent of ultrasound attenuation and soft tissue bias [10,13]. Therefore, the gender differences in AD-SoS may in part be related to differences in soft tissue thickness between the two genders. Indeed, it has been reported that ankle edema reduced the ultrasound velocity through the heel [26].

Unlike BMC, QUS parameters were not related to lifestyle factors such as sun exposure, calcium intake, and physical activity in the study population. Our findings are in

Table 5
Linear regression models with AD-SoS and BTT as outcomes and anthropometric measures, and body composition parameters as predictors entered as sequential blocks[a]

		Boys		Girls	
		AD-SoS β (SE) p[b]	BTT β (SE) p	AD-SoS β (SE) p	BTT β (SE) p
Block 1, Anthropometric measures	Age (years)	8.23 (3.6) 0.02	0.03 (0.01) 0.01	12.11 (2.8) 0.00	0.03 (0.009) 0.000
	Height (cm)	0.56 (0.8) 0.49	−0.002 (0.003) 0.54	2.1 (0.8) 0.01	0.002 (0.003) 0.35
	Tanner stage	13.85 (5.7) 0.02	0.02 (0.02) 0.23	20.8 (5.4) 0.00	0.06 (0.02) 0.001
R^2 [c]		0.455	0.521	0.397	0.483
Block 2, Lean mass	Lean mass (kg)	0.0006(0.001) 0.53	1.2×10^{-5} (0.00) 0.001	−0.003(0.01) 0.02	5.0×10^{-6}(0.00) 0.24
ΔR^2 [c]		0.026	0.001	0.084	0.002
Block 3, Percentage fat	Percentage fat (%)	−3.38 (0.6) 0.00	−0.001(0.002) 0.000	−2.87 (0.7) 0.00	−0.009(0.002) 0.000
ΔR^2 [c]		0.119	0.096	0.061	0.057
R^2 [d]		0.601	0.618	0.542	0.542

[a] References for discrete variables were as follows, Tanner stages = Tanner I.
[b] β estimates represent values adjusted for all predictors entered in the models.
[c] R^2 variance or additional variance of the outcomes (AD-SoS or BTT) explained by each block.
[d] Total R^2 (variance) of the outcome (AD-SoS or BTT) explained by entering all blocks: that is, all predictors.

agreement with another pediatric study using QUS measurements of the heel [6].

QUS variables, AD-SoS, and BTT were related to growth variables such as height and weight, as these also reflect bone size. These findings agree with those of earlier studies using phalangeal, calcaneal, tibial QUS both in adults and children [8,9,12,27]. In accordance with others [12], the coefficients of correlations were stronger with height than with weight, suggesting that QUS parameters are affected more by bone size than by body thickness.

To our knowledge, our study is the first to assess the respective contribution of lean and fat mass to QUS parameters in a pediatric population, after adjusting for classical predictors. We have previously demonstrated the powerful impact of body composition parameters, fat and lean mass, on DXA-derived BMD in children [14]. In the current study, the relation between lean mass and QUS parameters after adjusting for anthropometric correlates was not consistent in the multivariate analyses. This is in concordance with previous reports in adult females [28–31]. Indeed, Gregg et al. [28] showed that although lean mass was a significant correlate for SOS, its effect on BMD was stronger than that on SOS. Others showed a positive correlation between lean mass and QUS parameters of the calcaneus in women, but these correlations disappeared after adjustment for BMI [29], or age and weight [31]. Kroke et al. [30] showed that lean mass did not contribute to the variance in SOS at the calcaneus. The lack of correlation between lean mass and ultrasound parameters may be explained by the fact that relative low muscle or lean mass in the phalanx could not reflect the muscle mass or lean mass present around other skeletal sites assessed by DXA (spine, hip, and total body) [32].

In boys, there was a significant negative correlation between percentage fat mass and both QUS parameters. In accordance with what was reported in adult females, we did not find a correlation between SOS parameters and fat mass [29], nor percent fat mass [28] in univariate analyses in girls. However, in multivariate analyses, percentage fat mass was a negative predictor of both AD-SoS and BTT in both genders. Soft tissue thickness around the phalanx can affect the measurement of AD-SoS. This is due to the fact that ultrasound velocity in bone is about 3000–4000 m/s while in soft tissue is around 1550–1600 m/s [33]. The larger the amount of soft tissue, the slower the transmission of sound across the composite compartment of the phalanx that is reflected in AD-SoS and to a lesser extent on BTT. This is because BTT, unlike AD-SoS, is largely independent of ultrasound attenuation and soft tissue bias [13]. Indeed, the latter was reflected in the trend for larger β estimates relating AD-SoS, as compared to BTT, with percentage fat mass.

In summary, this study demonstrated that QUS parameters of the phalanges similar to BMC are strongly correlated to growth variables such as height, age, and puberty in healthy youth. However, contrary to BMC, lifestyle factors did not seem to affect QUS parameters. Furthermore, fat mass and lean mass, which have been previously demonstrated to be consistent robust independent predictors of BMC, did not have a consistent affect on QUS parameters. Although the pattern of increase of QUS parameters with age and with pubertal stages requires a longitudinal study, the current study provides QUS data expressed by age group and by Tanner stages that may be useful for the assessment of the bone status of Lebanese children.

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References

[1] Kaufman JJ, Einhorn TA. Perspective: ultrasound assessment of bone. J Bone Miner Res 1993;8:517–25.

[2] Genant HK, Engleke K, Fuerst T, Glüer C-C, Gramp S, Harris ST, et al. Noninvasive assessment of bone mineral and structure: state of the art. J Bone Miner Res 1996;11:707–30.

[3] Glüer C-C. Quantitative ultrasound techniques for the assessment of osteoporosis: expert agreement on current status. J Bone Miner Res 1997;12:1280–8.

[4] Duquette J, Lin J, Hoffman A, Houde J, Ahmadi S, Baran D. Correlations among bone mineral density, broadband ultrasound attenuation, mechanical indentation testing, and bone orientation in bovine femoral neck samples. Calcif Tissue Int 1997;60:181–6.

[5] Glüer C-C, Wu CY, Genant HK. Broadband ultrasound attenuation signals depend on trabecular orientation: an in vivo study. Osteoporos Int 1993;3:185–8.

[6] Cvijetić S, Barić IC, Bolanča S, Jureša V, Ožegovic DD. Ultrasound bone measurement in children and adolescents, correlation with nutrition, puberty, anthropometry, and physical activity. J Clin Epidemiol 2003;56:591–7.

[7] Garnero P, Dargent-Molina P, Hans D, Schott AM, Breart G, Meunier PJ, et al. Do markers of bone resorption add to bone mineral density and ultrasonographic heel measurement for the prediction of hip fracture in elderly women? The EPIDOS prospective study. Osteoporos Int 1998;8:563–9.

[8] Vignolo M, Brignone A, Mascagni A, Ravera G, Biascotti B, Aicardi G. Influence of age, sex, and growth variables on phalangeal quantitative ultrasound measures: a study in healthy children and adolescents. Calcif Tissue Int 2003;72:681–8.

[9] Baroncelli GI, Federico G, Bertelloni S, de Terlizzi F, Cadossi R, Saggese G. Bone quality assessment by quantitative ultrasound of proximal phalanges of the hand in healthy subjects aged 3–21 years. Pediatr Res 2001;49:713–8.

[10] Barkmann R, Lüsse S, Stampa B, Sakata S, Heller M, Glüer C. Assessment of the geometry of human finger phalanges using quantitative ultrasound in vivo. Osteoporos Int 2000;11:745–55.

[11] Njeh CF, Richards A, Boivin CM, Hans D, Fuerst T, Genant HV. Factors influencing the speed of sound through the proximal phalanges. J Clin Densitom 1999;2:241–9.

[12] Halaba Z, Pluskiewicz W. The assessment of development of bone mass in children by quantitative ultrasound through the proximal phalanxes of the hand. Ultrasound Med Biol 1997;23:1331–5.
[13] Barkmann R, Rohrschneider W, Vierling M, Tröger J, de Terlizzi F, Cadossi R, et al. German reference data for quantitative transverse transmission ultrasound of finger phalanges. Osteoporos Int 2002; 13:55–61.
[14] Arabi A, Tamim H, Maalouf J, Khalife H, Choucair M, Vieth R, et al. Sex differences in the effect of body-composition variables on bone mass in healthy children and adolescents. Am J Clin Nutr 2004; 80:1428–35.
[15] Young D, Hopper JL, Nowson CA, et al. Determinants of bone mass in 10- to 26-years-old female: a twin study. J Bone Miner Res 1995;10:558–67.
[16] Ilich JZ, Skugor M, Hangartner T, Baoshe A, Matkovic V. Relation of nutrition, body composition and physical activity to skeletal development: a cross-sectional study in preadolescent females. J Am Coll Nutr 1998;17:136–47.
[17] Arabi A, Nabulsi M, Maalouf J, Choucair M, Khalife H, Veith R, et al. Bone mineral density by age, gender, pubertal stages and socioeconomic status in healthy Lebanese children and adolescents. Bone 2004;35:1169–79.
[18] Hamill PVV, Drizd TA, Johnson CL, Red RB, Roche AF, Moore WM. Physical growth: National Center for Health Statistics percentiles. Am J Clin Nutr 1979;32:607–29.
[19] Tanner JM. Physical growth and development. In: Forfar JO, Arnell CC, editors. Textbook of Pediatrics, 2nd ed. Scotland UK: Churchill Livingstone; 1998. p. 249–303.
[20] Salamoun MM, Kizirian A, Tannous R, Nabulsi M, Choucair M, Deeb M, et al. Low calcium and Vitamin D intake in healthy children and adolescents and their correlates. Eur J Clin Nutr 2005; 59:177–84.
[21] Glastre C, Braillon P, David L, Cochat P, Meunier PJ, Delmas PD. Measurement of bone mineral content of the lumbar spine by dual energy X-ray absorptiometry in normal children: correlations with growth parameters. J Clin Endocrinol Metab 1990;70:1330–3.
[22] Faulkner RA, Bailey DA, Drinkwater DT, Mckay HA, Arnold C, Wilkinson AA. Bone densitometry in Canadian children 8–17 years of age. Calcif Tissue Int 1996;59:344–51.
[23] Boot AM, de Ridder MAJ, Pols HA, Krenning EP, de Muinck Keizer-Schrama SMPF. Bone mineral density in children and adolescents: relation to puberty, calcium intake, and physical activity. J Clin Endocrinol Metab 1997;82:57–62.
[24] Seeman E. Sexual dimorphism in skeletal size, density and strength. J Clin Endocrinol Metab 2001;86:4576–84.
[25] McCormick DP, Ponder SW, Fawcett HD, Palmer JL. Spinal bone mineral density in 335 normal and obese children and adolescents: evidence for ethnic and sex differences. J Bone Miner Res 1991;6:507–13.
[26] Johansen A, Stone MD. The effect of ankle oedema on bone ultrasound assessment at the heel. Osteoporos Int 1997;7:44–7.
[27] Lequin MH, van Rijn RR, Robben SG, Hop WC, van Kuijk C. Normal values for tibial quantitative ultrasonometry in Caucasian children and adolescents (aged 6 to 19 years). Calcif Tissue Int 2000;67:101–5.
[28] Gregg EW, Kriska AM, Salamone LM, Wolf RL, Roberts MM, Ferrell RE, et al. Correlates of quantitative ultrasound in the Women's Healthy Lifestyle Project. Osteoporos Int 1999;10:416–24.
[29] Saadi HF, Reed RL, Carter AO, Dunn EV, Qazaq HS, Al-Suhaili AR. Quantitative ultrasound of the calcaneus in Arabian women: relation to anthropometric and lifestyle factors. Maturitas 2003;44:215–23.
[30] Kroke A, Klipstein-Grobusch K, Bergmann MM, Weber K, Boeing H. Influence of body composition on quantitative ultrasound parameters of the os calcis in a population-based sample of pre- and postmenopausal women. Calcif Tissue Int 2000;66:5–10.
[31] Hans D, Schott AM, Arlot ME, Sornay E, Delmas PD, Meunier PJ. Influence of anthropometric parameters on ultrasound measurements of os calcis. Osteoporos Int 1995;5:371–6.
[32] Schoenau E, Frost HM. The "muscle bone unit" in children and adolescents. Calcif Tissue Int 2002;70:405–7.
[33] Njeh CF, Hans D, Fuerst T, Gluer CC, Genant HK. Quantitative Ultrasound: Assessment of Osteoporosis and Bone Status. London UK: Martin Duniz Ltd; 1999.