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Quantitative Ultrasound at the Hand Phalanges in Adolescent Girls is Related to Their Overall Physical Fitness

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A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation; D – writing the article; E – critical revision of the article; F – final approval of article

Abstract

Background. Growing of the skeleton, depends on genetic, health, nutritional and environmental influences.

Objectives. The aim of the study was to assess the ultrasound properties of bone measured at hand phalanges in adolescent girls regarding the influence of pubertal status and level of physical fitness.

Material and Methods. The study group was 56 adolescent girls aged 12–14 yrs, the controls were 86 girls matched for age, recruited from 1256 subjects undergoing bone measurement for screening purposes. The skeletal status (amplitude-dependent speed of sound – Ad-SoS) was assessed by quantitative ultrasound (QUS) at proximal phalanges using DBM Sonic 1200. Physical fitness was assessed by the Zuchora index and pubertal development by the Tanner scale.

Results. The adolescent girls from our study group had greater body weight, height, BMI and Ad-SoS values than the controls. Overall physical fitness was highest in girls with the lowest BMI and lowest in girls with the highest BMI values. The highest results of the Ad-SoS were reported in girls presenting highest level of physical fitness. They were statistically significantly higher than in girls with a minimal level of physical fitness. There was a statistically significant correlation between the overall physical fitness score and Ad-SoS results. No correlations between Ad-SoS and the Tanner scale, particular the elements of physical fitness (speed, jumping ability, flexibility, shoulder muscular strength, abdominal muscle strength) and BMI were shown.

Conclusions. The bone properties assessed by QUS at the hand phalanges in adolescent girls aged 12–14 years depend on their overall physical fitness. Pubertal development, body size and particular elements of physical fitness, especially shoulder muscular strength, have limited influence (*Adv Clin Exp Med* 2016, 25, 2, 279–284).

Key words: adolescence, bone, physical fitness, quantitative ultrasound.

The morphological development of the human body, especially the growing of the skeleton, depends on genetic and health factors, nutrition and environment. Most dynamic skeletal gain occurs within 13–16 years in girls, and 16–18 years in boys, respectively. Bone size and mass are correlated with body size, body mass index (BMI), waist and abdomen circumferences, and depend on physical activity, nutrition and muscle strength [1, 2]. The occurrence of puberty at the proper time and nor-

mal growth hormone and thyroid hormone secretion influence bone mass and mineralization. On the other hand, in the time of puberty, the physical activity of girls typically decreases, which can negatively influence bone mass. Various diseases can result in lower bone mass and size [3–6]. Worsened mechanical properties of bones were found, using ultrasound, in children and adolescents suffering from different diseases such as diabetes mellitus, chronic renal failure or leukemia survivors [7–9].

Ultrasound assessment of the mechanical properties of bones using portable devices is non-invasive, safe and easily available. Phalangeal quantitative ultrasound (QUS) measurement has been validated in various clinical studies [10–13]. This technique, by measuring the amplitude-dependent speed of sound (Ad-SoS), may provide useful information on bone mass but also on bone tissue architecture and elasticity. Ultrasound measurements are able to detect bone growth and ageing, and moreover, to assess the fracture risk in various metabolic bone diseases [13–15]. There are differences among studied populations, and no available data on the ultrasound measurements of phalangeal bones in healthy female adolescents of the Lower Silesia region exists. There are the studies carried out in other populations [16, 17]. Assessments of QUS and physical fitness in children are extremely rare. The only known studies have shown a negative correlation between moderate physical activity and QUS results of the tibia and radius in younger girls, aged 9–13 years, and in Polish boys aged 13–15 years [18, 19].

The aim of our study was the ultrasound assessment of bone measured at the hand phalanges in adolescent girls (secondary school) regarding BMI, the influence of pubertal status and the level of physical fitness including muscular strength.

Material and Methods

Subjects

The study was carried out with 56 adolescent girls, aged 12.25–14.2 years, mean age 13.1 ± 0.5 years (156.9 ± 6.6 months), the pupils of classes 1 and 2 of a secondary school in a small city of the Lower Silesia region (Chocianów). The current study was a part of the school children's in-

terdisciplinary studies “The Year of Health” program, our similar study concerning schoolboys was published previously [19]. The subjects studied were divided by school class level into two groups: group I (attending class 1, $n = 36$) and group II (attending class 2, $n = 20$). All of them were healthy, without any chronic medication or diseases. The control group was 86 girls matched for age. The controls were recruited from a group of 1256 subjects undergoing bone measurement for screening purposes in the Metabolic Bone Diseases Unit, Zabrze, Poland. The general anthropometric characteristics of the subjects studied are presented in Table 1.

All subjects (patients and controls) were interviewed by a physician using a special questionnaire in order to collect data on pubertal and general health status, congenital diseases and fracture occurrences among family members. Subjects with factors of potential influence on bone metabolism (either prolonged diseases of the thyroid gland, liver or kidneys, gastrointestinal surgery or medications using corticosteroids, anticonvulsants, thyroid hormone etc. or being treated with any drugs affecting bones) were not included (in the study group or controls). The parents gave written consent for the participation of their children in the study. The Local Ethics Committee gave approval for the study protocol.

Methods

Anthropometric Measurements

In all subjects, body weight, height and body mass index (BMI) (as weight in kg divided by height squared (kg/m^2)) were established. Information concerning hand dominance was obtained from all of the subjects, and all of them were right-handed.

Table 1. General anthropometric characteristics of subjects and controls, together with the results of phalangeal Ad-SoS at dominant hand (data presented as mean \pm SD)

	Study group $n = 56$	Control group $n = 86$	p-value
Age [months]	156.93 ± 6.55	158.84 ± 6.33	0.08
Height [cm]	160.67 ± 6.59	156.63 ± 7.38	0.002
Body mass [kg]	52.53 ± 11.70	45.46 ± 8.67	0.0001
BMI [kg/m^2]	20.36 ± 3.70	18.42 ± 2.74	0.001
Ad-SoS [m/s]	2046.84 ± 43.09	2002.31 ± 53.08	0.0000001

BMI – body mass index; Ad-SoS – amplitude-dependent speed of sound.

QUS Measurement

The skeletal status was assessed by QUS measurements at the proximal phalanges with the use of the DBM Sonic 1200 device (IGEA, Carpi, Italy). The unit consists of two probes mounted on an electronic caliper, one emitter and another receiver. The latter records the ultrasound energy after it has crossed the phalanx. The amplitude-dependent speed of sound (Ad-SoS, in m/s) was determined in the distal metaphyses of the proximal phalanges in the second through fifth fingers of the hand. The SoS in bone tissue was calculated with the first signal with an amplitude of at least 2 mV at the receiving probe; thus, the measured SoS is amplitude-dependent. Acoustic coupling was achieved with standard ultrasound gel. All measurements (in the study and control groups) were carried out by one experienced operator (WP). The precision of QUS measurements, expressed as a variation coefficient (CV%) was 0.64%. CV% was established on the basis of 75 bone scans with repositioning of the device caliper (5 measurements in each subject). The detailed methodology was described by Pluskiewicz and Drozdowska [20].

Physical Activity Questionnaire

The study employed a questionnaire to assess the physical activity of the girls. The overall physical fitness was determined using the Zuchora Index of Physical Fitness. The test consisted of 6 trials to establish an overall physical fitness (speed, jumping ability, flexibility, shoulder muscular strength, abdominal muscle strength and endurance) defined on a scale 1–6 (minimum – excellent). This test is standardized regarding age, and the calculations of the results are age- and height-dependent [21].

Pubertal Development Assessment

Pubertal status was based on the Tanner scale, which is assessed on genital (G1–G5) and pubic hair (P1–P5) stages (1 – no development and 5 – the highest level of pubertal development) [22]. The occurrence and regularity of menses as breast development were analyzed. It was self-reported by girls and ascertained by an assisting physician.

Statistical Analysis

All statistical analyses were carried out using the STATISTICA 10 program. The analyzed data was presented as mean values and standard deviations (SD). Differences between the groups stud-

ied were assessed using Student's *t*-test for independent samples (for normally distributed data) or the Mann-Whitney *U* test (for non-normally distributed data). The correlations between the variables analyzed were calculated according to Spearman's or Pearson's tests, as appropriate. All results were considered statistically significant at $p < 0.05$.

Results

Despite being the same age, the adolescent girls from our study group (from Chocianów, in Lower Silesia) had greater body weight, height and BMI values than the controls from Upper Silesia. Their mean Ad-SoS results were also higher than in the control group (Table 1). There were no differences in Ad-SoS between the younger and older group, and scans of the dominant and non-dominant hands. Since there were no statistically significant differences in the anthropometric parameters, Ad-SoS, or physical activity scores between groups I and II from our subjects, they were presented and analyzed as an entire group. The only difference between groups I and II was observed in pubertal development, as assessed by the Tanner scale (4.18 ± 0.87 vs. 4.83 ± 0.5 ; $p < 0.01$). In the younger group (class I), 86% of girls reported menarche; in the older group (class II) 100% of girls had had menses.

The overall physical fitness in the girls was determined using the Zuchora Index of Physical Fitness. The mean value of general physical fitness was 3.04 ± 0.94 . It was highest in girls with the lowest BMI and lowest in girls with the highest BMI values.

Table 2. Correlations between Ad-SoS and Tanner scale, physical fitness and BMI in adolescent girls

	Correlation coefficient	Statistical significance
Tanner scale	0.15	ns.
Overall physical fitness	0.32	$p < 0.05$
Speed	0.16	ns.
Jumping ability	0.14	ns.
Shoulder muscular strength	0.21	ns.
Flexibility	0.23	ns.
Abdominal muscle strength	0.15	ns.
BMI	-0.21	ns.

BMI – body mass index.

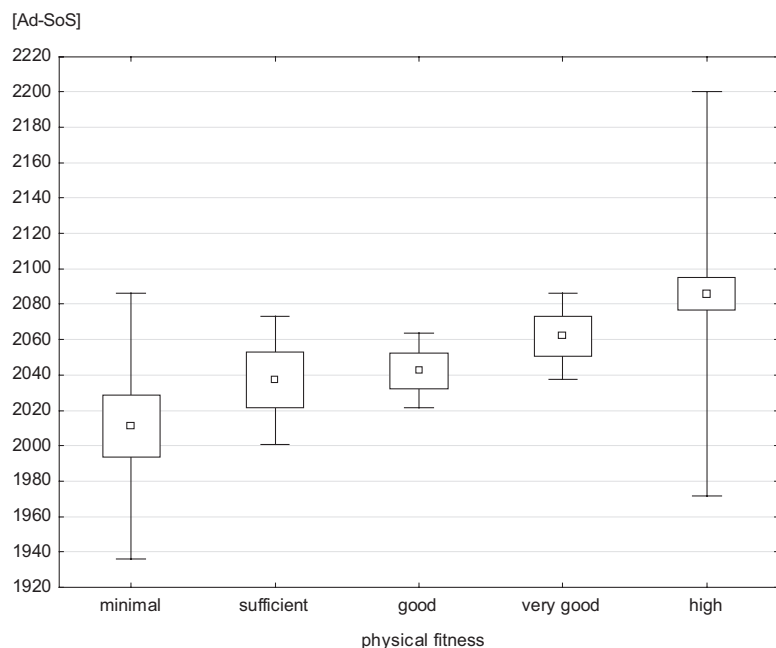


Fig. 1. Results of Ad-SoS at hand phalanges in adolescent girls regarding their overall physical fitness

Similarly, the highest results of Ad-SoS were reported in girls presenting the highest level of physical fitness. They were statistically significantly higher than in girls with the minimal level of physical fitness ($p < 0.05$) (Fig. 1).

There was a statistically significant correlation between the overall physical fitness score and Ad-SoS results in the adolescent girls from our study. No correlations between Ad-SoS and the Tanner scale, particular elements of physical fitness (speed, jumping ability, flexibility, shoulder muscular strength and abdominal muscle strength) and BMI were shown (Table 2).

Discussion

This cross-sectional study was carried out in adolescents schoolgirls from a certain city in Lower Silesia to assess the ultrasound properties of bone measured at hand phalanges regarding the influence of body size, pubertal status, level of physical fitness and muscular strength. The subjects originated from the city of Chocianów (8000 inhabitants) located on the border of an area of copper industries (copperworks and mines). Our previous study, performed on adolescent boys from the same school, revealed that the QUS at hand phalanges depended on pubertal development and shoulder muscle strength. The overall physical fitness in the boys had limited influence on their bone properties assessed by QUS. Moreover, in the boys there were no differences in Ad-SoS between the groups compared [19].

In the current study, the adolescent girls from our group had higher Ad-SoS results and greater

body weight, height and BMI values than the controls from the Upper Silesia region. This could be caused by the better economic conditions of the population living in this industrialized region. Moreover, the school in Chocianów participated in European programs on healthy nutrition, which could be another important factor [19]. It is well known that environmental factors, poor nutrition and diseases can worsen bone status [6–8]. There were no differences in Ad-SoS between the younger and older group, or scans of the dominant and non-dominant hands. The most interesting observation was that the highest Ad-SoS result in girls presented the highest level of physical fitness, and they also had the lowest BMI. This suggests the influence of physical fitness but not BMI on the QUS properties of phalangeal bones in adolescent schoolgirls. Similarly, a negative tendency in the relation of BMI and Ad-SoS was observed in adolescent boys from our previous study [19].

Moreover, the differences in body size between both boys and girls from the two neighboring regions of one country are very intriguing and require dedicated studies. Possible hereditary, environmental, economic and nutritional factors should be carefully analyzed.

The greatest mineralization of the skeleton has been reported in girls aged 13–16 yrs; in boys it occurs at a later time. This is influenced by a number of factors like body mass, sexual development, physical fitness and environmental factors [2, 5, 6, 18]. The impact of the place of residence could influence physical development, since the girls from our study group had generally higher weight, height and BMI than the controls. These anthropometric factors could be responsible for the bet-

ter bone status assessed by QUS. There was no correlation between Ad-SoS and BMI or body mass in the girls from our study, contrary to other studies [4–6]. Physical fitness could influence Ad-SoS in our group, since a statistically significant positive correlation between them was shown. An increase of both hip and spine bone mineral density was reported by Weeks et al. following 8-months' training in 13-year-old girls [23].

Our subjects' bone status was analyzed within their age 12–14 years, reflecting an early phase of skeletal growth and mineralization. Further Ad-SoS increase is possible in the future, which was shown in adolescent girls and boys from Up-

per Silesia [16, 17] and other populations [3–5, 24, 25]. The positive influence of age on Ad-SoS is important in achieving peak bone mass, which is crucial for skeletal fragility and fracture risk in older age [19, 24]. The influence of overall physical fitness on phalangeal Ad-SoS is important in light of the positive role of exercise in the prevention and management of osteoporosis [26, 27].

The bone properties assessed by QUS at the hand phalanges in adolescent girls aged 12–14 years depend on overall physical fitness. Pubertal development, body size and particular elements of physical fitness, especially shoulder muscular strength, have limited influence.

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