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Abstract To establish the reference values for quantitative ultrasound (QUS) indices (speed of sound [SOS]), and broadband ultrasonic attenuation [BUA]) in healthy Japanese adolescents, and to evaluate the effects of age and body size on QUS in comparison with their effects on bone mineral density (BMD), 632 healthy adolescents aged 12 through 17 years recruited from a larger cohort study (Japanese Population-based Osteoporosis [JPOS] Study), were examined in terms of bone mass measurements by QUS at the calcaneus (Sahara; Hologic) and by dual-energy X-ray absorptiometry at the distal one-third radius and ultradistal forearm. We present sex- and age-specific mean values of the QUS and BMD indices. BMD increased significantly up to 17 years of age in males and up to 16 years in females. However, the age-related change in the QUS indices in males was not as clear as that seen for BMD and no age-related change in the QUS indices was observed in females. Significant positive correlation coefficients between BMD and body size were observed in both sexes even after adjusting for the effect of age. SOS showed no correlation with body size and BUA showed a positive but weak correlation with body size in both sexes. Thus, the relationships of age and body size to BMD and QUS were different from each other, even though the QUS indices had significant positive correlations with BMD, allowing for the effect of age.

Key words quantitative ultrasound · Sahara · Japanese adolescents · sex · body size

Introduction

Osteoporosis is one of the major public health problems worldwide. Many preventive activities against this involutional disease have been introduced and performed to reduce postmenopausal bone loss. However, making peak bone mass (PBM) as great as possible has recently been recognized to be a more important issue for the prevention of osteoporosis later in life [1]. The PBM was suggested to be achieved during adolescence through early adulthood [2]. However, it is not known precisely whether the age at the PBM varies depending on the skeletal sites or on methods of bone mass measurements. It is important, therefore, to clarify the pattern of bone acquisition during adolescence at different skeletal sites evaluated by different techniques, and to clarify the determinants of the PBM.

Dual-energy X-ray absorptiometry (DXA) is a standard technique for bone mass measurement and has been used in many studies examining bone status of children and adolescents. Recently, quantitative ultrasound (QUS) has become a promising technique for bone assessment [3]. Several studies have demonstrated that QUS has a predictive power for hip fracture similar to that of bone mineral density (BMD) at the femoral neck [4–6]. Methodologically, QUS has some advantages over DXA, especially for children; that is, no radiation exposure and shorter scanning time. Furthermore, because BMD derived from DXA is not volumetric but areal, this index may overestimate the actual BMD gain during skeletal growth in adolescents. QUS may be a more appropriate technique to evaluate bone mass in growing children. However, reference values for QUS parameters of healthy Japanese children and adolescents remain to be clarified. There have been some studies on the QUS of Japanese, in which the QUS machines, used were predominarily Achilles [7] or Cuba Clinical [8]. There have been no studies reported for a relatively new device, Sahara (Hologic Waltham, MA, USA).

The purposes of the present study were: (1) to establish the reference values of the QUS indices of Sahara in healthy Japanese adolescents, and (2) to evaluate the effects of major determinants of bone mass (that is, age, weight, and height) on QUS indices in comparison with their effects on BMD, measured by DXA.
Subjects and methods

Subjects

The present study was conducted as the adolescent part of the second-wave survey of a larger cohort study (JPOS Study) [9], and involved three cohorts, in the northeastern part of the main island of Honshu (Nishiaizu Town, Fukushima Prefecture), Shikoku (Sangawa Town, Kagawa prefecture), and the southwestern islands (Hirara city, Okinawa Prefecture). We recruited healthy adolescents aged 12 through 17 years from the cohorts set up at baseline. The number of adolescents who participated in the present study was 665. Subjects with a history or apparent present involvement of any disease affecting bone metabolism and those who were administered drugs affecting bone turnover were excluded. Consequently, 632 adolescents served as the subgroup of Japanese adolescents free from apparent abnormalities affecting bone mass. We obtained written informed consent for all the study procedures from each subject in advance.

Bone mass measurement

We measured the ultrasound characteristics of the heel bone, using an ultrasound bone densitometer (Sahara, Hologic). This apparatus yields speed of sound (SOS) and broadband ultrasound attenuation (BUA) during transmission through the calcaneus between transducers attached on both sides of the heel with coupling gel. The heel width was automatically measured at the same time. The measurement was principally performed on the right foot. When the subjects had a history of fractures or any bone disease in the right foot, the left heel was measured. We examined the subjects after at least 30 min rest in the test room, where the temperature was maintained at 25±1°C. The precision of the machine in vivo (expressed as the coefficient of variation; CV) was 0.3% for SOS and 5.0% for BUA from five daily measurements on five different individuals. BMD was measured on the same day by DXA at the distal one-third site of the radius and the ultradistal site of the forearm (pDXA; Norland, Fort Atkinson, IA, USA/Stratec, Pforzheim, Germany). The short-term CVs of the BMD measurement in vivo, calculated from five measurements on different days for each of five volunteers, were 1.2% and 1.4% for the distal one-third site of the radius and ultradistal forearm, respectively [10]. No significant change in the values of the QUS indices of a calcaneus phantom or in the BMD value of the forearm phantom was seen during the study period.

Body size measurement

Height (cm) and weight (kg) of the subjects were measured with an automatic scale (Body measure 2; Takei Kagaku, Tokyo, Japan). Body mass index (BMI in kg/m²) was calculated as weight (kg) divided by height (m) squared.

Interviews

Detailed interviews were performed by trained nurses according to a questionnaire which was delivered to and was completed by the subject beforehand. The questionnaire included past history of diseases or medications which may affect bone metabolism.

Statistical data analysis

The values for all the indices were expressed as means and SD. All statistical analyses were performed using the SAS system for personal computers (Release 6.12; SAS Institute, Cary, NC, USA).

Results

Basic characteristics of the subjects

Table 1 shows body size indices of the subjects with each year of age. Height and weight increased significantly with increasing age up to age 16 or 17 years in the male and female subjects. Significant differences in height and weight between neighboring age groups were seen up to 14 years of age in the male subjects.

There was no significant difference in any index among the three geographical study areas in any age group. No significant difference was observed either in height or weight between the present subjects and a representative sample of the Japanese adolescent population obtained from the National Nutrition Survey [11].

Age and sex-specific QUS and BMD values

Table 2 shows age and sex-specific mean QUS values and BMD at the distal one-third site of the radius and the ultradistal forearm. BMD increased up to 17 years of age in males and up to 16 years in females. However, age-related change in the QUS indices was not as clear as that seen for BMD in males, and no age-related change in the QUS indices was observed in females. The correlation coefficients between age and QUS indices were significant in males but not in females. There was no significant difference in the mean values of BMD or the QUS indices among the three study areas in any age group.