Original Article

Radiographic Absorptiometry of the Middle Phalanx (Digit II) in a Caucasian Pediatric Population: Normative Data

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Abstract. The availability of improved therapies for children with diseases affecting bone growth and/or metabolism has caused increased interest in bone mineral density (BMD) assessment. The purpose of this study was to determine normal values for phalangeal radiographic absorptiometry (RA) in a Caucasian pediatric population. Five hundred and seventy-two healthy Caucasian children and adolescents (aged 5–19 years) were enrolled in this study. For RA one posteroanterior exposure of the left hand and one lateral exposure of the left index finger were taken. All films were analyzed, yielding BMD (mg Al/mm²) values for two phalangeal sites: one at the proximal quarter of the phalangeal length (BMD25%) and the second at the midpoint of the phalangeal length (BMD50%). Also skeletal age (SA) was assessed, as data normalized for SA can be used in populations which show a dissociation between SA and calendar age. We found that the BMD25% was significantly higher in girls than in boys for the SA group 11–14 years. The BMD50% was significantly higher in girls than in boys for the SA group 11–15 years. Our data show that BMD25% remains fairly constant until the SA of 12.0 years in boys and 10.1 years in girls; after these skeletal ages BMD shows a sharp increase. The same applies to BMD50%, which remains fairly constant until the SA of 12.4 years in boys and 10.7 years in girls. In this paper we present normative data for RA in a pediatric population. These data normalized for skeletal age could be implemented in a clinical setting.

Keywords: Absorptiometry; Adolescent; Hand; Infant; Radiography

Introduction

Noninvasive methods for bone mineral density (BMD) assessment are currently used in an adult population in a wide variety of clinical settings. In the pediatric population there are two main indications to measure BMD. The first is to assess the loss of bone mineral as a result of various diseases or therapies for diseases that cause osteopenia [1,2]. In children there are several causes for a low BMD, either biological or iatrogenic as a result of medication. A second indication is to enhance the knowledge on the attainment of peak bone mass, which is considered to be an important risk factor for the future risk of osteoporosis [3,4].

In children bone densitometry has several problems. One very important one is the way the three-dimensional growth of the skeleton affects two-dimensional measurements. This makes the interpretation of two-dimensional techniques, such as single-energy X-ray absorptiometry (SXA) or dual-energy X-ray absorptiometry (DXA), extremely difficult. With these techniques it is virtually impossible to distinguish between the effects of bone growth and true bone density changes [5]. Furthermore, there are several recent publications which suggest that a change in the fat–lean body mass distribution, which
inevitably occurs during growth, dramatically influences DXA measures [6–8]. In light of these publications the use of DXA might not be as suitable in a pediatric population as it is in an adult population.

Another technique used for assessing BMD is quantitative computed tomography (QCT) [9]. This technique measures true volumetric BMD independently of surrounding soft tissue. As such QCT would in theory be suitable to distinguish between growth and actual bone density changes [5]. However, QCT carries a relatively high level of radiation exposure – although exposure is still low compared with conventional radiographs of the axial skeleton, such as those of the thoracic or lumbar spine [1]. The relative inability of children to remain immobile for a prolonged period is another drawback for the implementation of QCT. We currently perform CT in small children, below the age of 5–6 years, under general anesthesia. Although this is considered ethically acceptable for clinical indications, it is the accepted consensus in The Netherlands that this is unethical for the sole assessment of BMD.

The oldest technique in the field of bone densitometry, with publications dating back to the 1930s, is radiographic absorptiometry (RA) [10–12]. In RA bone density is assessed on conventional radiographs, mostly those of the hand. To correct for the influences of different films, exposure times, voltage settings and film processing an aluminum wedge is placed within the field of view. Several studies have shown that RA is as good at predicting fracture risk in postmenopausal women as DXA or quantitative ultrasound [13–15].

In all children with a disease influencing bone growth and/or metabolism it is common practice to obtain a radiograph of the hand. This is done to assess skeletal age (SA), an important indicator of bone maturation. The addition of the aluminum calibration wedge on the film is only a minor effort which then facilitates RA. Therefore, we propose the use of RA as a relatively cheap and easy procedure to assess BMD in a pediatric population [16,17].

Calendar age (CA) may not be indicative of biological development, especially in children whose disease affects bone maturation and/or metabolism and who consequently show a dissociation between SA and CA [18,19]. We therefore advocate the use of BMD data normalized for SA. In this paper we present the normative data from RA of the middle phalanx of the left index finger, acquired in a healthy Caucasian pediatric population aged 5–19 years.

Materials and Methods

Study Subjects

Participants were recruited by advertisement, in the urban region of Rotterdam, The Netherlands. All were asked to complete a short questionnaire, relating to hand dominance, date of birth, sex and race. Furthermore, the questionnaire contained questions related to chronic illness, medication or diet affecting bone growth and/or metabolism. A history of previous fractures and their causes was taken.

After the application of exclusion criteria, 16 children were excluded from the study because of chronic or current diseases (1 exostosis, 1 acute vascular purpura, 2 epilepsy and 12 cases of chronic respiratory disease). The exclusion criteria contained known causes of bone metabolism and/or development disorders such as chronic disease, renal failure, hormone deficiency, prolonged immobilization, corticosteroid medication and hormonal supplementation. In total 572 children and adolescents (278 boys, median age 12.8 ± 3.6 years (range 5.0–19.5 years) and 294 girls (median age 12.6 ± 3.8 years (range 5.2–19.9 years) were included in the study. Informed consent was obtained explicitly from parents or guardians and, if appropriate, the child (in The Netherlands this is mandatory in children aged 12 years and over). The study was performed according to recommended guidelines (Declaration of Helsinki, Hong Kong 1989) and the guidelines of the Internal Review Board of the University Hospital Rotterdam and the Erasmus University Rotterdam, Faculty of Medicine and Health Sciences, The Netherlands.

One hundred and eight children had a history of fractures. All these fractures were typical for a pediatric population and related to minor accidents such as falling form bicycles or trees and sport traumas.

Tanner stages were evaluated through self-assessment. The use of self-assessment has previously been validated by Duke et al. [20]. Subjects were shown pictures and written information pertaining to breast and pubic hair development for girls and genitalia and pubic hair development for boys. They were asked to select the one that had the closest resemblance to their own status. In case of discrepancies between variables, emphasis was placed on breast development in girls and genital development in boys [20,21]. Girls were asked whether or not menarche had taken place, and if so at what age. We also asked the girls whether they had ever gone 6 months or more without menstruating.

Height was measured, without shoes, using a wall-mounted ruler [22]. Weight was measured, without shoes, on an electronic weight scale. Body mass index (BMI), as an indicator of nutritional status, was calculated as the ratio of weight to height² (kg/m²).

Radiography

Standardized radiographs of the left hand, one postero-anterior (PA) and second a lateral of the left index finger (LAT) were taken, on a single film using a dedicated cassette (Fig. 1) (Philips Diagnost H, Imation GTU film, x-II Trimax intensifying screens, small 0.6 mm focus, film–focus distance 1.5 m, 45 kV, 16 mAs). To assess SA all radiographs were scored in quartiles by two trained investigators (R.v.R., M.L.) according to the Greulich and Pyle hand atlas [23].