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Original Article

Correlation Between Central and Peripheral Bone Mineral Density Around the Elbow Measured by Dual-Energy X-Ray Absorptiometry in Healthy Children and Adolescents

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Abstract

This pilot study was performed to evaluate the correlation between central bone mineral density (BMD) and peripheral BMD around the elbow in children and adolescents and to compare BMD values across skeletal sites. Twenty-seven healthy volunteers between 5 and 18 yr of age were recruited for the study. Anthropometric measurements including height and weight were performed. Central BMD at the lumbar spine and left femur and peripheral BMD at the supracondylar area, medial condyle, lateral condyle, and olecranon were measured using dual-energy X-ray absorptiometry (DXA). Higher BMD levels were found in the central skeleton (lumbar spine and femur) than in peripheral sites around the elbow ($p < 0.001$). BMD values around the elbow ranged from 44.4% to 63.2% compared to the BMD values of the central skeleton. Among the peripheral sites around the elbow, the highest BMD was observed at the supracondylar area and olecranon, and the lowest BMD was found at the lateral condyle. Peripheral DXA measurements around the elbow were significantly correlated with central DXA measurements at the lumbar spine and femur. In conclusion, this study demonstrated that the measurements of BMD around the elbow were correlated with BMD at central sites. Given the small sample size in this pilot study, further study with a large cohort is required to use the BMD measurements around the elbow as a valid clinical tool for fracture risk assessment and population-based epidemiological studies.

Key Words: Bone mineral density; children and adolescents; dual-energy X-ray absorptiometry; elbow.

Introduction

Peak bone mass attained during childhood and adolescence is an important factor for determining the risk of osteoporosis in adult life *(1)*. Children with certain conditions including osteogenesis imperfecta, prolonged immobilization, pubertal delay, and endocrine disease and those who have received glucocorticoid or anticonvulsant medication are at greater risk of developing osteoporosis *(2)*. Therefore, early detection of low bone mass in these children can lead to early and appropriate intervention.

Dual-energy X-ray absorptiometry (DXA) is the preferred method for assessing bone mineral status in children due to its rapidity, low radiation dose, and high precision and accuracy *(3)*. Because the measurement of bone mineral density (BMD) is limited to the central skeleton, peripheral BMD has not been screened. Recently, the assessment of peripheral BMD has grown in importance, as peripheral bone fracture can have features of osteoporotic fracture *(4)*. Peripheral DXA provides a quick, easy,

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and convenient method for assessing BMD in young subjects. Peripheral BMD at the forearm and calcaneus has been shown to correlate well with central BMD measurements and to predict fracture risk in children *(5)*.

Increasing data suggest that children with a low BMD have an increased risk of fracture, as do adults with osteoporosis *(6–8)*. Supracondylar fracture of the distal humerus is one of the most common fractures in children and is seen most frequently between the ages of 3 and 10 yr *(9)*. The standard treatment for a displaced supracondylar fracture is closed reduction and internal fixation using percutaneous pinning. The thinner bone of the supracondylar area, both in the lateral and medial ridges and in the central coronoid and olecranon fossa, combine to produce a structurally weaker area of the distal humerus. When forced into hyperextension, the olecranon can act as a fulcrum through which an extension force can propagate a fracture across the medial and lateral columns *(10)*. Thus, we hypothesized that the supracondylar area of the distal humerus in children may have lower BMD than other areas around the elbow. However, there has been no study regarding peripheral BMD around the elbow joint in children and adolescents. In addition, there is little information available on the relationship between peripheral DXA and central DXA in children and adolescents *(5,11)*.

Therefore, we performed the current pilot study to evaluate the correlation between central and peripheral BMDs around the elbow in children and adolescents and to compare BMD values across skeletal sites.

Materials and Methods

The present prospective pilot study was approved by our institutional review board (IRB protocol number: B-1504/293-003). Informed consent was obtained from all participants or their legal guardians.

Subjects

Healthy volunteers between 5 and 18 yr of age were recruited for the study. All the participants were of Korean ethnicity. The subjects were excluded by interview and a physical examination if they had any of the following: (1) history of a chronic disease that affects bone growth and metabolism; (2) prior history of medication affecting bone growth and metabolism, such as corticosteroids, thyroid hormones, and anticonvulsants; (3) history of 2 or more recurrent fractures; and (4) history and physical findings of endocrine diseases, including precocious puberty.

Anthropometric and DXA Measurements

Anthropometric measurements were performed immediately before DXA. Height and weight were measured without shoes using an automatic weight- and height-measuring machine (Kiker plus; G-Tech International Co., Ltd., Seoul, Korea). Body mass index (BMI) was calculated by dividing the weight (in kilogram) by height squared (kilogram per square meter).

Central and peripheral BMDs were measured using a Lunar Prodigy DXA bone densitometer (GE Lunar Corporation, Madison, WI). All scans were performed with the child in a supine position and without sedation. The same technician collected all measurements according to the manufacturer's standards, including the positioning of each region of interest. The instrument automatically selected the scan mode (standard, thick, or thin) according to the subject's height or weight. The central BMD was measured at the anteroposterior lumbar spine (L1–L4) and the left femur (femoral neck, trochanter, shaft, and total proximal femur). The peripheral BMD was measured at 4 areas around the left elbow: supracondylar area, medial condyle, lateral condyle, and olecranon. Each region of interest around the elbow was defined as a circular area of 0.29 cm^2 and placed in cancellous bone without violating the olecranon fossa. Quality control was carried out daily using a phantom according to the manufacturer's instructions and the mean coefficient of variation was 0.33% during the study period. All BMD measurements (gram per square centimeter) were collected by a research assistant who did not otherwise participate in the present study.

Sample Size Estimation and Statistical Analysis

Prior sample size estimation was performed for the current pilot study. When we assumed a correlation coefficient of 0.5 between central BMD and elbow BMD, the sample size was calculated to be 26 subjects (α-error 0.05, β-error 0.8). The normality of each variable was tested using the Kolmogorov–Smirnov test. Partial correlation was used to determine the relationship between the central and peripheral BMDs while controlling for the effect of sex and BMI. Repeated-measures analysis of variance was used to analyze the differences between peripheral and central BMDs. Statistical analyses were conducted using SPSS software for Windows (Version 22.0; SPSS, Chicago, IL), and null hypotheses of no difference were rejected if p values were <0.05.

Results

Twenty-seven volunteers were recruited for the present study. Seventeen volunteers were male, and 10 were female. The mean age of volunteers was 11.6 ± 5.5 yr, and the mean BMI was 20.1 ± 0.75 kg/m^2 (Table 1).

BMD levels were higher in the central skeleton (lumbar spine and femur) than in peripheral sites around the elbow ($p < 0.001$). BMD values around the elbow ranged from 44.4% to 63.2% of the BMD values of the central skeleton. Among the peripheral sites around the elbow, the highest BMD was observed at the supracondylar area and olecranon, and the lowest BMD was found at the lateral condyle. The mean BMD value of the supracondylar area (0.55 ± 0.15 g/cm^2) was 37.5% higher than that of the lateral condyle (0.40 ± 0.13 g/cm^2; $p < 0.001$) and 12.2% higher than that of the medial condyle (0.49 ± 0.15 g/cm^2; $p < 0.001$; Fig. 1).

All peripheral DXA measurements around the elbow were significantly correlated with central DXA