Title: Broadband ultrasonic attenuation of children and young adults in Japan

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BROADBAND ULTRASONIC ATTENUATION OF CHILDREN AND YOUNG ADULTS IN JAPAN

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Abstract

The purpose of this study was to establish broadband ultrasonic attenuation (BUA: dB/MHz) as bone mineral density (BMD) norms for healthy young Japanese and to evaluate the standard values for an ultrasonic bone analyzer (Cuba Clinical, McCue Ultrasonics Ltd., Winchester, England), which facilitates BMD measurement without exposure to radiation. The subjects were 472 healthy young individuals with no endocrine or skeletal disorders, 197 males (mean age 16y 5m) and 275 females (mean age 15y 7m) aged from 5 to 29 years. BUA was measured at the left calcaneus. The subjects were divided into five age-stratified different age groups of five years intervals. The mean BUA values (dB/MHz) obtained were 40.6, 60.9, 78.0, 90.4 and 86.0 for males, and 41.9, 61.0, 73.4, 68.4 and 70.8 for females in the 5–9, 10–14, 15–19, 20–24 and 25–29 age groups, respectively. A significant positive correlation was observed between BUA and age in both males and females except in the male 25–29 age group and the female 20–24 and 25–29 age groups. A significantly different BUA between males and females was found in the 20–24 and 25–29 age groups (p<0.001). The BUA values obtained in this study may serve as BMD norms for children and young adults. It might be thought that measuring BUA from childhood through early adulthood made it possible to determine peak values and peak periods of BMD, providing useful information for assessment of growth and development.

Key words: Broadband ultrasonic attenuation—Ultrasonic bone analyzer—Bone mineral density—Young Japanese—Calcaneus

INTRODUCTION

Broadband ultrasonic attenuation (BUA: dB/MHz) measured as an indicator of bone mineral density (BMD) with ultrasonic bone analyzer is free of exposure to radiation and simple and easy to use, thus it is being widely used in Japan. The measurement of BUA has...
been shown to have high precision and to relate well to dual energy x-ray absorptiometry (DXA) measurements\(^5,9,12\). Two measurement methods are currently available, a wet process with water and a dry method with gel as a medium for close contact between the subject and ultrasonic source\(^1\). Many reports on the wet method have been published, but there are fewer studies of the dry method, which has become commercially available more recently. No standard values have been established for the dry method in children or young adults\(^2,10,12\). This study was conducted to measure BUA using an ultrasonic bone analyzer (Cuba Clinical, Macue Ultrasonics Ltd., Winchester, England) for the purpose of obtaining normal values for children and young adults in Japan.

### SUBJECTS AND METHODS

The study included 472 healthy young individuals without any endocrine or skeletal disorders, 197 males (mean age 16y 5m) and 275 females (mean age 16y 7m) aged 5 to 29 years (Table 1).

BUA was measured in the left calcaneus using the ultrasonic bone analyzer. The precision was studied by performing five repeated scans on each subject. It was 0.8% expressed as the percentage coefficient of variation. The subjects were divided into five age groups by every 5 years (5–9, 10–14, 15–19, 20–24 and 25–29 years old) and by gender to evaluate the results. Two transducers faced with silicone rubber coupling pads were mounted on the footplate. The subject’s foot with applied

### Table 1 Distribution of subjects by age and gender

<table>
<thead>
<tr>
<th>Age</th>
<th>Number</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>5~9</td>
<td>38</td>
<td>110</td>
<td>11</td>
</tr>
<tr>
<td>10~14</td>
<td>53</td>
<td>14</td>
<td>92</td>
</tr>
<tr>
<td>15~19</td>
<td>37</td>
<td>19</td>
<td>74</td>
</tr>
<tr>
<td>20~24</td>
<td>35</td>
<td>24</td>
<td>39</td>
</tr>
<tr>
<td>25~29</td>
<td>34</td>
<td>29</td>
<td>30</td>
</tr>
<tr>
<td>Total</td>
<td>197</td>
<td>275</td>
<td>17</td>
</tr>
</tbody>
</table>

Fig. 1 Comparison of broadband ultrasonic attenuation by age and gender
BUA IN CHILDREN AND YOUNG ADULTS

in both males and females except in males aged 25–29 and females aged 20–24 and 25–29 (p<0.001) (Fig. 2).

DISCUSSION

Langton et al.\(^7\) showed that, when ultrasound is transmitted through a certain object, its amplitude diminishes due to scattering and absorption, and this effect depends on the frequency of the ultrasound transmitted and the strength of the object. They stated that the attenuation property could be represented as BUA by performing a Fourier transformation. BUA is said to reflect the density and trabecular architecture of the bone\(^3\).

Other calculated values, “Velocity of Sounds” (VOS) or “Speed of Sound” (SOS), on the other hand, represent an ultrasonic transmission velocity between the two transducers. VOS is rarely used because the soft tissues around the calcaneus and fat in the medullary canal interfere with ultrasound transmission, causing the value to be underestimated\(^5\).

BMD has been measured mainly in adults for assessment of osteoporosis, health education, etc. and been shown to negatively correlate with aging\(^3,13\). Sato et al.\(^11\) measured BMD in healthy Japanese aged 6 to 20 using

RESULTS

The following BUA values (dB/MHz) were obtained: 40.6±11.7 in males aged 5–9, 41.9±9.2 in females aged 5–9, 60.9±18.7 in males aged 10–14, 61.0±14.5 in females aged 10–14, 78.0±16.9 in males aged 15–19, 73.4±18.3 in females aged 15–19, 90.4±16.4 in males aged 20–24, 68.4±14.7 in females aged 20–24, 86.0±15.5 in males aged 25–29, and 70.8±15.4 in females aged 25–29. The values tended to increase with age in both males and females (Fig. 1). A significant difference was observed among the 5–9, 10–14 and 15–19 aged groups in males by multiple comparison. A significant difference was observed among the 5–9 and 10–14 aged groups in females by multiple comparison. BUA peaked at age 20–24 in males and 15–19 in females. Statistically significant gender differences were found in the 20–24 and 25–29 age groups (p<0.001). A significant positive correlation was observed between BUA and age in both males and females except in males aged 25–29 and females aged 20–24 and 25–29 (p<0.001) (Fig. 2).

Fig. 2 Correlation between broadband ultrasonic attenuation and age in each gender

<table>
<thead>
<tr>
<th>Gender</th>
<th>Equation</th>
<th>Correlation coefficient</th>
<th>p-value</th>
<th>R^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>Y = 20.941 + 3.174 x; R^2 = 0.568</td>
<td>0.75</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>Y = 18.63 + 3.363 x; R^2 = 0.393</td>
<td>0.63</td>
<td>&lt;0.001</td>
<td></td>
</tr>
</tbody>
</table>

jelly was positioned on the plate, and the transducers were moved to make firm contact with the skin. Transducers were placed evenly on both sides of the calcaneus where petroleum jelly had been applied.
computed x-ray densitometry (CXD), a modification of microdensitometry. Tokumaru\textsuperscript{12} evaluated the calcaneus in 5 to 18-year-old healthy children with dry ultrasonography (AOS-100) and found a good correlation between the Transmission Index (TI) and BMD of the lumbar spine with DXA, which is an established quantitative method of bone assessment. Exposing children to radiation, though minimal, is of a major concern. The ultrasonic method is timesaving and simple to use with no need for a radiographic control area, and it allows repeated measurements for follow-ups over time or for mass screening in school children\textsuperscript{2,12}. A good correlation exists between BUA measurements in the calcaneus and BMD values of the lumbar spine and proximal femur obtained with DXA. Therefore, BUA is useful as a screening device to assess bone density in children.

Based on BMD data in healthy Japanese, Sato \textit{et al.}\textsuperscript{11} estimated the start of pubertal growth spurt to be at around 9 years of age in females and 11 in males. They also reported that growth peaked at around 13 in females and 14 in males and that BMD tended to increase until adulthood with significantly higher BMD in females until age 15. Our results indicated no gender difference in the 5–9, 10–14, and 15–19 age groups. The different outcomes may be due to differences in the number of subjects and method of measurement between the two studies. Tokumaru\textsuperscript{12} showed that BMD increased with age at a significantly higher rate at age 14–15 in males and 11–14 in females. Females are said to mature earlier with an earlier onset of the pubertal growth spurt than males. Our results also showed that the BUA peak was reached earlier in females, suggesting the involvement of growth and sex hormones. The subjects of this study are healthy young individuals without any endocrine or skeletal disorders. The precision was studied by performing repeated scans. The amount of calcium intake, physical activity and growth rate have been recognized to be factors affecting the value of BUA. It will be necessary to consider these factors in the future.\textsuperscript{4,8} All these data indicate that the BUA values obtained in this study can serve as sensitive parameter values of bone density and are useful in identifying the status of growth and development in children and young adults. It has been suggested that ultrasonic bone density measurements may represent bone quality and architecture as well. This also needs to be studied in the future.

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REFERENCES


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