Metacarpal Bone Mineral Density, Body Mass Index and Lifestyle among Postmenopausal Japanese Women: Relationship of Body Mass Index, Physical Activity, Calcium Intake, Alcohol and Smoking to Bone Mineral Density: The Hizen-Oshima Study

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Yahata, Y., Aoyagi, K., Okano, K., Yoshimi, I., Kusano, Y., Kobayashi, M., Moji, K. and Takemoto, T. Metacarpal Bone Mineral Density, Body Mass Index and Lifestyle among Postmenopausal Japanese Women: Relationship of Body Mass Index, Physical Activity, Calcium Intake, Alcohol and Smoking to Bone Mineral Density: The Hizen-Oshima Study. Tohoku J. Exp. Med., 2002, 196(3), 123–129 —— The present study was designed to investigate the influence of modifiable risk factors (body weight and lifestyle) for bone loss on bone mineral density (BMD). We examined age-specific changes in metacarpal BMD, and its associations with body mass index and lifestyle among 532 community-dwelling postmenopausal Japanese women. Measurements of the second metacarpal BMD were obtained from the hand radiographs using computer-assisted radiographic absorptiometry. Body height and weight were measured, and body mass index (BMI) was calculated. Physical activity index was calculated using validated questionnaire. Daily calcium intake and amount of ingested alcohol were estimated by semiquantitative food frequency questionnaire. Current smoking status was obtained by questionnaire. Metacarpal BMD decreased significantly with increasing age. Simple correlation analysis indicated that metacarpal BMD correlated significantly with BMI and physical activity index. On the other hand, metacarpal BMD did not correlate with calcium intake and alcohol drink-

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Osteoporosis (low bone mass or density) is one of the most prevalent chronic health conditions among the elderly (Cummings et al. 1985; Ross 1996). Since fractures due to osteoporosis lead to considerable disability and many premature deaths, osteoporosis and osteoporotic fractures are of major public health concerns (Cummings et al. 1985).

Considerable progress has been made over the last two decades in the development and evaluation of noninvasive techniques for assessing bone mineral status. Bone densitometry is currently considered the best approach to diagnose osteoporosis and predict fracture risk (Ross 1996). Numerous studies have demonstrated that a variety of methods, including single-photon and single x-ray absorptiometry, dual-photon and dual x-ray absorptiometry, spinal and peripheral quantitative computed tomography, and quantitative ultrasonography, can be used for these and other clinical and research purposes (Genant et al. 1996). However, some of these techniques are expensive, time consuming, or the equipment require a large space. Recent developments in computer-assisted radiographic absorptiometry using the hand radiographs provide readily accessible and relatively inexpensive method for assessing bone mineral density (BMD) and fracture risk (Genant et al. 1996; Huang et al. 1998).

Although several risk factors for bone loss have been reported (Cummings et al. 1985; Ross 1996), there are modifiable (e.g., weight, physical activity, diet, drinking alcohol and smoking) and non-modifiable factors (e.g., age, sex and race). For primary prevention of diseases, it is important to achieve a healthy lifestyle. With respect to weight, low body weight is reported to be associated with low BMD among Japanese populations (Kajita et al. 1995; Nagase et al. 1999; Yamaguchi et al. 2000; Fukuharu et al. 2001). However, there is no agreement on the association between BMD and other lifestyle factors such as physical activity, calcium intake, alcohol drinking and smoking (Kajita et al. 1995; Nagase et al. 1999; Yamaguchi et al. 2000; Fukuharu et al. 2001). In order to elucidate whether these modifiable risk factors for bone loss influence metacarpal BMD in our population sample, we examined age-specific changes in metacarpal BMD, and its associations with body mass index and lifestyle among community-dwelling postmenopausal Japanese women.

**Subjects and Methods**

The Hizen-Oshima Study is a prospective population-based cohort study of musculoskeletal conditions (e.g., osteoporosis and osteoarthritis). We recruited community-dwelling women aged 40 years or over in Oshima town, Nagasaki prefecture, Japan. The women were identified by the municipal electoral list and contacted through mailings. The town of Oshima has a population of approximately 5800, and the total population of women aged 40 or over is approximately 2000.
All women aged 40 or over were invited to participate in the study. The baseline examination was performed at the Oshima Health Center between 1998 and 1999. A total of 586 women (approximately 30% of eligible women) participated in the study. Despite having a shipyard in the town, Oshima is mainly a rural (farming/fishery) district. Approximately half of the women who participated in the study continue to grow rice and vegetables by manual labor, sometimes using machinery. At baseline, all participants were noninstitutionalized and lived independently. All subjects gave written informed consent before examination.

Measurements of the second metacarpal BMD were obtained from the hand radiographs using a computer-assisted radiographic absorptiometry, the Bonalyzer II (Teijin, Tokyo). The reproducibility expressed as coefficient of variation (CV), measured on 5 occasions consecutively within 1 hour, was 0.56% for metacarpal BMD measurements calculated in a random sample of 20 of the subjects.

Height (m) and weight (kg) were measured with the subject in light clothing and without shoes, and body mass index (BMI) was calculated as weight (kg)/height (m²). Physical activity index was calculated as the metabolic equivalents, per day, from the number of hours per day spent sleeping, sitting, and in light, moderate, and heavy activities (Sallis et al. 1985). Daily calcium intake and alcohol drinking were estimated by semiquantitative food frequency questionnaire (Tsubono et al. 1996). The questionnaire was validated against a 28-day diet record. The Spearman rank correlation coefficient between the dietary record and the questionnaire was 0.53 for calcium intake in women. Current smoking status was obtained by questionnaire.

Statistical analysis

Data were analyzed using the Statistical Analysis System version 6.12. (SAS Institute Inc., Cary, NC, USA). Menopausal status was missing in 3 women, and 51 women who were in menstruation were excluded from the analysis, leaving 532 postmenopausal women for data analyses. Women with total energy of <500 kcal or >4000 kcal were excluded from the analyses (Willett 1998). Calcium intake and alcohol drinking were transformed into logarithm values. For statistical purposes, alcohol drinking was set as 0.1 g when the actual value was 0 g. Age-specific means of metacarpal BMD were determined using general linear modeling method (ANOVA). Correlations between metacarpal BMD and BMI, physical activity index, calcium intake and alcohol intake were examined by Pearson correlation analysis. Student’s t-test was used for differences in metacarpal BMD based on current smoking status. Multiple linear regression analysis was used to explore the effects of age, BMI, physical activity, calcium intake, alcohol drinking and current smoking status on metacarpal BMD. Age-adjusted means of metacarpal BMD among lean, normal and obese women were determined using general linear modeling method (ANCOVA).

RESULTS

Table 1 shows the characteristics of participating subjects. Metacarpal BMD significantly decreased with increasing age (Table 2). Metacarpal BMD among those aged 80-89 years was 32% lower than that of those aged 43-49 years.

Results of correlation analyses between metacarpal BMD and BMI, physical activity index, calcium intake and alcohol drinking are shown in Table 3. Metacarpal BMD correlated significantly with BMI and physical activity index. On the other hand, metacarpal BMD did not correlate with calcium intake and alcohol drinking. Metacarpal BMD of current smokers (2.19 [0.34], n=23) was not different from that of non-smokers (2.18 [0.31], n=496).


Table 1. Characteristics of subjects (n = 532)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Mean (s.d.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>66.1 (8.1)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>149.2 (5.9)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>62.2 (6.8)</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>23.4 (3.5)</td>
</tr>
<tr>
<td>Physical activity index (METs)</td>
<td>92.5 (14.4)</td>
</tr>
<tr>
<td>Calcium intake (mg/day)</td>
<td>663 (371)</td>
</tr>
<tr>
<td>Alcohol intake (g/day)</td>
<td>0.8 (3.5)</td>
</tr>
<tr>
<td>Current smoking</td>
<td>4.4 (2.3/619)</td>
</tr>
</tbody>
</table>

*Data are mean (s.d.).

Table 2. Metacarpal bone mineral density (BMD) by age group

<table>
<thead>
<tr>
<th>Age group (years)</th>
<th>n</th>
<th>Metacarpal BMD</th>
<th>Mean (s.d.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>45-49</td>
<td>11</td>
<td>2.66</td>
<td>0.16</td>
</tr>
<tr>
<td>50-59</td>
<td>102</td>
<td>2.41</td>
<td>0.28</td>
</tr>
<tr>
<td>60-69</td>
<td>227</td>
<td>2.19</td>
<td>0.26</td>
</tr>
<tr>
<td>70-79</td>
<td>162</td>
<td>2.04</td>
<td>0.26</td>
</tr>
<tr>
<td>80-89</td>
<td>30</td>
<td>1.81</td>
<td>0.25</td>
</tr>
<tr>
<td>p for trend</td>
<td></td>
<td></td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Table 3. Simple correlation analysis between metacarpal bone mineral density (BMD) and body mass index (BMI), physical activity index, calcium intake and alcohol drinking

<table>
<thead>
<tr>
<th>Metacarpal BMD</th>
<th>BMI</th>
<th>Physical activity index</th>
<th>Calcium intake</th>
<th>Alcohol intake</th>
</tr>
</thead>
<tbody>
<tr>
<td>r</td>
<td>0.13</td>
<td>0.15</td>
<td>0.02</td>
<td>0.06</td>
</tr>
<tr>
<td>p</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>0.62</td>
<td>0.20</td>
</tr>
</tbody>
</table>

r, correlation coefficient.

Table 4. Multiple regression analysis showed that age and BMI significantly influenced metacarpal BMD; increasing age was associated with decreased metacarpal BMD and greater BMI increased metacarpal BMD. However, physical activity index, calcium intake, alcohol drinking and current smoking did not significantly influence metacarpal BMD. We repeated the analysis using calcium intake/total energy, instead of calcium intake in order to exclude any influence of body size, but the findings were similar (data not shown). Age-adjusted means (standard error) of metacarpal BMD in lean BMI < 20, normal (20 ≤ BMI < 25) and obese women (BMI ≥ 25) were 2.11 (0.03), 2.17 (0.01) and 2.23 (0.02), respectively. Lean women had significantly lower BMD, compared with normal or obese women (data not shown).

Discussion

Various methods, including single-photon and single x-ray absorptiometry, dual-photon and dual x-ray absorptiometry, spinal and peripheral quantitative computed tomography, and quantitative ultrasonography, have been used for measurement of bone density in recent years. The computer-assisted radiographic absorptiometry used in the present study is a portable, on-site computerized densitometer, which allows processing of hand radiographs in less than 10 minutes (Huang et al. 1998). In addition to its low cost, less technical expertise and smaller space are required compared with standard bone measurements such as dual x-ray absorptiometry and quantitative computed tomography. Thus, hand radiographic absorptiometry techniques are attractive options for medical facilities with existing x-ray equipment, and limited space or technical expertise. Furthermore, in terms of precision and accuracy, the modern forms of radiographic absorptiometry are at least as good as other bone mass measurement techniques (Genant et al. 1996).

Our finding using computer-assisted radiographic absorptiometry was consistent with those reported by Matsumoto et al. (1991) who indicated a progressive decrease of metacarpal
Table 4. Multiple linear regression model for metacarpal bone mineral density (BMD) 
($R^2 = 0.393$)

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Standard error</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>3.3087</td>
<td>0.2000</td>
</tr>
<tr>
<td>Age (years)</td>
<td>-0.0222</td>
<td>0.0014</td>
</tr>
<tr>
<td>BMI (kg/m$^2$)</td>
<td>0.0099</td>
<td>0.0032</td>
</tr>
<tr>
<td>Physical activity index (METs)</td>
<td>0.0002</td>
<td>0.0007</td>
</tr>
<tr>
<td>Calcium intake (mg/day)$^a$</td>
<td>0.0120</td>
<td>0.0227</td>
</tr>
<tr>
<td>Alcohol intake (g/day)$^a$</td>
<td>-0.0110</td>
<td>0.0093</td>
</tr>
<tr>
<td>Current smoking$^a$</td>
<td>-0.0149</td>
<td>0.0561</td>
</tr>
</tbody>
</table>

BMD with increasing age after the age of 50. Furthermore, metacarpal BMD also correlated significantly with BMD at spine ($r=0.61$), hip ($r=0.60$) and radius ($r=0.84$) measured by dual x-ray absorptiometry (Matsumoto et al. 1991).

In the present study, greater BMI was associated with increased metacarpal BMD, and lean women had significantly lower BMD, compared with normal or obese women. Many studies reported that obesity (greater body weight and BMI) is associated with higher BMD (Ribot et al. 1987; Nishizawa et al. 1991; Albala et al. 1996; Takata et al. 1999; Murillo-Urba et al. 2000). The protective effect of obesity on bone loss appears to be related to both mechanical factors and to estrogen synthesis in adipose tissue (Ribot et al. 1994). However, since obesity is an important risk factor for cardiovascular disease and diabetes (Sowers et al. 2001), appropriate body mass (BMI: 20–25 kg/m$^2$) or prevention for leanness should be recommended for good general health.

Physical activity helps to increase or maintain BMD at skeletal sites that are subjected to loading (Sinaki and Offord 1988; Krall and Dawson-Hughes 1994; Heinonen et al. 1995; Duppe et al. 1996; Dornemann et al. 1997), and physical activity during childhood is reported to be an important determinant of peak bone mass (Cooper et al. 1995). Metacarpal BMD was not associated with physical activity index in our multiple regression model, which may be influenced by the lack of physical activity during childhood in our study. However, improved muscle strength and coordination are other benefits of physical activity that may reduce the risk of fall-related fractures (Aoyagi et al. 2000).

Calcium intake was not associated with metacarpal BMD in the present study. Adequate dietary levels of calcium were reported to be associated with lower rates of bone loss, in some but not all studies (Matkovic et al. 1979; Cooper et al. 1988; Lau et al. 1988; Wickham et al. 1989). Ruiz et al. (1995) reported that the effect of calcium might be greatest during growth and development. However, we were not able to obtain information on calcium intake during that period. On the other hand, a number of studies indicated that alcohol intake and smoking influence bone loss, although others could not confirm these findings (Ross 1996). In the present study, neither alcohol intake nor smoking significantly influenced metacarpal BMD. Only few of our subjects drank alcohol (1.1%, >20 g/day) or smoked cigarettes (4.4%). Thus, alcohol drinking and smoking do not seem to have a major influence on BMD in our subjects.

Recent studies of Japanese women in urban areas indicated that physical activity was
associated with higher BMD (Yamaguchi et al. 2000; Fukuharu et al. 2001), which is inconsistent with our results. Our study site was a rural district, and our subjects were not representatives of the general population. These factors may in part explain the different results. In this context, the Japanese Society for Bone and Mineral Research recommends the use of lumbar spine dual x-ray absorptiometry as a standard bone measurement because of good precision and accuracy (Orimo et al. 1998). Measurement of BMD in different regions such as the lumbar spine instead of the second metacarpal bone, could have possibly yielded different results (Kajita et al. 1995). Further studies are necessary to explore the association between BMD and lifestyle factors using bone measurements at different sites.

In conclusion, we have demonstrated in the present study that metacarpal BMD significantly decreased with increasing age, and greater BMI was associated with increased metacarpal BMD. Maintenance of adequate body mass (prevention for leanness) is important for prevention of postmenopausal bone loss (osteoporosis). Although physical activity index, calcium intake, alcohol drinking and current smoking were not important determinants of metacarpal BMD in the present study, lifestyle-related preventative measures are recommended for prevention of osteoporosis.

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References


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