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Original Article

Age and Sex Differences in the Bone Mineral Density of the Distal Forearm Based on Health Check-up Data of 6343 Japanese

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Abstract. Bone mineral density (BMD) predicts osteoporotic fractures. The incidence of osteoporotic fractures in Japan is lower than among Caucasians, but fewer data on the BMD of Asians have been reported. This study attempted to clarify the age and sex differences in the forearm BMD of healthy adult Japanese and to assess racial differences between Japanese and Caucasians. The subjects were 6343 healthy adult Japanese (5281 females, 1062 males) who underwent a health check-up at a health care service center between February 1995 and August 1999. Subjects' age ranged from 15 to 80 years. The BMD of the distal radius and ulna of the non dominant forearm was measured by dual-energy X-ray absorptiometry. Overall, the forearm BMD of men was greater than that of women in all age groups. Peak BMD was 0.484 g/cm^2 in the 40–44 year age group of women and 0.590 g/cm^2 in the 30–34 year age group of men. The forearm BMD of women under 50 years of age (the average age at menopause) increased slightly with age (2.0%/decade, $p < 0.0001$), but it did not among their male counterparts. After 50 years of age, BMD of the women decreased linearly (–1.6%/year, $p < 0.0001$) with age, the rate of decrease being 1.7-fold faster than in their male counterparts. Rates of gain and loss of forearm BMD differ between the sexes. In comparison with data previously reported, we did not find any evidence of racial differences in BMD as an explanation for the lower incidence of osteoporotic fractures in Japan.

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Introduction

Age-related bone loss is becoming an important public health problem in countries with aging populations as it is associated with fragility fractures that can substantially lower the level of activities of daily living (ADL) in the elderly. Since attainment of optimal peak bone mass is recommended as one of the strategies to prevent osteoporosis [1], it is important to evaluate bone mass in every decade of life.

Measuring forearm bone mineral density (BMD) by dual-energy X-ray absorptiometry (DXA) is an easy, quick, reliable and noninvasive method [2] of evaluating bone mass among people living in communities. BMD measurement of the distal segment of the radius should be meaningful not only in regard to the prevention of Colles' fractures [3,4] but for the following reasons as well. First, forearm BMD also reflects axial and total BMD. [5,6] It has been reported that BMD of the distal radius is well correlated with BMD of the spine [7] and femur [8], where fractures have a great impact in decreasing ADL, and that radial BMD is a significant predictor of fractures at other sites [9–13]. Second, a constant trabecular volumetric BMD ratio between vertebral and distal radial sites has been found [14]; and finally, forearm bone has scarcely any deformity [5] that could distort bone density values, unlike spinal and femoral bone. Thus, measuring forearm BMD has many advantages in terms of evaluating bone health and making comparisons in terms of age, sex and ethnicity.

Based on this rationale, we analyzed forearm BMD in the health check-up data of 6343 healthy Japanese residents. This large sample enabled us to obtain normative data and to identify age characteristics and sex differences in forearm BMD. The Japanese are an interesting population to study in terms of bone health, because the incidence of osteoporotic fractures in Asians is lower than among the Caucasians [15–18]. A descriptive study of bone mass in such a population would provide clues to the racial differences in osteoporosis. To our knowledge, only one report on the forearm BMD of Japanese has ever been published [19]; however, the sample size in that study was inadequate to determine the basic characteristics of the forearm BMD of Japanese. The purpose of this paper was to clarify age and sex differences in the forearm BMD of healthy adult Japanese; ethnic differences between the present Japanese population and Caucasians are also discussed.

Subjects and Methods

The subjects were 6343 healthy people (5281 females, 1062 males) living in Shibata city, Toyosaka city, and the surrounding county in Niigata Prefecture, Japan, who underwent a health check-up that included BMD measurement at Shibata Comprehensive Health Care Service Center between February 1995 and August 1999. With regard to the 1419 subjects (22.4%) who had BMD measured twice or more during the period, data from the first examination were used for analysis. The population comprised both household and working populations. Subjects ranged in age from 15 to 80 years old. Average age was 48.2 (SD 12.8) years in the females and 53.5 (SD 10.9) in the males. Height and weight data were available for 4847 (91.8%) females and 1060 (100%) males. The average height, weight and body mass index values were 154.6 cm (SD 6.0), 53.2 kg (SD 7.4) and 22.3 kg/m^2 (SD 3.0) for the females, and 165.4 cm (SD 6.3), 63.4 kg (SD 9.0), and 23.1 kg/m^2 (SD 2.7) for the males.

BMD of the distal radius and ulna of the nondominant forearm was measured for all subjects DXA using a DTX-200 Osteometer (Osteometer MediTech, Rødovre, Denmark), which is distributed in Japan by Toyo Medic (Tokyo). The DTX-200 system software version 1.54J automatically scans 24 mm of the radius and the ulna from a point with an 8-mm radius–ulna gap to the proximal direction. This site includes 13% trabecular bone. Details of the DXA measurement protocol have been described previously [20]. The long-term in vitro CV value of the BMD measurements using the standard material was 0.7%.

A self-reported history of disease or conditions that might affect calcium metabolism was available for only 1047 females among the 6343 subjects. These data, however, allowed us to estimate the proportion of persons with such diseases to characterize the study population. Eighty-nine women (8.5%) were postmenopausal, and their average age at menopause was 49.3 years (SD 4.1).

The mean and standard deviation (SD) of BMD were calculated by age group to obtain normative data for healthy Japanese. Simple regression analysis was used to identify an association between BMD and age. This association was re-evaluated by multiple regression analysis with weight as an independent variable, since body size has been known to be independently correlated with BMD [21]. A p value less than 0.05 was judged to be statistically significant.

Results

Mean BMD values by 5-year age groups are shown in Table 1. Simple regression analysis revealed that mean BMD increased slightly from the 15–19 through the 40–44 year age groups among females, and that mean BMD decreased with age thereafter. The relationship between age and BMD in females is demonstrated in Fig. 1, and the relationships appeared to be different before and after approximately 50 years of age, the estimated mean age of menopause. Among those below 50 years of age, BMD increased slightly with age, the regression equation being $Y = 0.0009X + 0.4368$ [Y: BMD (g/cm^2), X: age (years); $r^2 = 0.022$, $p < 0.0001$]. The BMD increase in premenopausal women was alternatively expressed as 2.0% per decade. The tendency to increase held even after adjusting for weight (slope 0.0007, $p < 0.0001$). In contrast, BMD decreased steeply with age among those 50 years of age and older (–1.6%/year), and the regression equation was $Y = -0.0074X + 0.8356$ ($r^2 = 0.280$, $p < 0.0001$).

Among the males, BMD peaked in the 30–34 year age group (Table 1), but mean BMD did not change significantly from the 15–19 through the 45–49 year age groups ($p = 0.2666$). Thereafter, mean BMD decreased with age. Figure 2 shows BMD plotted against

Table 1. Means and standard deviations (SD) of bone mineral density (BMD) of the distal forearm by 5-year age groups

	Female BMD (g/cm^2)		Male BMD (g/cm^2)	
Age group (years)	n	Mean (SD)	n	Mean (SD)
15–19	18	0.447 (0.047)	5	0.455 (0.057)
20–24	123	0.462 (0.051)	9	0.554 (0.048)
25–29	325	0.466 (0.049)	19	0.580 (0.080)
30–34	580	0.465 (0.048)	15	0.590 (0.052)
35–39	433	0.473 (0.050)	63	0.582 (0.058)
40–44	515	0.484 (0.050)	112	0.580 (0.056)
45–49	668	0.479 (0.054)	152	0.571 (0.061)
50–54	598	0.455 (0.063)	137	0.565 (0.071)
55–59	750	0.412 (0.065)	155	0.552 (0.076)
60–64	779	0.376 (0.065)	225	0.522 (0.070)
65–69	427	0.354 (0.070)	135	0.501 (0.077)
70–74	50	0.321 (0.066)	29	0.484 (0.073)
75–79	13	0.287 (0.052)	6	0.408 (0.088)
80–84	2	0.228 (0.040)	0	–

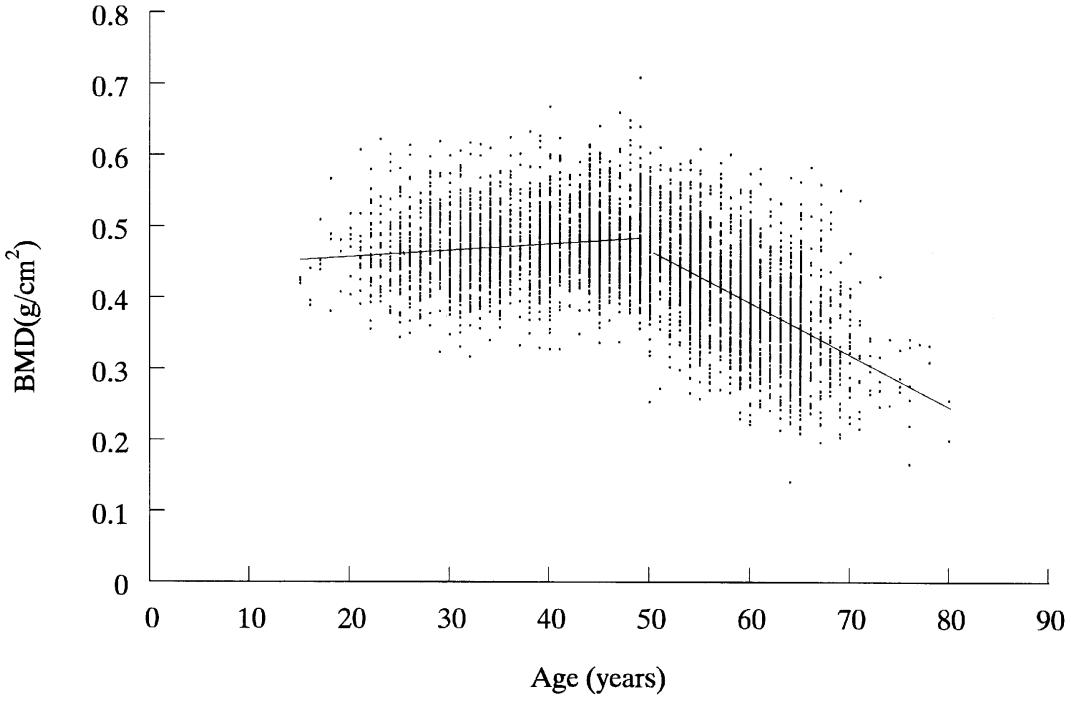

Fig. 1. Scatter plot of bone mineral density (BMD) versus age in females. The relationship between them is different before and after the age of around 50 years. Among those under 50 years of age, BMD increased slightly with age (2.0%/decade), the regression equation being $Y = 0.0009X + 0.4368$ [Y: BMD (g/cm^2), X: age (years), $r^2 = 0.022$, $p < 0.0001$]. In contrast, among those 50 years of age and older, BMD decreased steeply with age (−1.6%/year), the regression equation being $Y = -0.0074X + 0.8356$ ($r^2 = 0.280$, $p < 0.0001$).

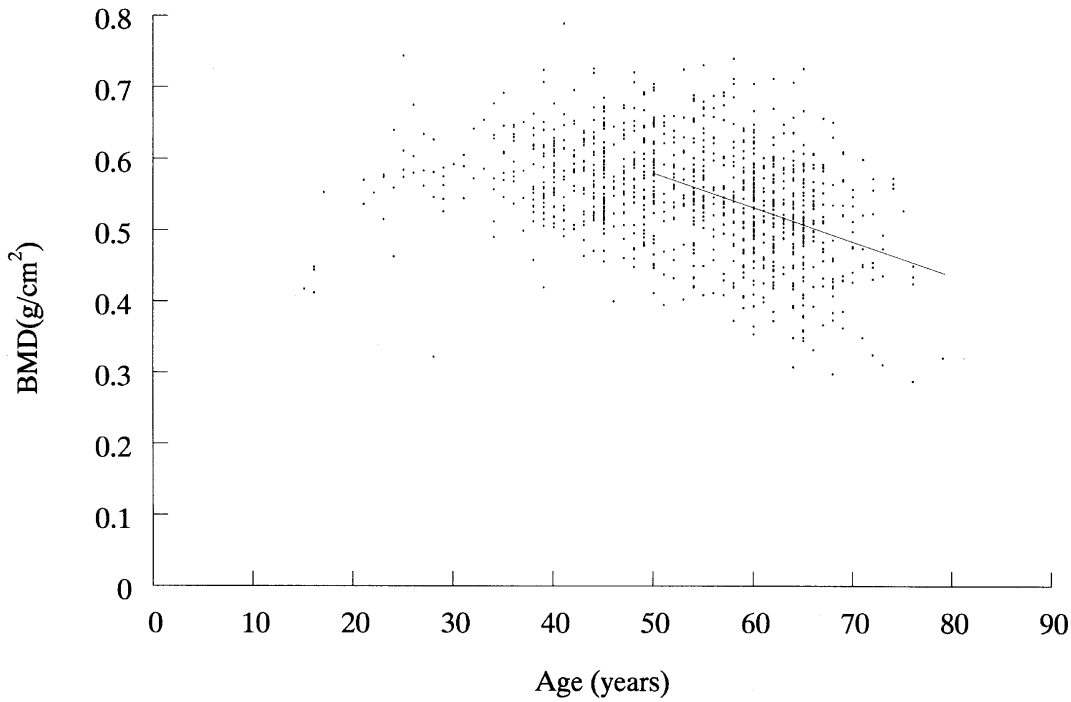

Fig. 2. Scatter plot of bone mineral density (BMD, g/cm^2) versus age in males. Among those under 50 years of age, the slope of the regression equation was not statistically significant ($p = 0.2666$). For those 50 years of age and older, BMD decreased linearly with age (−0.87%/year), the regression equation being $Y = -0.0049X + 0.8233$ ($r^2 = 0.132$, $p < 0.0001$).

age. Overall, BMD decreased with age, the regression equation being $Y = -0.0024X + 0.6751$ ($r^2 = 0.122$, $p < 0.0001$). A comparison of BMD between before and after 50 years of age showed that BMD decreased linearly with age in those 50 years of age and older, the regression equation being $Y = -0.0049X + 0.8233$ ($r^2 = 0.132$, $p < 0.0001$). The rate of decrease in BMD in men after 50 years of age was -0.0049 g/cm^2/year (-0.87%/year), 1.5-fold slower than in their female counterparts.

Multiple regression analysis was performed with forearm BMD as a dependent variable and age and weight as independent variables. The regression coefficient of age for female subjects under 50 years of age was still statistically significant after adjusting for weight ($p < 0.0001$) (Table 2), but the regression coefficient of age for their male counterparts was not significant ($p = 0.0769$). Among subjects 50 years of age and older (Table 3), the regression coefficients of age for both sexes were statistically significant after adjusting for weight ($p < 0.0001$). After the adjustment, the rate of decrease in forearm BMD in women after 50 years of age was -0.0069 (g/cm^2/year), and 1.7-fold faster than that of their male counterparts. Age and weight explained 40.6% of the variance in forearm BMD for the women and 22.6% for the men. After adjusting for weight, age explained 29.2% of the variance in BMD for women, 16.0% more than for men. Weight explained 9.4–16.4% of the variance in BMD throughout the age groups in both sexes.

The average age of the 1047 female subjects for whom detailed data were available was 33.3 years (SD 10.0). No subjects reported having diseases of the parathyroid gland. Fourteen women (1.3%) underwent oophorectomy. Eighteen (1.7%) had used oral contraceptives at some time. No subject underwent osteoporosis treatment.

Table 2. Results of the multiple regression analysis with forearm bone mineral density (BMD, g/cm^2) as a dependent variable, and age and weight as independent variables, in subjects under 50 years of age

Independent variable	Regression coefficient	Standard error	r^2	p-value
Female				
Age (years)	0.0007	0.0001	0.022	<0.0001
Weight (kg)	0.0025	0.0001	0.131	<0.0001
Male				
Age (years)	0.0007	0.0004	0.003	0.0769
Weight (kg)	0.0027	0.0003	0.164	<0.0001

Table 3. Results of the multiple regression analysis in subjects 50 years of age and older

Independent variable	Regression coefficient	Standard error	r^2	p-value
Female				
Age (years)	−0.0069	0.0002	0.292	<0.0001
Weight (kg)	0.0035	0.0002	0.114	<0.0001
Male				
Age (years)	−0.0041	0.0005	0.132	<0.0001
Weight (kg)	0.0028	0.0003	0.094	<0.0001

Discussion

This cross-sectional study found that the forearm BMD of premenopausal women increased slightly (2%/decade) with age even when body size was taken into account. Previous cross-sectional studies in Caucasian women also observed increases of 2% [22] and 3.2% [23] per decade, and there is no evidence of Japanese women having an advantage over Caucasians in terms of forearm BMD gain.

The explanation of the BMD gain in premenopausal women is either that individual forearm bone mass actually increases through perimenopausal age, or a cohort effect in which younger generations have had lower bone density. We are unable to make a final decision as to which hypothesis to adopt. With regard to the former, several cross-sectional [22–24] and one longitudinal [25] study have reported increasing forearm BMD in premenopausal women after a rapid increase at the age of puberty. Matkovic et al. [22] thought of this phenomenon as a continuous periosteal expansion of tubular bone mass with age. Therefore, it is reasonable to accept the hypothesis that premenopausal women have the potential to increase forearm BMD. However, the latter hypothesis cannot be rejected. Hirota et al. [26] suggested that individual differences in the forearm BMD of premenopausal Japanese women were significantly explained by differences in dietary factors, such as calcium and protein, and physical activity. The lower BMD in younger women may be due to their lower intake of calcium or other nutrients. As evidence of this, the national nutrition survey in 1997 revealed that younger adult Japanese women consumed less calcium (15–19 years, 488 mg; 20–29 years, 499 mg; 30–39 years, 526 mg; and 40–49 years, 548 mg) [27], which may have been reflected in the BMD increase. Another piece of evidence may be that lower BMD was found at younger ages in women but not in men under 50 years of age. This may be partially attributable to the relatively small sample size. The sex difference, however, could be more plausibly explained by the difference in eating behavior between the sexes. That is to say, today's young women diet and/or skip meals, but young men rarely do [28]. Since our data were cross-sectional, longitudinal studies are needed to interpret the results.

The decreasing rate of BMD in the distal forearm is a good indicator for characterizing the bone health of a population. After the menopause, BMD in women decreased linearly with age at a rate 1.7-fold faster than in their male counterparts. Although number of years after the menopause is a better predictor of BMD, in this study we evaluated the rate of decrease of BMD

on the basis of chronological age for comparison with those in other reports. The rate of decrease of BMD in the distal radius from 50 years of age onward has been reported to be between 1.1% and 2.1%/year in Caucasian women [4,29,30]. The rate of decrease in the Japanese women in this study was 1.6%/year, which does not support a racial difference.

Felson et al. [21] reported a sex difference in the association between weight and radial BMD, with weight substantially affecting radial BMD in females but not in males; a difference in estrogen in adipose tissue was hypothesized as the explanation. However, our data did not find any such sex difference before and after the menopause. We believe that muscle mass or muscle strength, as a correlate of weight, is simply associated with radial BMD regardless of age and sex.

The presence of racial differences in forearm BMD between Asian Japanese and Caucasians has been somewhat controversial. Bhudhikanok et al. [31] reported the forearm bone mineral content, not density, of Asians to be lower than in Caucasians, perhaps due to the smaller bone size of Asians, and consequently concluded that no significant differences in BMD exist. Davis et al. [32] also supported the lower bone mineral content of Asians in most bone sites, although white women had lower BMD of the distal radius than Asians. The absolute values of our data cannot be compared directly with previously reported BMD since the sites measured and apparatus used have not been uniform. Kelly et al. [20] obtained normative distal forearm BMD data for female Caucasians by using a DTX-100 Osteometer with single-photon X-ray absorptiometry (SXA). The DTX-100 measures bone mass in the same area of the forearm as the DTX-200 does by automatic scanning. The forearm BMD measured with DXA in this study is almost the same as that measured by SXA, because BMD measurements by the two methods have been demonstrated to be highly correlated [33]. Comparisons with Kelly et al.'s data [20] showed that the average BMD values in the present Japanese women were slightly lower in all age groups than in white American women.

The present study has limitations. It should be noted that 'rate' of BMD change over ages in this study was determined by changes in a cross-sectional assessment of the population, rather than longitudinal changes. In general, the age-related change in BMD in a cross-sectional study is explained by the true change and a cohort effect. Another limitation was that the number of the subjects below 20 years of age was small. We were unable to clarify the BMD increase in the growing phase.

In summary, the present study yielded the following findings: (1) Peak BMD was 0.484 g/cm^2 in the 40–44 year age group of women and 0.590 g/cm^2 in the 30–34 year age group of men. (2) The forearm BMD of premenopausal women increased slightly (2.0%/decade) with age, even taking body size into account, but it did not in their male counterparts. (3) After the menopausal age, forearm BMD in women decreased linearly with age 1.7-fold faster than in their male counterparts. The rates of gain and loss of forearm BMD differed between the sexes. We did not find any evidence of racial differences in BMD to explain the lower incidence of osteoporotic fractures in Japan. This suggests that factors other than bone density, such as bone quality and living environment, may contribute to the lower incidence in Japanese, and this should be explored in future studies.

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