Relationship between Bone Mineral Density and Body Composition Estimated by Dual-Energy X-ray Absorptiometry: Comparison between Groups Aged 20–39 and 40–59 Years

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Bone mineral density (BMD) is affected by lean body mass and body weight to various degrees in the course of aging. The attempt of this study is to determine the optimal time to begin prevention of osteoporosis. In this study, female hospital employees aged 20–59 years were divided into 2 age groups, 20–39 years and 40–59 years based on age at peak BMD, and the relations of total BMD, subtotal BMD and lumbar spine BMD to lean body mass and body weight were examined in both groups. Subtotal BMD was calculated by subtracting head BMD from total BMD along with whole body measurement. While persistent positive correlations were found among all factors in the 20–39-years-old group, subtotal BMD and lumbar spine BMD were positively correlated to lean body mass in the 40–59-years-old group. Thus, lean body mass and body weight appeared to exert a profound influence on subtotal BMD in those aged 20–39 years, but lean body mass in those aged 40–59 years. Lean body mass appears to provide the best prediction of subsequent development of osteoporosis.

Low bone mineral density (BMD) values measured by dual-energy X-ray absorptiometry (DXA) devices indicate a risk of osteoporosis and subsequent bone fracture, such as proximal femoral fracture (1), which could significantly affect quality of life, and are invaluable findings for prevention of osteoporosis.

For the evaluation of BMD to diagnose osteoporosis, total BMD, lumbar spine BMD and femoral BMD have been measured. Although they are the conventional diagnostic criteria for osteoporosis, it is important to introduce the concept of evaluating subtotal BMD. By "head exclusion in subjects with high BMD" (2), the significance of change in BMD becomes more apparent. Therefore, subtotal BMD corresponding to BMD of body portion without head, is introduced to this study.

BMD is related to calcium intake (3-6), exercise (4, 7), lean body mass (8-14), and body weight (15). In order to overcome the difficulty of monitoring calcium intake and lifestyle, attempts have been made to utilize changes in lean body mass and body weight as substitute risk indicators. For example, lean body mass is significantly higher in individuals without osteoporosis than in those with osteoporosis (16). Therefore, measurement of lean body mass may help to develop a new method for prediction of osteoporosis.

In this study, we evaluate total BMD, subtotal BMD, lumbar spine BMD, lean body mass and body weight of ambulatory workers aged 20–59 years who are divided into 2 age groups based on age at peak BMD, 20–39 years and 40– 59 years, and examine the effects of lean body mass and body weight on BMD in both groups.

MATERIALS AND METHODS

Subjects

This study was carried out using healthy, ambulatory, Japanese, female community hospital workers who were evaluated between December 2006 and November 2010. The persons treated for osteoporosis during the study period were excluded and the remainders were the subjects (n = 179; shift workers, 66.5%; full-time workers, 33.5%) aged 20–59 years (median, 37 years). This study was approved by our hospital's Institutional Review Board, and written informed consent was obtained from all participants.

Measuring device and measurement region

Total BMD (including the head, spine, ribs, pelvis, and extremities), subtotal BMD (including spine, ribs, pelvis and extremities), lumbar spine BMD (L2–4), lean body mass and body weight were measured using a DXA device (QDR Discovery; Hologic Inc., W. Waltham, MA, USA). Total BMD, subtotal BMD, lean body mass and body weight values were derived from a single whole-body scan in order to reduce radiation exposure. Lumbar spine BMD was derived from a lumbar spine scan. Subjects were placed in the supine position with their feet shoulder-width apart and both hands open, without using a pillow to support the head. The DXA device used in this study provided a 0.4% coefficient of variation for BMD when using a lumbar phantom.

Analytical curves

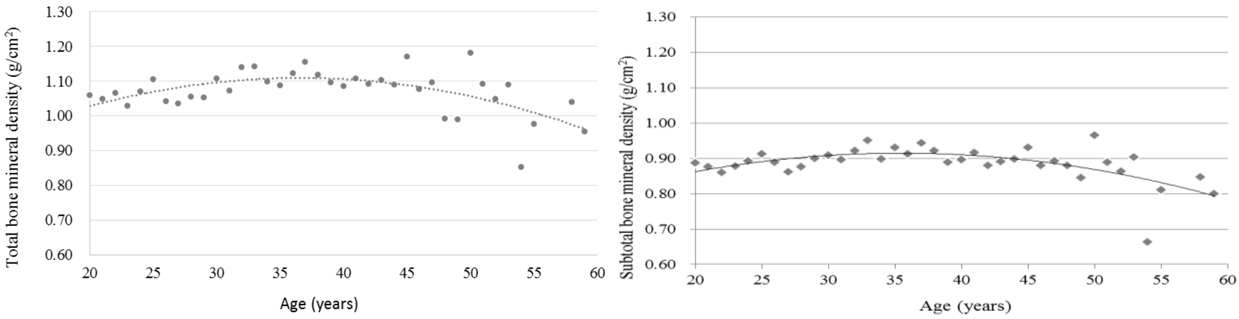
Average total BMD, subtotal BMD, lumbar spine BMD, lean body mass and body weight were calculated for each age group (1-year age groups between 20 and 59 years). These average values were plotted to construct polynomial analytical curves. Age at maximum average subtotal BMD was estimated using the polynomial curve formula. Based on this age, subjects were divided into 2 age groups: 20 years to the age at peak BMD and the age at peak BMD to 59 years. Polynomial curves also were constructed for total BMD, subtotal BMD, lumbar spine BMD, lean body mass, and body weight in order to compare both age groups. Furthermore, correlation coefficients were calculated between total BMD, subtotal BMD, lumbar spine BMD, lean body mass and body weight.

Statistical analysis

Comparisons between groups were performed using the independent *t* test. Correlations between variables were evaluated using Pearson's correlation coefficient. All statistical analyses were performed using SPSS version 13.5J (SPSS Inc., Tokyo, Japan), with *P* values of <0.05 considered statistically significant.

RESULTS

Polynomial curves for total BMD, subtotal BMD, lumbar spine BMD and lean body mass increased with age until the age at peak BMD, and then subsequently decreased (Fig. 1).



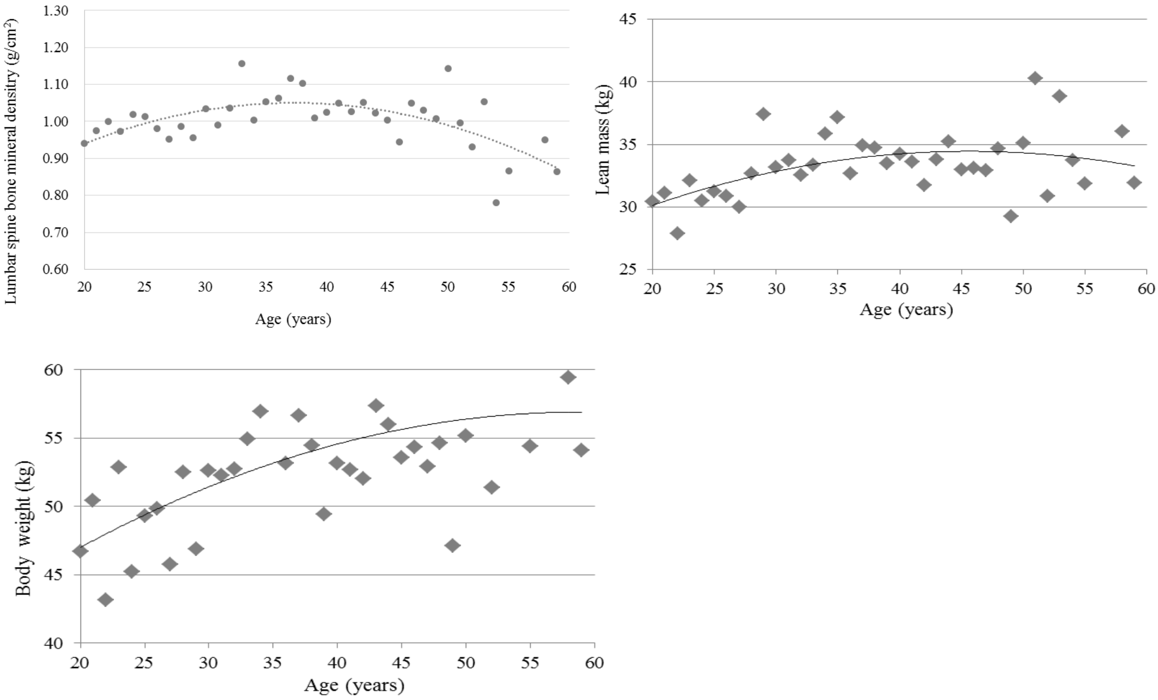


Figure 1. Polynomial curves of average total bone mineral density (BMD), subtotal BMD, lumbar spine BMD, lean body mass and body weight in individuals aged 20–59 years.

The polynomial curve formula for subtotal BMD was as follows:
$y = -0.0002x^2 + 0.0155x + 0.6403$.
Using this formula, peak BMD apparently occurred at 39 years of age (Fig. 1). Therefore, subjects were divided into the following age groups: 20–39 years (n = 97) and 40–59 years (n = 82).

Subtotal BMD in the 20–39-years-old group was significantly higher than that in the 40–59-years-old group, however, there was no significant difference in total BMD, lumbar spine BMD, lean body mass or body weight between groups (Table I). Total BMD, subtotal BMD, lumbar spine BMD, lean body mass and body weight were all positively correlated to age in the 20–39-years-old group (Table II), but total BMD, subtotal BMD and lumber spine BMD were negatively correlated to age in the 40–59-year-old group (Table III). In the 20-39-years-old group, total BMD, subtotal BMD and lumbar spine BMD were positively correlated to lean body mass or body weight (Table II). However, subtotal BMD and lumber spine BMD were positively correlated to lean body mass in the 40-59-years-old group (Table III).

Table I. Comparison of measurements between groups

	20-39 years old mean ± SD	40-59 years old mean ± SD	*p* -value
Total BMD (g/cm^2)	1.086 ± 0.075	1.066 ± 0.099	0.128
Subtotal BMD (g/cm^2)	0.900 ± 0.057	0.877 ± 0.072	0.020
Lumbar spine BMD (g/cm^2)	1.017 ± 0.100	0.993 ± 0.129	0.180
Lean body mass (kg)	32.943 ± 3.829	33.653 ± 3.679	0.210
Body weight (kg)	52.610 ± 7.548	54.729 ± 7.123	0.056

All data are expressed as mean ± SD. Abbreviation: BMD, bone mineral density.

Table II. Outcomes of Pearson's correlation analysis in the 20–39-years-old group

	Age	Body weight	Lean body mass
Total BMD（g/cm^2)	0.387 **	0.309 **	0.345 **
Subtotal BMD（g/cm^2)	0.278 **	0.45 **	0.469 **
Lumbar spine BMD（g/cm^2)	0.395 **	0.465 **	0.419 **
Lean body mass (kg)	0.376 **	0.376 **	
Body weight (kg)	0.313 **		

**Significant correlation. Abbreviation: BMD, bone mineral density.

Table III. Outcomes of Pearson's correlation analysis in the 40–59-years-old group

	Age	Body weight	Lean body mass
Total BMD（g/cm^2)	-0.388 **	0.064	0.162
Subtotal BMD（g/cm^2)	-0.391 **	0.182	0.331 **
Lumbar spine BMD（g/cm^2)	-0.384 **	0.156	0.290 **
Lean body mass (kg)	-0.037	0.787 **	
Body weight (kg)	0.139		

**Significant correlation. Abbreviation: BMD, bone mineral density.

DISCUSSION

In this study, we divided the subjects into 2 age groups—20–39 years and 40–59 years on the age of peak BMD. Total BMD, subtotal BMD and lumbar spine BMD in the 20–39-years-old group were related to lean body mass and body weight. However, the 40–59-years-old group demonstrated a different result; subtotal BMD and lumbar spine BMD were related to lean body mass but not to body weight. These results suggest that subtotal BMD can be substituted for lumbar spine BMD to predict osteoporosis.

In the 20–39-year-old group, the age was positively correlated with total BMD, subtotal BMD, lumbar spine BMD, lean body mass and body weight, whereas in the 40–59-years-old group, the age was negatively correlated with total BMD, subtotal BMD and lumbar spine BMD. The previous study (17) reported a negative correlation between age and subtotal BMD or lean body mass. Such discrepancy may be explained by the inclusion of older subjects (up to 78 years of age) in the previous study.

Subtotal BMD was found to be relatively high in the 20–39-years-old group. In this group, subtotal BMD, as well as total BMD and lumbar spine BMD, was positively correlated with lean body mass and body weight. However, subtotal BMD and lumbar spine BMD were positively correlated with lean body mass in the 40-59-years old group. Polynomial curves for subtotal BMD, lumbar spine BMD and lean body mass gradually increased with age, followed by an age-bound decrease. Therefore, the correlation between subtotal BMD and lean body mass appeared to be similar in both age groups. Lean body mass was similar in individuals aged 20–49 years and the age at maximum body weight was 40–49 years (18). No significant difference in lean body mass (19) and body weight (19, 20) were reported between post- and peri-menopausal women. In this study, the positive correlations of subtotal BMD and lumbar spine BMD with body weight were observed in the 20-39-years-old group but not in the 40-59-years-old group. As body weight is composed of fat and lean body mass, it might be more variable than lean body mass in each age group.

Because low BMD during the growth period is a risk factor for future osteoporosis (21), subtotal BMD at the age of 20–39 years is an important factor. Both lean body mass and body weight were found to be correlated with subtotal BMD at this time period; thus, lean body mass and body weight exerted great effects on subtotal BMD at the age of 20–39 years. On the other hand, lean body mass exerted effects on subtotal BMD at the age of 40-59 years.

Lifestyle habits, which should have been investigated in the present study, are one of our future targets. Nonetheless, hospital workers were selected as the test subjects due to their relatively constant lifestyle and workload. Exercise is known to improve muscle strength (22) and increase lean body mass. The increase in lean body mass is a sign of the increase in subtotal BMD, as shown in this study.

In conclusion, lean body mass and body weight exerted great effects on subtotal BMD in 20-39-years-old group, but only lean body mass did in 40-59-years-old group. Therefore, lean body mass may be a useful parameter to detect changes in subtotal BMD of female adults.

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