Environ Health Prev Med (2009) 14:46–51
DOI 10.1007/s12199-008-0056-7

REGULAR ARTICLE

# Correlation between bone mineral density and body composition in Japanese females aged 18–40 years with low forearm bone mineral density

**Misao Arimatsu · Takao Kitano · Naoko Kitano · Makoto Futatsuka**

Received: 22 January 2008 / Accepted: 30 September 2008 / Published online: 11 November 2008

**Abstract**

*Objectives* To clarify the relationship between bone mineral density (BMD) and body composition in Japanese women aged 18–40 years with low forearm BMD.

*Methods* The subjects were Japanese199 women who had been selected for inclusion in the study based on a low forearm BMD determined at the Annual Women's Health Examination. The subjects' mean (± standard deviation) age, body height, body weight, and body mass index (BMI) were 33.5 (±4.3) years, 158.1 (±5.1) cm, 49.6 (±5.7) kg, and 19.8 (±2.1), respectively. The BMD of the lumbar spine, total body, and left arm were measured using dual-energy X-ray absorptiometry (DXA). Fat mass (FM), bone-free lean tissue mass (LTM), and body fat percentage (BF%) were measured simultaneously with DXA.

*Results* In the structural equation model, the standardized regression weights for the path from BMI to BMD of all sites were 0.273–0.434. Conversely, the BF% to BMD of the total body and left arm were −0.192 and −0.296, respectively. In multiple regression analysis, the FM index (FMI) was significantly associated with the BMD of the lumbar spine as a weight-bearing site. The LTM index (LTMI) was significantly associated with the BMD of the total body and left arm as a non-weight-bearing site.

*Conclusions* Young females with low forearm BMD had low body weight and BMI. Thinness was shown to be a risk factor for low BMD, in accordance with results reported elsewhere. A gain in body weight may have the effect of increasing BMD, but our results suggest that to increase BMD, the gain in body weight must include increases in LTM, and not FM alone.

**Keywords** Body composition · Bone mineral density · Cross-sectional study · Dual-energy X-ray absorptiometry · Young Japanese women

## Introduction

The World Health Organization has reported that osteoporosis is an important public health problem in developed countries [1]. In terms of the bone life cycle, bone mass reaches its peak in individuals during their 20s and 30s and then decreases with age.

Khan reported [2] that common causes of low bone mineral density (BMD) among premenopausal females include ovulatory disturbances and low body weight. In addition, while there are numerous reports of young females with low bone mass who are either athletes with menstrual disorders or females with anorexia nervosa [3–6], there are not many reports on young females in the general population with low bone mass [7].

It is well known that body weight is associated with BMD [8–14]. However, body weight is composed of fat

---

M. Arimatsu
Department of Fundamental Nursing, School of Health Sciences,
Kumamoto University, Kumamoto, Japan

T. Kitano (✉)
Department of Public Health,
Graduate School of Medical Sciences, Kumamoto University,
1-1-1 Honjo, Kumamoto 860-8556, Japan
e-mail: kitano@gpo.kumamoto-u.ac.jp

N. Kitano
Faculty of Environment and Symbiotic Sciences,
Prefectural University of Kumamoto, Kumamoto, Japan

M. Futatsuka
Kyushu University of Nursing and Social Welfare,
Kumamoto, Japan

mass (FM) and fat-free mass, and there is disagreement as to which has a greater effect on BMD [15–20]. VanItallie et al. [21] demonstrated that FM and fat-free mass unadjusted by body height are not suitable for use in the evaluation of body composition, since the effects of body height on FM or fat-free mass differ. One recommended method of adjusting for the effects of body height is to adjust FM and fat-free mass separately by body height [22, 23].

Fat-free mass is composed of bone mass and bone-free lean tissue mass (LTM). Fat mass, bone mass [or, more properly, bone mineral content (BMC)], and LTM can each be measured with dual-energy X-ray absorptiometry (DXA). Khosla et al. [15] suggested that the strength of the relation between BMD and LTM weakens when body height is corrected, because body height is closely correlated with LTM.

We previously studied the correlation between body composition and BMD of the forearm in young Japanese females aged 18 through 40 years who had undergone an Annual Women's Health Examination [24]. The results showed a positive correlation between BMD and body mass index (BMI) and an inverse correlation between BMD and body fat percentage (BF%). We therefore concluded that it is necessary to consider body composition when estimating BMD, especially in young females [24].

We conducted a secondary examination with the aim of clarifying the physical characteristics of females who had low forearm BMD in that initial health examination. We particularly focused on the relationship between body composition and BMD. The BMC, FM, and LTM were measured with DXA to evaluate body composition, and the FM and LTM indices were used because these took the effects of body height into consideration. The results of this study are reported here.

## Subjects and methods

### Subjects

The first study was conducted from April 1994 to March 1999 in Kumamoto City, Japan. During this period a total of 3460 females aged 18–40 years old participated in an Annual Women's Health Examination that included BMD measurements of the forearm (distal) by DXA (DTX-200; Osteometer, Toyo Medic, Japan). We collected data on females who were assessed as having low BMD based on a BMD cut-off point of 0.41 g/cm$^2$ on the forearm [25] in this first Annual Women's Health Examination. A total of 539 females were selected as targets for the second examination. These individuals were sent a letter recommending that they undergo the second examination. A total of 267 females underwent the second examination. However, 11 of these had undergone BMD measurements two or more times were excluded from the analysis. A further 51 cases were excluded from the second examination due to a history of chronic disease or taking medications known to affect bone metabolism (i.e., gynecologic disease, thyroid treatment, or rheumatic disease). Six other cases were excluded from the analysis because of a lack of data. Ultimately, 199 females met the inclusion criteria for the study.

This study was designed before the Ministry of Health, Labor and Welfare adopted Ethical Guidelines for Epidemiological Research was and conducted in conformity with the Helsinki Declaration. At the beginning of the examination, the purpose and procedure of the study were explained to the subjects, that they were free to withdraw at any time and that they were each to sign a consent form. The risk of exposure was explained to one pregnant participant, and her BMD was not measured.

### Measurements

Characteristics such as age, menstrual history, childbirth, and past history were recorded for each participant. Body height and body weight were measured with a scale and a stadiometer, respectively, just before the bone mass measurement , with the subject standing barefoot. The BMI (kg/m$^2$) was calculated as body weight (kg) divided by body height squared (m$^2$). The BMD (g/cm$^2$) of the lumbar spine (L2–4), total body, and left arm were measured by whole-body scanning with DXA (QDR-2000; Hologic, Waltham, MA). Body composition, namely FM (kg), LTM (kg), BMC (g), and BF% (%) was measured simultaneously with the measurement of BMD using DXA. The basic theory of measurement and the methodology for DXA technology have been described in detail elsewhere [26]. Total body BMD, FM, LTM, and BMC have been analyzed using results excluding those for the head mass [27].

Both FM and LTM were divided by body height squared (m$^2$) to give the FM index (FMI, kg/m$^2$) and LTM index (LTMI, kg/m$^2$). This model has been described in detail elsewhere [21–23].

### Statistical analysis

Data are indicated by mean ± standard deviation (SD). Pearson correlation coefficients were calculated in order to discuss correlations among the variables as body height, body weight, BMI, BF%, FM, LTM, total body BMC, BMD of total body, lumbar spine and left arm, FMI, and LTMI. In addition, as at the first examination, a hypothesized structural equation model (SEM) was formulated (Fig. 1), and standardized regression weights for BMI and

BF% obtained by DXA were calculated against BMD. Multiple regression analysis was used to test for the associations between BMD and body composition taking into account the FMI and LTMI. Statistical analyses were performed using SPSS ver.14.0 (SPSS Japan Inc, Tokyo). The SEM analyses were calculated with AMOS ver.5 (SPSS Japan). The results were considered to be significant when the *P* value was less than 0.05.

## Results

### Physiological characteristics

Table 1 shows the characteristics of the subjects for the second examination, as well as for the first examination participants who were not targeted for the second examination. Body weight, BMI, and BF% were significantly lower in the second examination subjects. Among the females targeted for the second examination, there was no statistically significant difference in characteristics between those who underwent the second examination and those who did not (data not shown).

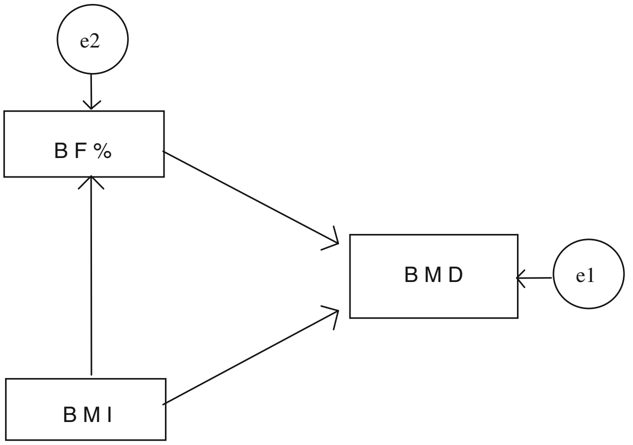

**Fig. 1** Relationship between body mass index (BMI), body fat percentage (BF%) and bone mineral density (BMD) using the structural equation model. *e1* error 1, *e2* error 2

**Table 1** Comparison of first examination results between those targeted and not targeted for the second examination

| Characteristics of subjects | Second examination | |
|---|---|---|
| | Not targets[a] ($n = 2921$) | Targets[b] ($n = 539$) |
| Age (year) | 33.2 ± 4.1 | 33.0 ± 4.2 |
| Body height (cm) | 157.7 ± 5.0 | 157.9 ± 5.0 |
| Body weight (kg) | 51.5 ± 7.0 | 48.4 ± 6.0** |
| BMI (kg/m$^2$) | 20.7 ± 2.7 | 19.4 ± 2.2** |
| BF%: by BIA (%) | 25.0 ± 5.5 | 23.1 ± 5.3** |

** $P < 0.01$; unpaired *t* test

All values are given as the mean ± standard deviation

BMI, Body mass index; BF%, body fat percentage; BIA, bioelectrical impedance analysis; BMD, bone mineral density

[a] BMD of the forearm (distal) more than 0.41 g/cm$^2$ at first examination

[b] BMD of the forearm (distal) below 0.41 g/cm$^2$ at first examination

Table 2 shows the characteristics of the subjects of the second examination. The BMI and the BF% were 19.8 ± 2.1 kg/m$^2$ and 27.7 ± 6.2%, respectively. In this subject cohort, 87.4% of female respondents had a regular menstrual cycle during the previous 6 months, and 84.4% had experienced childbirth. There were no differences in body height, body weight, BMI, FM, LTM, or BMC between females with and without a history of childbirth and abnormal menstrual cycles (data not shown).

The simple correlation coefficients of BMD of the forearm in the first examination with BMD of the total body, BMD of the lumbar spine, and BMD of the left arm were $r = 0.278$ ($P < 0.01$), $r = 0.225$ ($P < 0.01$), and $r = 0.263$ ($P < 0.01$), respectively.

### Body composition and bone mineral density

Table 3 shows the Pearson correlation coefficients among the variables, including body height, body weight, BMI, FM, LTM, total body BMC, BMD of total body, lumbar spine and left arm, FMI, and LTMI of the subjects. The BMD of the total body showed a significant positive correlation with all variables, with the exception of the FMI, and the BMD of the lumbar spine had a significant positive correlation with all variables, with the exception of body height. The BMD of the left arm exhibited a significant positive correlation with all variables except for BF% and FMI. The FM was positively correlated with body weight and BMI, respectively, but not with body height. In contrast, LTM was positively correlated with body weight, BMI, and body height, respectively. The correlation coefficients between FM and LTM, and between FMI and LTMI, were 0.169 ($P < 0.05$), and 0.137 ($P = 0.054$), respectively.

Evaluations of the influence of BMI and BF% on BMD are shown in Table 4, based on the SEM shown in Fig. 1. The standardized regression weights for path from BMI to BMD of all sites were 0.273–0.434. Conversely, BF% to BMD of the total body and the left arm were −0.192 and −0.296, respectively.

Table 5 shows the results of multiple regression analysis. The FMI was significantly associated with the BMD of the lumbar spine, while the LTMI was significantly associated with the BMD of the total body and left arm. The coefficient of determination was 0.053–0.102. The results of the analysis of variance showed the regression equation to be significant.

**Table 2** Subject characteristics ($n = 199$)

| Subject characteristics | Measurement values | | |
|---|---|---|---|
| | Mean ± standard deviation | Range | |
| | | Minimum | Maximum |
| Age (years) | 33.5 ± 4.3 | 19 | 40 |
| Age at menarche (years) | 12.9 ± 1.2 | 10 | 18 |
| Body height (cm) | 158.1 ± 5.1 | 143.4 | 175.0 |
| Body weight (kg) | 49.6 ± 5.7 | 34.7 | 66.6 |
| BMI (kg/cm$^2$) | 19.8 ± 2.1 | 15.9 | 27.4 |
| BF%: by DXA (%) | 27.7 ± 6.2 | 12.5 | 46.7 |
| FM: by DXA (kg) | 12.3 ± 4.0 | 5.0 | 27.4 |
| LTM: by DXA (kg) | 30.0 ± 2.9 | 20.2 | 38.3 |
| Total body BMC (g) | 1303.9 ± 163.2 | 937.9 | 1814.1 |
| BMD of total body (g/cm$^2$) | 0.847 ± 0.050 | 0.734 | 0.989 |
| BMD of lumbar spine (g/cm$^2$) | 0.969 ± 0.100 | 0.680 | 1.266 |
| BMD of left arm (g/cm$^2$) | 0.621 ± 0.033 | 0.520 | 0.716 |

DXA, Dual-energy X-ray absorptiometry; FM, fat mass; LTM, bone-free lean tissue mass; BMC, bone mineral content

All values are given as the mean ± standard deviation. Head mass was excluded from FM, LTM, and total body BMC, respectively

**Table 3** Pearson correlation coefficient among the variables of study subjects in second examination ($n = 199$)

| Variables | Body height | Body weight | BMI | BF% | FM | LTM | Total body BMC | FMI | LTMI |
|---|---|---|---|---|---|---|---|---|---|
| Body height | | 0.444** | −0.119 | −0.089 | 0.108 | 0.659** | 0.613** | −0.082 | −0.019 |
| Body weight | | | 0.836** | 0.577** | 0.794** | 0.672** | 0.684** | 0.711** | 0.497** |
| BMI | | | | 0.688** | 0.807** | 0.347** | 0.383** | 0.835** | 0.570** |
| BF% | | | | | 0.943** | −0.144** | 0.205** | 0.962** | −0.110 |
| FM | | | | | | 0.169* | 0.417** | 0.980** | 0.130 |
| LTM | | | | | | | 0.662** | 0.046 | 0.738** |
| Total body BMC | | | | | | | | 0.300** | 0.335** |
| FMI | | | | | | | | | 0.137 |
| BMD of total body | 0.296** | 0.373** | 0.232** | 0.058 | 0.186** | 0.371** | 0.849** | 0.128 | 0.233** |
| BMD of lumbar spine | 0.087 | 0.272** | 0.247** | 0.149* | 0.213** | 0.171* | 0.609** | 0.195** | 0.148* |
| BMD of left arm | 0.227** | 0.330** | 0.230** | 0.002 | 0.139* | 0.388** | 0.636** | 0.098 | 0.314** |

*$P < 0.05$, **$P < 0.01$

FMI, Fat mass index; LTMI, bone-free lean tissue mass

**Table 4** Standardized regression weight among BMD, BMI, and BF% by the structural equation model

| Path | BMD of total body | BMD of lumbar spine | BMD of left arm |
|---|---|---|---|
| BMD ← BMI | 0.365** | 0.273** | 0.434** |
| BMD ← BF% | −0.192* | −0.038 | −0.296** |
| BF% ← BMI | 0.688** | 0.688** | 0.688** |
| Squared multiple correlation | 0.073 | 0.062 | 0.099 |

*$P < 0.05$; **$P < 0.01$

## Discussion

The results of this study indicate an association between BMD and body composition in young females with low BMD in the general population. We compared the results of the first examination between two groups of females—those who were targeted for the second examination and those who were not. The targets of the second examination were found to have significantly a lower body weight, BMI, and BF% than those who were not targeted for the second examination and to have significantly lower body weight and BMI than those of similar age groups in the National Nutrition Survey of Japan [28, 29]. These results agree with those of previous studies reporting an association between body weight and BMD [8–14].

The correlation coefficients between the forearm BMD measured in the first examination and the total body, lumbar, and left arm BMD measured in this study were

**Table 5** Standardized regression coefficient of fat mass index and bone-free lean mass index in the multiple regression analysis

| Variables | BMD of total body | BMD of lumbar spine | BMD of left arm |
|---|---|---|---|
| FMI | 0.098 | 0.178* | 0.056 |
| LTMI | 0.220** | 0.123 | 0.306** |
| $R$ | 0.253 | 0.230 | 0.319 |
| $R^2$ | 0.064 | 0.053 | 0.102 |

$^*P < 0.05$; $^{**}P < 0.01$

$R$ multiple correlation coefficient, $R^2$ coefficient of determination

LTMI, Bone-free lean tissue mass index

0.225–0.278. While there are reports of a correlation coefficient of about 0.6 between forearm and lumbar spine BMD measured with DXA, the same apparatus as used in the first examination, there are also reports of a correlation coefficient of about 0.2 in studies of premenopausal females [30, 31]. Part of the reason for the low BMD values in the subjects included in our study was that young females were also included and we also limited enrollment to those with low forearm BMD. In addition, the devices used in the forearm and left arm measurements were different and, therefore, a simple comparison cannot be made. However, a correlation coefficient of 0.3 was reported in a study of female university students [31], indicating the difficulty of assigning a relation to all local measurement results and interpreting these.

Since the measurement of body weight includes FM, LTM, and bone mass, there is still some controversy on which measurement is the most effective in determining BMD—FM or LTM. Here we evaluated the relationship between BMD and body composition by BF%, FMI, and LTMI. The FMI and LTMI were adjusted for differences in the effect of body height on FM and LTM. VanItallie et al. [21] demonstrated that body height explained 2% of the variance in FM and 45% of the variance in fat-free mass. Our results show that the simple correlation coefficients of body height with FM and LTM were $r = 0.108$ ($P = 0.131$) and $r = 0.659$ ($P < 0.01$), respectively. In comparison, correlation coefficients of FMI and LTMI with body height were $r = -0.082$ and $-0.019$, respectively.

Among the results of this study, FMI was significantly correlated with BMD of the spine, and LTMI was significantly correlated with the BMD of the total body and left arm. Davis et al. [16] and Lee et al. [17] reported that FM was correlated with body weight-bearing sites because most FM applies a load and affects BMD. These findings agreed with our results.

On the other hand, Douchi et al. [18] indicated that total LTM was an important determinant of arm and lumbar spine BMD. Gordon et al. [19] found LTM to be the most important predictor of bone mineral in young adult females. Tudor-Locke [20] indicated that both LTM and FM contribute to increased compressive forces during skeletal loading but that LTM alone produces a tensile force on bone. In our study, LTMI showed a significant relation with the BMD of the left arm. The LTM we measured was truly LTM: this refers to nonfat soft tissue mass, not including bone tissue. A substantial proportion of LTM is muscle [32]. Thus, while both FM and LTM are loads that affect BMD, LTM is thought to also have a mechanical stress effect on bones.

It is also known that the most of the body weight gain after adulthood is from fat [33]. Ohmura et al. [34] showed that FM remains stable up to the age of 20–39 years and then increases up to the age of 50–59 years, as opposed to the LTM, which remains relatively constant throughout life. Thus, when the weight of people with low body weight increases, there is a strong likelihood that FM is a key factor in that increase. In the results of this study, BF% was negatively correlated with BMD. Takada et al. [35] reported that weight increases are ineffective in terms of BMD unless they include an increase in fat-free mass. In this context, increasing or maintaining LTM would seem to be more important. Other reports state that LTM decreases with age [36], suggesting that conscious effort is required to maintain LTM.

This study has a number of limitations. The subjects had low forearm BMD and, consequently, there was a bias toward a thin group. It is believed that this characteristic affected the low coefficient of determination of the structure equation model with BMI and BF%, and of the regression equation with FMI and LTMI. Moreover, this study was a cross-sectional one, and a further follow-up study will be necessary to clarify the relation between body composition and BMD.

In conclusion, young females with low forearm BMD had low body weight and low BMI. This result agrees with those of many previous reports, and we reconfirmed that thinness was one of the risk factors for low forearm BMD in young females. Additionally, an investigation of the relationship between body composition and BMD showed that BF% was negatively correlated with BMD and that both FMI and LTMI have a positive effect on skeletal loading. The LTMI also has a positive effect on non-skeletal loading. Thus, a gain in body weight may have the effect of increasing BMD. However, our result suggests that to increase BMD, the gain in body weight must include increases in LTM, and not FM alone.

**Acknowledgments** We thank the participants in this study.

## References

1. World Health Organization. Prevention and management of osteoporosis, technical report series, no. 921. Geneva: Switzerland; 2000.
2. Khan A. Premenopausal women and low bone density. Can Fam Physician. 2006;52:743–7.
3. Grinspoon S, Thomas E, Pitts S, Gross E, Mickley D, Miller K, et al. Prevalence and predictive factors for regional osteopenia in women with anorexia nervosa. Ann Intern Med. 2000;133:790–4.
4. Turner JM, Bulsara MK, McDermott BM, Byrne GC, Prince RL, Forbes DA. Predictors of low bone density in young adolescent females with anorexia nervosa and other dieting disorders. Int J Eat Disord. 2001;30:245–51.
5. Robinson TL, Snow-Harter C, Taaffe DR, Gillis D, Shaw J, Marcus R. Gymnasts exhibit higher bone mass than runners despite similar prevalence of amenorrhea and oligomenorrhea. J Bone Miner Res. 1995;10:26–35.
6. Davis MC, Hall ML, Jacobs HS. Bone mineral loss in young women with amenorrhoea. Br Med J. 1990;301:790–3.
7. Chijiwa M, Matsuo H, Maruo T. Characteristics of bone turnover in young women with low bone mineral density (in Japanese). Nihon Kounenki Igakkai Zasshi. 2002;10:207–15.
8. Hawker GA, Jamal SA, Ridout R, Chase C. A clinical prediction rules to identify premenopausal women with low bone mass. Osteoporos Int. 2002;13:400–6.
9. Salamone LM, Cauley JA, Black DM, Simkin-Sliverman L, Lang W, Gregg E, et al. Effect of a lifestyle intervention on bone mineral density in premenopausal women: a randomized trial. Am J Clin Nutr. 1999;70:97–103.
10. Michaelsson K, Bergstrom R, Mallmin H, Holmberg L, Wolk A, Ljunghall S. Screening for osteopenia and selection by body composition. Osteoporos Int. 1996;6:120–6.
11. Yoshimura N, Hashimoto S, Morioka S, Sakata K, Kasamatsu T, Copper C. Determinants of bone loss in a rural Japanese community: the Taiji study. Osteoporos Int. 1998;8:604–10.
12. Rico H, Arribas I, Casanova FJ, Duce AM, Hernández ER, Cortes-Prieto J. Bone mass, bone metabolism, gonadal status and body mass index. Osteoporos Int. 2002;13:379–83.
13. Komiya Y, Nakao H, Kuroda Y, Arizono K, Nakahara A, Miyauchi M, et al. Relationships of change in radius bone mineral density for seven years of working women around thirty years old with lifestyle, body measurement data and laboratory data (in Japanese). Nihon Eiseigaku Zasshi. 2006;61:327–31.
14. Uusi-Rasi K, Sievänen H, Pasanen P, Oja P, Vuori I. Association of physical activity and calcium intake with the maintenance of bone mass in premenopausal women. Osteoporos Int. 2002;13:211–7.
15. Khosla S, Atkinson EJ, Riggs BL, Melton LJ. Relationship between body composition and bone mass in women. J Bone Miner Res. 1996;11:857–63.
16. Davis JW, Novotny R, Wasnich RD, Ross PD. Ethnic, anthropometric, and lifestyle associations with regional variations in peak bone mass. Calcif Tissue Int. 1999;65:100–5.
17. Lee JS, Kawakubo K, Sato H, Kobayashi Y, Haruna Y. Relationship between total and regional bone mineral density and menopausal state, body composition and life style factors in overweight Japanese women. Int J Obes. 2001;25:880–6.
18. Douchi T, Yamamoto S, Nakamura S, Oki T, Maruta K, Nakae M, et al. Lean mass as a significant determinant of regional and total body bone mineral density in premenopausal women. J Bone Miner Metab. 1998;16:17–20.
19. Gordon CL, Webber CE. Body composition and bone mineral distribution during growth in females. Can Assoc Radiol J. 1993;44:112–6.
20. Tudor-Locke C, McColl RS. Factors related to variation in premenopausal bone mineral status: a health promotion approach. Osteoporos Int. 2000;11:1–24.
21. VanItallie TB, Yang MU, Heymsfield SB, Funk RC, Boileau RA. Height-normalized indices of the body's fat-free mass and fat mass: potentially useful indicators of nutritional status. Am J Clin Nutr. 1990;52:953–9.
22. Komiya S. Historical introduction and areas of body-composition research (in Japanese). Kenkou Kagaku. 1998;20:1–8.
23. Nakao T, Komiya S. Reference norms for a fat-free mass index and fat mass index in the Japanese child population. J Physiol Anthropol Appl Human Sci. 2003;22:293–8.
24. Arimatsu M, Kitano T, Kitano N, Inomoto T, Shono M, Futatsuka M. Correlation between forearm bone mineral density and body composition in Japanese females aged 18–40 years. Environ Health Prev Med. 2005;10:144–9.
25. Orimo H, Sugioka Y, Gorai I, Nakamura T, Fukunaga M, Hotokebuchi T, et al. Diagnostic criteria of primary osteoporosis (in Japanese). Nihon Kotsu Taisha Gakkai Zasshi. 1995;13:113–8.
26. Modlesky CM, Lewis RD, Yetman KA, Rose B, Rosskopf LB, Snow TK, et al. Comparison of body composition and bone mineral measurements from two DXA instruments in young men. Am J Clin Nutr. 1996;64:669–76.
27. Roubenoff R, Kehayias JJ, Dawson-Hughes B, Heymsfield SB. Use of dual-energy X-ray absorptiometry in body-composition studies: not yet a "gold standard". Am J Clin Nutr. 1993;58:589–91.
28. Ministry of Health, Labor and Welfare. Annual report of the National Nutrition Survey. Tokyo: Daiichi; 1997.
29. Ministry of Health, Labor and Welfare. Annual report of the National Nutrition Survey. Tokyo: Daiichi; 1998.
30. Minaguchi H, Gorai I, Taga M, Nakayama M, Tagauchi Y. Measurement of bone mineral density of radius by DTX-200 (OSTEOMETER) (in Japanese). Nippon Sanka Fujinka Gakkai Kanagawa Chihobukai Kaishi. 1995;32:12–6.
31. Kirimura T, Yoshimoto Y. Evaluation of bone mineral density at the total body, the upper limb, the distal 1/3 of the radius, and the ultra distal region of the radius and ulna by dual energy X-ray absorptiometry (in Japanese). CNAS Hyogo Bull. 1999;6:111–7.
32. Faulkner RA, Bailey DA, Drinkwater DT, Wilkinson AA, Houston CS, Mckay HA. Regional and total body bone mineral content, bone mineral density, and total body tissue composition in children 8–16 years of age. Calcif Tissue Int. 1993;53:7–12.
33. Tunenari T, Tsutsumi M, Ohno K, Yamamoto Y, Kawakatsu M, Shimogaki K, et al. Age- and gender-related changes in body composition in Japanese subjects. J Bone Miner Res. 1993; 8(4):397–402.
34. Ohmura A, Kushida K, Yamazaki K, Okamoto S, Katsuno H, Inoue T. Bone density and body composition in Japanese women. Calcif Tissue Int. 1997;61:117–22.
35. Takada H, Washino K, Iwata H. Risk factor for low bone mineral density among females: the effect of lean body mass. Prev Med. 1997;26:633–8.
36. Kim H, Tanaka K, Amagai H, Suzuki T. Age-related changes of body composition by dual-energy X-ray absorptiometry in Japanese men and women (in Japanese). Japan Taikugaku Kenkyu. 1999;44:500–9.