Low Serum Concentrations of 25-Hydroxyvitamin D in Young Adult Japanese Women: A Cross Sectional Study

Kazutoshi Nakamura, MD, MPH, Mitsue Nashimoto, BA, Shigeki Matsuyama, BA, and Masaharu Yamamoto, MD

From the Department of Community Preventive Medicine, Niigata University Graduate School of Medical and Dental Sciences, and the Atagonosono Nursing Home, Niigata, Japan

OBJECTIVES: The vitamin D nutrition status of young adult women is unclear, but a recent preliminary report suggested that they may have vitamin D insufficiency. This study assessed the serum concentrations of 25-hydroxyvitamin D (25[OH]D), an index of vitamin D nutrition status, in young adult Japanese women in comparison with those in older women and investigated whether serum 25(OH)D concentrations are associated with other calcium-related hormones and bone mass.

METHODS: A cross sectional study of 77 healthy women, age 19 to 66 y, working in nursing homes in Japan was conducted in the winter of 1999 and 2000. The investigation included blood tests, forearm bone mass measurements, and a lifestyle questionnaire.

RESULTS: The mean serum 25(OH)D concentration in women younger than 30 y was 34.0 nmol/L (standard deviation [SD] = 11.0) and significantly lower than that in women 30 y and older (50.0 nmol/L, SD = 14.4). The proportion of subjects younger than 30 y who had serum 25(OH)D concentrations less than 30 nmol/L was 42.1% and was significantly higher ($P < 0.001$) than the proportion of those 30 y and older (10.3%). There was a weak but significant linear association between serum 25(OH)D concentrations and forearm bone mineral content ($R^2 = 0.114$, $P = 0.0052$) but not between serum 25(OH)D concentrations and bone mineral density. The association held after adjusting for body weight ($R^2 = 0.139$, $P = 0.0111$). Serum intact parathyroid hormone concentrations were within the normal range and not associated with serum 25(OH)D concentrations.

CONCLUSIONS: Serum 25(OH)D concentrations in young adult Japanese women (<30 y old) are lower than those of older adult women (30 to 66 y), and lower serum 25(OH)D concentrations are likely associated with lower forearm bone mineral content. *Nutrition* 2001;17:921–925. ©Elsevier Science Inc. 2001

KEY WORDS: bone mineral content, female, 25-hydroxyvitamin D, Japanese, vitamin D insufficiency, young adult

INTRODUCTION

Vitamin D nutrition status, which is most closely reflected by the serum concentration of 25-hydroxyvitamin D (25[OH]D), the stable form of vitamin D metabolized in the liver,[1] is a topic currently of interest in relation to bone health. Insufficient serum concentrations of 25(OH)D are thought to lead to secondary hyperparathyroidism, which is a contributing factor to the age-related acceleration of bone loss.[2,3]

Vitamin D insufficiency is common in elderly people and seems to be a serious health problem.[4] Vitamin D insufficiency in the elderly has been explained mainly by an age-related decrease in serum 25(OH)D concentration, probably resulting from a reduction in vitamin D biosynthesis in the skin.[5,6] Contrary to expectations, low levels of serum 25(OH)D have been recently reported in young women.[7] In comparison with the large number of epidemiologic studies on the vitamin D nutrition in elderly women, however, there have been fewer studies in young women.

We reported low serum 25(OH)D concentrations in female Japanese college students,[7] but that study was not designed to compare the serum 25(OH)D concentrations of young adult women with those of their older counterparts. Environmental factors such as seasons and occupation (indoor versus outdoor) are important determinants of serum 25(OH)D concentration because of their relation to ultraviolet exposure and may have considerably affected the results of the study. Thus, a better designed epidemiologic study was needed to confirm our preliminary findings.

To address the question of whether young adult women have inadequate vitamin D nutrition status, we studied a wide age range of adult working women in the same setting. The purposes of the present study were to assess the serum 25(OH)D concentrations of young adult Japanese women in comparison with their older counterparts and evaluate the effects of low 25(OH)D concentrations by simultaneously evaluating other calcium-regulating hormones, in particular parathyroid hormone (PTH) and 1,25-dihydroxyvitamin D (1,25$[OH]_2$D), and bone mass.

Correspondence to: Kazutoshi Nakamura, MD, MPH, Division of Social and Environmental Medicine, Department of Community Preventive Medicine, Niigata University Graduate School of Medical and Dental Sciences, 1-757 Asahimachi-dori, Niigata City 951-8510, Japan. E-mail: kazun@med.niigata-u.ac.jp

0899-9007/01/$20.00
PII S0899-9007(01)00662-1

SUBJECTS AND METHODS

We targeted an accessible adult female population—127 healthy women working at three nursing homes in Niigata (latitude 37°48 to 59′N), Japan–and 80 (63.0%), aged 19 to 66 y, agreed to participate in this study. Three of the women were taking vitamin D supplements and were excluded. No subject was taking any sex steroid hormones or medication for osteoporosis. Ultimately, 77 women were included in the analysis. The subjects were engaged in ordinary daytime work, but 39 subjects were also on night duty four or five times a month. The day after night duty was always a day off. Informed consent was obtained from all subjects. No foods in Japan are fortified vitamin D. The design of this study was approved by the Ethics Committee of Niigata University School of Medicine.

The investigation was conducted in conjunction with a vitamin D nutrition study on the institutionalized elderly in the winter of 1999 to 2000 and included blood tests, bone mass measurements, and a lifestyle questionnaire. The subjects in nursing home A were examined in early December, those in home B in the late December, and those in home C in mid-February. The total hours of sunshine in the 5-wk period before each examination, which is thought to reflect current serum 25(OH)D concentrations,[8] were 107 (3.1 h/d), 52.2 (1.5 h/d), and 61.4 (1.8 h/d), respectively.

Non-fasting blood specimens were drawn from a cubital vein and promptly stored at approximately 5°C in a refrigerator. After centrifugation, the serum was frozen the same day and maintained at −80°C until the biochemical analyses were conducted, in March 2000. Serum 25(OH)D was determined by high-performance liquid chromatography.[9] The interassay coefficients of variation (CVs) were 4.2% for $25(OH)D_2$ and 2.6% for $25(OH)D_3$. We measured serum intact PTH to determine whether secondary hyperparathyroidism was present due to decreased serum 25(OH)D ($25[OH]D_2$ + $25[OH]D_3$) concentrations. Serum intact PTH was determined by two-site immunoradiometric assay (Nichols Institute Diagnostics, San Juan Capistrano, CA, USA).[10] The reference value of intact PTH in the laboratory was 1.06 to 6.90 pmol/L, and the interassay CV was 6.5%. Serum $1,25(OH)_2D_3$, to which $25(OH)D_3$ is converted in the kidney and which is the final activated form of vitamin D, was determined by radioimmunoassay (IDS Ltd., Boldon, England, UK; reference value = 48 to 144 pmol/L), with an interassay CV of 14.8%. The bone mineral content (BMC) and bone mineral density (BMD) of the nondominant forearm were measured in 74 subjects by dual-energy x-ray absorptiometry with a DTX-200 Osteometer (software version 1.54J, Osteometer MediTech A/S, Rødovre, Denmark).[11] The long-term CV value using the standard phantom was 0.7%.

A self-reported questionnaire on consumption of vitamin D–rich food, sunscreen use (yes or no), menstrual history, body weight, and current medication was administered to the subjects. The subjects were specifically asked to report the frequency of their consumption of vitamin D–rich foods, including fish, the major source of vitamin D in Japanese people,[12] and eggs by choosing one of the following: 0 = rarely (less than once/wk), 1 = sometimes (1 to 3 times/wk), or 2 = frequently (4 or more times/wk). The reliability of the self-reported weight of healthy Japanese women was confirmed previously.[13]

The mean and standard deviation (SD) were calculated for continuous variables. One of the aims of this study was to assess serum 25(OH)D levels in young women and compare these levels with those of older adult women. However, we do not have a clear definition for "young adult" with regard to vitamin D insufficiency. Therefore, the study population was divided into conventional 10-y age groups, and the average 25(OH)D levels of those groups were compared. Analysis of variance with Scheffé's multiple comparison test was used to test differences between any two mean values. The chi-square test was used for statistical evaluation of associations between two categorical sets of data. Simple and multiple linear regression analyses were used to evaluate the associations between serum 25(OH)D concentrations and predictor variables. Multiple regression analysis also was used for the statistical adjustment of the relation between bone mass and serum 25(OH)D concentrations. Subjects on occasional night duty were coded as 1 and the others as 0. The SAS statistical package (version 6.12) was used for the computations. $P < 0.05$ was considered statistically significant.

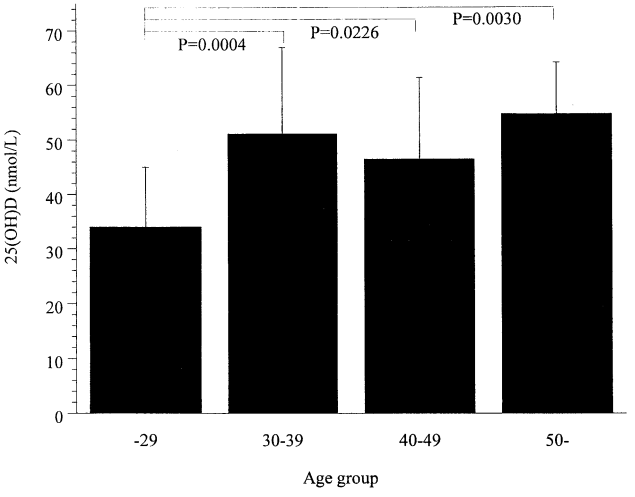

FIG. 1. The mean serum 25(OH)D concentrations of the 10-y age groups. The mean serum 25(OH)D concentrations in those younger than 30 y and those in their 30s, 40s, 50s, and older were 34.0 nmol/L (SD = 11.0), 51.1 nmol/L (SD = 15.8), 46.5 nmol/L (SD = 14.8), and 54.7 nmol/L (SD = 9.4), respectively. The mean serum 25(OH)D concentrations in those younger than 30 y was significantly lower than those in all other age groups. The mean serum 25(OH)D concentrations of those in their 30s, 40s, and 50s and older were not significantly different. 25(OH)D, 25-hydroxyvitamin D; SD, standard deviation.

RESULTS

The mean age of the subjects was 32.9 y (SD = 11.3), and their mean body weight was 52.0 kg (SD = 6.2). Subjects' average serum $25(OH)D_3$ concentration was 42.0 nmol/L (SD = 15.1). Serum $25(OH)D_2$ was detected in only three subjects (2.1, 2.4, and 3.1 nmol/L). The mean concentration of serum 25(OH)D, the sum of the serum $25(OH)D_3$ and $25(OH)D_2$ values, was 42.1 nmol/L (SD = 15.1). The mean serum 25(OH)D concentrations of the 10-y age groups are shown in Fig. 1. The mean serum 25(OH)D concentrations in those younger than 30 y (n = 38) and those in their 30s (n = 17), 40s (n = 15), and 50s and older (n = 7) were 34.0 nmol/L (SD = 11.0), 51.1 nmol/L (SD = 15.8), 46.5 nmol/L (SD = 14.8), and 54.7 nmol/L (SD = 9.4), respectively. The mean serum 25(OH)D concentrations in those younger than 30 y were significantly lower than those in all other age groups (P = 0.0004, 0.0226, and 0.0030, respectively). The mean serum 25(OH)D concentrations of those in their 30s, 40s, and 50s and older were not significantly different. In this paper, adult women younger than 30 y are referred to as "young adult women." Age was then divided into two categories: those younger than 30 y were coded as 0 and those 30 y and older as 1.

The proportions of subjects who had serum 25(OH)D concentration below 30 nmol/L, which is generally considered to represent vitamin D insufficiency,[14,15] were 16 of 38 (42.1%) among those younger than 30 y and 4 of 39 (10.3%) among those 30 y and older, and the difference was statistically different (χ^2 = 10.15, $P < 0.001$).

The lifestyle characteristics of those younger than 30 y and

TABLE I.

COMPARISONS OF THE LIFESTYLE CHARACTERISTICS OF WOMEN YOUNGER THAN 30 Y AND THOSE 30 Y AND OLDER

	<30 y	≥30 y
Frequency of fish consumption	$df = 2$, $\chi^2 = 7.59$, $P = 0.022$	
Frequently, ≥4 times/wk	2 (5.4%)	11 (29.7%)
Sometimes, 1–3 times/wk	29 (78.4%)	22 (59.5%)
Rarely, <1 time/wk	6 (16.2%)	4 (10.8%)
Frequency of egg consumption	$df = 2$, $\chi^2 = 0.24$, $P = 0.885$	
Frequently, ≥4 times/wk	12 (32.4%)	11 (29.7%)
Sometimes, 1–3 times/wk	23 (62.2%)	23 (62.2%)
Rarely, <1 time/wk	2 (5.4%)	3 (8.1%)
Use of sunscreen	$df = 1$, $\chi^2 = 0$, $P = 1.000$	
Yes	15 (40.5%)	15 (40.5%)
No	22 (59.5%)	22 (59.5%)
Night duty (4 or 5 times/mo)	$df = 1$, $\chi^2 = 19.77$, $P < 0.001$	
Yes	29 (76.3%)	10 (25.6%)
No	9 (23.7%)	29 (74.4%)

those 30 y and older are compared in Table I. Subjects 30 y and older consumed fish more frequently than did those younger than 30 y, and a higher proportion of them were engaged in night duty.

Simple linear regression analysis associated serum 25(OH)D concentrations to age group (<30 versus ≥30 y old; $R^2 = 0.283$, $P < 0.0001$), total hours of sunshine ($R^2 = 0.218$, $P < 0.0001$), fish consumption ($R^2 = 0.110$, $P = 0.0040$), body weight ($R^2 = 0.070$, $P = 0.0246$), and night duty ($R^2 = 0.0671$, $P = 0.0229$), and multiple linear regression analysis associated serum 25(OH)D concentrations with all variables but night duty (Table II).

To evaluate the underlying adverse effects of low 25(OH)D concentration on bone health in this population, associations between serum 25(OH)D concentrations and serum intact PTH concentrations, serum $1,25(OH)_2D_3$ concentrations, and forearm BMC and BMD were tested. The mean serum intact PTH and $1,25(OH)_2D_3$ concentrations of the subjects were 2.88 (SD = 1.33) and 111.1 (SD = 33.6), respectively. No subject had a high serum intact PTH level, but one subject had a serum $1,25(OH)_2D_3$ concentration below the reference value. Serum 25(OH)D concentrations were not significantly associated with serum intact PTH concentrations ($P = 0.0532$), but serum $25(OH)D_3$ was linearly associated with the serum $1,25(OH)_2D_3$ concentrations ($R^2 = 0.064$, $P = 0.0267$), as shown in Fig. 2. Age and weight were not linked to serum $1,25(OH)_2D_3$ concentrations. The mean forearm BMC and BMD values were 2.94 g (SD = 0.36) and 0.453 g/cm^2 (SD = 0.051), respectively.

To assess serum 25(OH)D concentrations in relation to forearm bone mass, the following analyses were conducted only in subjects younger than 50 y ($n = 70$) because the bone mass of women decreases rapidly thereafter. Serum 25(OH)D concentrations were linearly associated with BMC ($R^2 = 0.114$, $P = 0.0052$; Fig. 3) but not significantly associated with BMD ($P = 0.2597$). Univariate analysis also associated BMC to weight ($R^2 = 0.082$, $P = 0.0231$). Serum 25(OH)D concentration was still a significant predictor ($R^2 = 0.139$, $P = 0.0111$) of BMC after adjusting for weight. BMC and BMD were not significantly associated with age group, serum intact PTH, or $1,25(OH)_2D_3$ concentrations.

TABLE II.

INDEPENDENT VARIABLES FOR SERUM 25-HYDROXYVITAMIN D CONCENTRATION (NMOL/L), SELECTED FROM THE SUBJECTS' AGE GROUP, TOTAL HOURS OF SUNSHINE, FISH CONSUMPTION, NIGHT DUTY, AND WEIGHT BY THE STEPWISE PROCEDURE OF MULTIPLE REGRESSION ANALYSIS

Independent variable	Regression coefficient	SE	R^2	P
Age group*	10.5	2.9	0.272	0.0005
Total hours of sunshine	0.22	0.059	0.129	0.0004
Fish consumption†	6.7	2.5	0.044	0.0086
Weight (kg)	0.52	0.22	0.042	0.0225

* Those younger than 30 y are coded as 0, and those 30 y and older as 1.

† Frequency of fish consumption is categorized as follows: 0 = rarely (less than once/wk), 1 = sometimes (1–3 times/wk), and 2 = frequently (≥4 times/wk).

SE = standard error

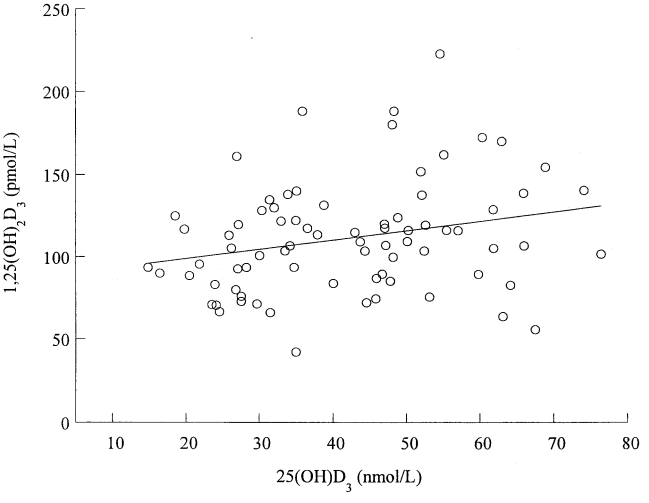

FIG. 2. Scatterplot of serum $25(OH)D_3$ versus $1,25(OH)_2D_3$ concentrations. The regression equation is $Y = 87.7 + 0.557X$ (Y: $1,25[OH]_2D_3$ [pmol/L], X: $25[OH]D_3$ [nmol/L], $R^2 = 0.063$, $P = 0.0280$). $1,25(OH)_2D_3$, 1,25-dihydroxyvitamin D_3; $25(OH)D_3$, 25-hydroxyvitamin D_3.

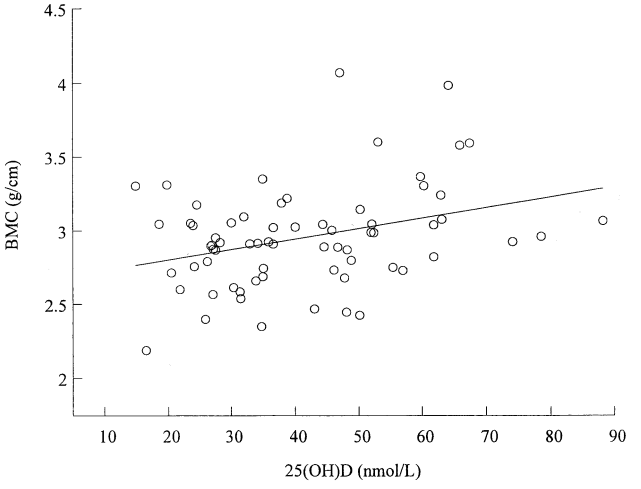

FIG. 3. Scatterplot of serum 25(OH)D concentrations versus forearm BMC (g). The regression equation is $Y = 2.64 + 0.00772X$ (Y: BMC [g], *X*: 25[OH]D [nmol/L], $R^2 = 0.114$, $P = 0.0052$). 25(OH)D, 25-hydroxyvitamin D; BMC bone mineral content.

DISCUSSION

The present study clearly demonstrated that the women younger than 30 y had lower serum 25(OH)D concentrations (mean = 34.0 nmol/L) than the women aged 30 to 66 y. This finding conflicts with the current belief that vitamin D nutrition status, i.e., that serum 25(OH)D concentrations decrease with age.[5,6] Moreover, when a serum 25(OH)D concentration cutoff value of 30 nmol/L was adopted, the prevalence of vitamin D insufficiency in women in their 20s was 42.1%, which is close to the rate (40.3%) in a previous study of female junior college students.[7] Although there have been few studies on vitamin D nutrition status in young adult women, Harris and Dawson-Hughes[16] reported low 25(OH)D concentrations (mean = 30.2 nmol/L in winter) in young adult black women (20 to 40 y old).

The reason the young adult Japanese women had low serum 25(OH)D concentrations needs to be addressed. We first speculated that differences in food preferences between generations might be contributory: young people consume less fish than older people. Multivariate analysis, however, showed that young adult women's low concentration of serum 25(OH)D was independent of frequency of fish consumption. Thus, frequency of fish consumption was not a significant factor in the low serum 25(OH)D concentrations of the young adult women. We did not evaluate the actual amount of fish intake, and we still suspect that low fish intake might have been responsible for the young adult women's low serum 25(OH)D concentrations because fish consumption in winter is a crucial factor in maintaining appropriate serum 25(OH)D concentrations in Japanese women.[12] Young women's specific eating behavior in relation to dieting[17] may be another contributory factor to their potential low intake of vitamin D in food.

There may have been a difference in outdoor activity between those younger than 30 y and those 30 y and older. Univariate analysis associated night duty with low serum 25(OH)D concentrations, but multivariate analysis did not. Although night duty was more prevalent in those younger than 30 y, restriction of outdoor activities by once-a-week night duty is unlikely to have greatly affected endogenous $25(OH)D_3$ production. Thus, such an explanation is hard to accept because all subjects were working in a similar occupational setting. Our data did not demonstrate any importance of sunscreen use on serum 25(OH)D concentrations. In the end, we were unable to clearly identify any causal factors responsible for the lower concentration of serum 25(OH)D in the young adult women.

Studies targeting middle-aged and elderly populations have shown positive associations between serum 25(OH)D concentrations and BMD at various bone sites.[18–21] This relation seems to be attributable to hyperparathyroidism secondary to the low serum 25(OH)D concentrations.[18] Our data showed that serum 25(OH)D concentrations in women, including young adults, were associated with forearm BMC. We recently reported that young adult women with vitamin D insufficiency had lower calcaneal bone mass as measured by quantitative ultrasound densitometry.[7] These results suggest that vitamin D nutrition status affects the bone mass of young women. Because hyperparathyroidism was not found in these subjects, other as yet unknown mechanisms may exist. Serum $25(OH)D_3$ concentrations have not been reported to have clear, direct biological effects, and thus their interactions with other calcium-regulating factors or female reproductive hormones may play a role. $1,25(OH)_2D_3$ may be a clue. Our data demonstrated that serum $25(OH)D_3$ concentrations reflected the serum $1,25(OH)_2D_3$ concentrations, although we did not find serum $1,25(OH)_2D_3$ concentrations to be associated with BMC.

The present study demonstrates that serum 25(OH)D concentrations are associated with weight-adjusted BMC, but not with BMD. An explanation for this observation is challenging. BMC is involved in the projected area; thus, BMC reflects the bone size of individuals. Low serum 25(OH)D concentrations may be correlated with bone size independent of body size. The site of measurement also might have influenced the findings. We measured BMD in the forearm, which is rich in cortical bone. Measuring BMD at this site may be less sensitive for detecting BMD differences than at other bone sites with more spongy bone. The lack of an association between serum 25(OH)D concentration and forearm BMD in an elderly Japanese women has been reported.[22]

In contrast, Oliveri et al.[23] reported that peripheral bone mass is not affected by low vitamin D concentration in young adults during winter. They interpreted their findings as adequate calcium intake compensating for a vitamin D deficit. In that context, the present association between serum 25(OH)D concentrations and BMC is convincing because the calcium intake of adult Japanese women is estimated to be as low as 400 to 600 mg/d.[24] In any event, vitamin D is recognized as having a critically important role in the development, growth, and mineralization of the skeleton in young people,[1] and thus the effects of low serum 25(OH)D concentrations on the bone health of young adult women should be clarified.

There may be another explanation of the present results. Problem eating behaviors of young women, such as dieting,[17] may lead to hypovitaminosis D, as a result of low vitamin D intake, and low bone mass, as a result of low calcium intake. This idea is supported by Van Loan and Keim's[25] recent finding of lower BMC values in women with high levels of cognitive eating restraint. They hypothesized that cognitive eating restraint triggers changes in women's reproductive hormones, such as lower progesterone concentrations, which in turn may cause lower BMC values.

Our study targeting women between 19 and 66 y old produced the following findings: 1) the mean serum 25(OH)D concentration of women younger than 30 y was significantly lower than those of their older counterparts; 2) the proportions of subjects who had serum 25(OH)D concentration below 30 nmol/L were 42.1% among those younger than 30 y and 10.3% in those 30 y and older, a significant difference; 3) serum $25(OH)D_3$ concentrations were significantly, linearly associated with serum $1,25(OH)_2D_3$ concentrations; and 4) serum 25(OH)D concentrations (in women younger than 50 y) were significantly, linearly associated with forearm BMC.

In conclusion, serum 25(OH)D concentrations in young adult Japanese women are lower than in their older counterparts (30 to 66 y), and vitamin D insufficiency seems more prevalent. In addition, lower serum 25(OH)D concentrations appear to be asso-

ciated with lower forearm BMC. The mechanisms responsible for these findings should be explored further by assessing biochemical markers of bone turnover.

ACKNOWLEDGMENTS

The authors thank the staffs of the nursing homes Atagonosono, Honaminosato, and Hoseien for their helpful assistance in data collection. They also thank Toyo Medic Inc. for allowing us to use the DTX-200 Osteometer.

REFERENCES

1. Holick MF. Vitamin D and bone health. J Nutr 1996;126:1159S
2. Freaney R, McBrinn Y, McKenna MJ. Secondary hyperparathyroidism in elderly people: combined effect of renal insufficiency and vitamin D deficiency. Am J Clin Nutr 1993;58:187
3. Chapuy MC, Schott AM, Garnero P, et al. Healthy elderly French women living at home have secondary hyperparathyroidism and high bone turnover in winter. J Clin Endocrinol Metab 1996;81:1129
4. Gloth FM III, Tobin JD. Vitamin D deficiency in old people. J Am Geriatr Soc 1995;43:822
5. Burnand B, Sloutskis D, Gianoli F, et al. Serum 25-hydroxyvitamin D: distribution and determinants in the Swiss population. Am J Clin Nutr 1992;56 537:
6. Dubbelman R, Jonxis JHP, Muskiet FAJ, Saleh AEC. Age-dependent vitamin D status and vertebral condition of white women living in Curaçao (The Netherlands Antilles) as compared with their counterparts in The Netherlands. Am J Clin Nutr 1993;58:106
7. Nakamura K, Nashimoto M, Tsuchiya Y, et al. Vitamin D insufficiency in Japanese female college students: a preliminary report. Int J Vitam Nutr Res. (in press)
8. Chen TC. Photobiology of vitamin D. In: Holick MF, ed. *Vitamin D: physiology, molecular biology, and clinical applications.* Totowa, NJ: Humana Press, 1999:17
9. Okano T, Mizuno N, Shida S, et al. A method for simultaneous determination of 25-hydroxyvitamin D_2 and 25-hydroxyvitamin D_3 in human plasma by using two steps of high-performance liquid chromatography. J Nutr Sci Vitaminol 1981; 27:43
10. Nussbaum SR, Zahradnik RJ, Lavigne JR, et al. Highly sensitive two-site immunoradiometric assay of parathyrin, and its clinical utility in evaluating patients with hypercalcemia. Clin Chem 1987;33:1364
11. Kelly TL, Crane G, Baran DT. Single X-ray absorptiometry of the forearm: precision, correlation, and reference data. Calcif Tissue Int 1994;54:212
12. Nakamura K, Nashimoto M, Hori Y, Yamamoto M. Serum 25-hydroxyvitamin D concentrations and related dietary factors in peri- and postmenopausal Japanese women. Am J Clin Nutr 2000;71:1161
13. Nakamura K, Hoshino Y, Kodama K, Yamamoto M. Reliability of self-reported body height and weight of adult Japanese women. J Biosoc Sci 1999;31:555
14. Van der Wielen RPJ, Löwik MRH, van der Berg H, et al. Serum vitamin D concentrations among elderly people in Europe. Lancet 1995;346:207
15. Chapuy MC, Preziosi P, Maamer M, et al. Prevalence of vitamin D insufficiency in an adult normal population. Osteoporos Int 1997;7:439
16. Harris SS, Dawson-Hughes B. Seasonal changes in plasma 25-hydroxyvitamin D concentrations of young American black and white women. Am J Clin Nutr 1998;67:1232
17. Nakamura K, Hoshino Y, Watanabe A, et al. Eating problems and related weight control behaviours in adult Japanese women. Psychother Psychosom 1999;68:51
18. Lukert BP, Carey M, McCarty B, et al. Influence of nutritional factors on calcium-regulating hormones and bone loss. Calcif Tissue Int 1987;40:119
19. Ooms ME, Lips P, Roos JC, et al. Vitamin D status and sex hormone binding globulin: determinants of bone turnover and bone mineral density in elderly women. J Bone Miner Res 1995;10:1177
20. Collins D, Jasani C, Fogelman I, Swaminathan R. Vitamin D and bone mineral density. Osteoporos Int 1998;8:110
21. Stone K, Bauer DC, Black DM, et al. Hormonal predictors of bone loss in elderly women: a prospective study. The Study of Osteoporotic Fractures Research Group. J Bone Miner Res 1998;13:1167
22. Nakamura K, Nashimoto M, Yamamoto M. Are the serum 25-hydroxyvitamin D concentrations in winter associated with forearm bone mineral density in healthy elderly Japanese women? Int J Vitam Nutr Res 2001;71:25
23. Oliveri MB, Wittich A, Mautalen C, Chaperon A, Kizlansky A. Peripheral bone mass is not affected by winter vitamin D deficiency in children and young adults from Ushuaia. Calcif Tissue Int 2000;67:220
24. Fujita T. Osteoporosis in Japan. factors contributing to the low incidence of hip fracture. Adv Nutr Res 1994;9:89
25. Van Loan MD, Keim NL. Influence of cognitive eating restraint on total-body measurements of bone mineral density and bone mineral content in premenopausal women aged 18–45 y: a cross sectional study. Am J Clin Nutr 2000;72: 837