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Longitudinal Measurements of Bone Density in Adolescent Girls and Intervention in Diet

Keiko Minamimae, Takako Maeda and Tsunakiyo Kasagi

Department of Women's and Children's Family Nursing, Faculty of Medicine, Tottori University, Yonago 683-0826 Japan

Ca intake raises bone mineral density (BMD) in adolescence. The present study aimed at improving BMD in adolescent girls by increasing Ca intake from foods, and developing a supportive method for keeping this eating habit. In July of 1997 and 1998, BMD of the left os calcis was measured by ultrasound bone densitometry in 55 college girls respectively in the 1st and 2nd grades by calculating levels of stiffness which served as the index for BMD. We told them the analyzed results both times, giving instruction in life-style for preventing osteoporosis in 1997 and explanation about Ca-rich foods in 1998. After the measurement in 1998, we selected 11 girls with low BMD for the following intervention in diet (intervention group): i) kind and amount of Ca-rich foods were daily recorded for 4 weeks; ii) difference between the calculated intake and necessary level was told; and iii) subjects were continually encouraged to take daily necessary level from foods. Then, BMD of the intervention group was measured 12 weeks after. Further, in 1999, we measured BMD for the intervention group and 10 selected students with normal BMD in the 2nd grade (non-intervention group). Mean stiffness was significantly lower ($P < 0.01$) in the 2nd grade than in the 1st. In the 2nd grade, the intervention group showed a significantly higher mean 12 weeks after than in July. In the 3rd grade, the decrease in stiffness was stopped in both groups. The longitudinal measurements of BMD over a 2-year period made adolescent girls recognize the decreasing tendency of BMD. We conclude that adolescent girls can maintain BMD by utilizing their knowledge of preventing osteoporosis and by taking ample Ca from foods.

Key words: adolescent girl; bone density; dietary guidance; longitudinal measurement

Bone mineral density (BMD) in women rapidly decreases after menopause, and the risk of having osteoporosis or bone fracture becomes higher. To prevent these diseases, it is important to increase the maximum BMD in adolescence and to maintain a healthy level (Hirota and Hirota, 1995). There are many factors affecting BMD; particularly, what is most important is eating habits (Irie et al., 1996; Yoshida et al., 1997). These days, however, young females are inclined to miss meals in order to lose weight, and therefore imbalance in diet is often produced in the population (Maruyama et al., 1993). In 1997, after passing out a booklet, we lectured female students on critical BMD at Tottori University College of Medical Care Technology; 6 weeks after, their Ca intake increased and stiffness rose significantly (Maeda and Kitagawa, 1997). However, their Ca intake decreased 12 weeks after to the same level as before our guidance. To get them to retain good health-keeping behavior firmly on a daily basis was a problem which had to be solved in the study.

To improve adolescent female BMD and to sustain the normal level, we carried out longitudinal measurements of BMD in adolescent girls, intervened in their eating habits and did a follow-up to investigate the effects over a 2-year period.

Abbreviations: BMD, bone mineral density; BUA, broadband ultrasound attenuation; SOS, speed of sound

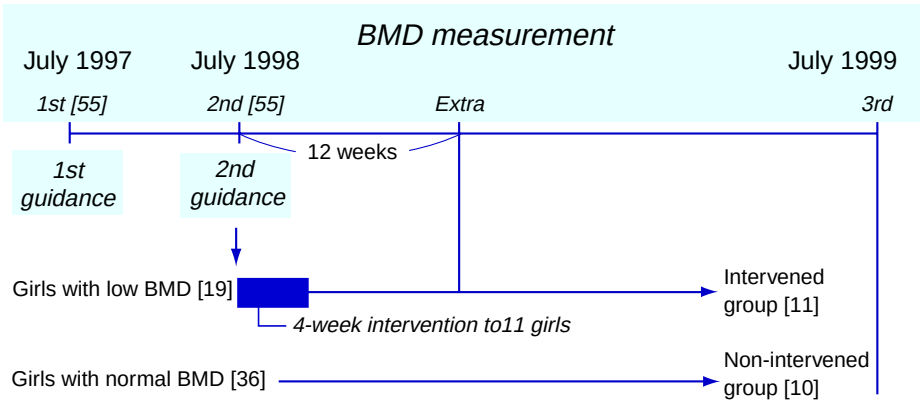

Fig. 1. Schema of study and subjects. The extra measurement of BMD 12 weeks after the 2nd measurement for the intervention group followed our 4-week intervention into the group.

Subjects and Methods

First-grade BMD measurement and 1st guidance

To measure BMD, we recruited volunteers out of the 80 female students in the 1st grade at Tottori University College of Medical Care Technology. We measured BMD of the left os calcis by the Achilles ultrasound bone densitometer (A-1000 PLUS, Lunar Corp., Madison, WI) by calculating levels of stiffness from the SOS and BUA, which serve as the indices for BMD (Yamazaki et al., 1992). The densitometer was self-managed by the subjects using the phantom of the heel once a week or more. The accuracy of the densitometer was examined in 5 volunteers by measuring their BMD 3 times a week: the coefficient of variation we observed was $2.0 \pm 1.3\%$. Fifty-five girls voluntarily applied, and their BMD was measured in July 1997 (Fig. 1); at the same time, we requested them to fill out questionnaires and to be interviewed by us. At the end of the session, BMD data were delivered to respective girls together with guidance booklets containing an explanation of the onset mechanism of osteoporosis, the need to increase BMD and methods for getting the maximum level, for example, eating foods rich in Ca, protein or vitamin D, taking substances which inhibit Ca assimilation, and understanding the need for exercise and sunbathing (1st guidance).

The questionnaire covered the following topics: i) condition of the body and health—height, weight, age of menarche and regularity in the menstrual cycle; ii) life-style—smoking or nonsmoking, frequency of taking alcohol and coffee, and duration of sunbathing, and iii) the kind of exercise, its duration and frequency. During the personal interview, we focused on the kind and amount of foods they had taken the day before.

Second-grade BMD measurement and 2nd guidance

In July 1998, we measured BMD again in the same subjects. Personal data and another booklet were delivered similarly at the end of the measurement. The contents of the booklet showed Ca-rich foods and recipes (2nd guidance).

Intervention in diet

As for the BMD index, we used stiffness of the bone calculated from the combined data of speed of sound (SOS) and broadband ultrasound attenuation (BUA); the mean for 20-

year-old Japanese females is 92 (Yamazaki et al., 1992). From the 2nd-grade students, we selected 19 girls with stiffness lower than 92 (Fig. 2), and explained the method of intervention. We obtained consent from 11 girls, and carried out the following intervention in their diet (intervention group; $n = 11$): i) the subjects recorded the kind and amount of Ca-rich foods they ate every day for 4 weeks; ii) we collected the data once a week, calculated Ca intake, and told them the results; and iii) as we informed them of the data, we encouraged their efforts and got them to confirm the next week's goal by discussing with them. Twelve weeks after, we re-measured BMD.

The name and daily intake of Ca-rich foods we requested the students to write were fish, sea weed, cow milk, dairy products, *tofu*, small fry, *komatsuna*, leaves of Chinese white radish and turnip and other brightly colored vegetables. We calculated their Ca intake every week, and told them how excessive or insufficient they were from the daily amount necessary for adolescent Japanese girls (600 mg). In the case of insufficiency, we advised those students to set a goal for the next week where they could resolve the insufficiency.

Third-grade BMD measurement

In July 1999, BMD was measured again when the students were in the 3rd grade. This time, we randomly selected 10 girls (non-intervention group) from those whose stiffness in the 2nd grade exceeded 92 (mean at 20 years of age). Stiffness ranged from 92 to 111 in the non-intervention group ($n = 10$), and from 67 to 87 in the intervention group ($n = 11$) (Fig. 1).

The amounts of food elements were calculated with a computing program NUTAS 4 (Nankodo, Tokyo, Japan). Statistical analysis was done with software StatView, Version 4 (Abacus Concepts Inc., Berkeley, CA).

Results

First-grade BMD and affecting factors

The 55 girl students showed a mean (± SD) of 98.64 ± 11.63 for stiffness (Fig. 3).

Physical conditions, health and BMD

The subjects ranged from 18 to 20 years in age, 147 to 171 cm in height (mean, 157.5 cm) and 41 to 63 kg in weight (49.9 kg). The mean age of menarche was 12.4 years. The menstrual cycle was "quite irregular" in 11 girls, "some-

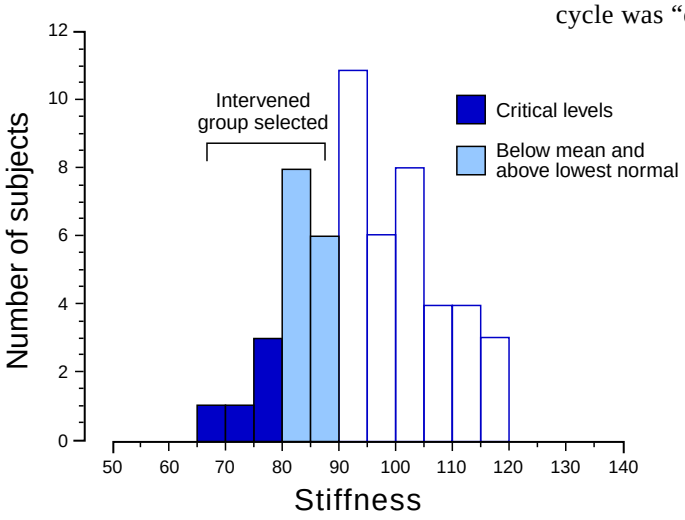

Fig. 2. Number of subjects classified by stiffness. Subjects for the intervention group were selected from girls with critical levels (67–79) and with levels above the lowest normal and below the mean at 20 years of age (80–87).

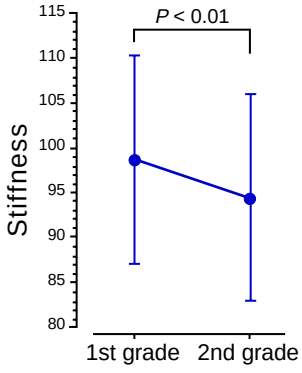

Fig. 3. Change in stiffness of 55 female subjects measured in the 1st and the 2nd grades. Shown are mean ± 1SD. The difference is significant ($P < 0.01$).

times shortened or lengthened" in 29 girls and "regular" in 15 girls. Stiffness showed no significant relation to body height, weight or menarche. There was no significant difference between the mean for stiffness and regularity in menstrual cycle.

Life-style and BMD

Among the 55 subjects, there was a habitual smoker ("I smoke every day"), and the remaining 54 students were nonsmokers. The frequency of drinking alcohol was "once or twice a week" in 4 girls and "sometimes" in 30 girls; 21 girls did not drink. The habit of coffee drinking was "negative" in 11 girls, "sometimes" in 23 girls, "1 to 2 cups a week" in 11 girls and "3 to 5 cups a week" in 10 girls. The daily total of sunbathing was less than 60 min in 34 girls, and 60 min or more in 21 girls. The frequency of smoking, drinking alcohol or coffee drinking and the duration of sunbathing showed no significant differences according to stiffness.

Exercise and BMD

Thirteen girls participated in sports, but the relation between stiffness and quantity of exercise (severity × duration × weekly frequency) was not significant.

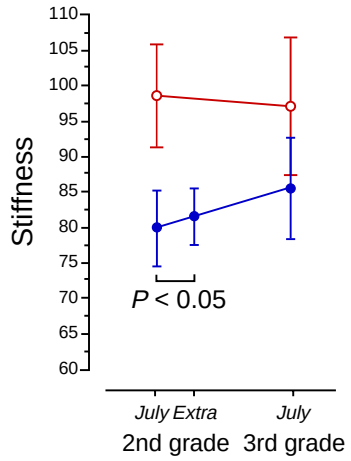

Fig. 4. Change in stiffness of the intervention group (●, $n = 11$) and non-intervention group (○, $n = 10$) measured in July of the 2nd grade (both groups), extra (12 weeks after the measurement in July; intervention group) and in July of the 3rd grade (both groups).

Foods and BMD

We observed 404.9 ± 284.4 mg as the daily mean (± SD) of Ca intake, which showed no significant relation to stiffness.

Second-grade BMD measurement

Stiffness data obtained 1 year later in the 2nd grade was 94.38 ± 11.62 (Fig. 3). We performed a *t*-test for the data matched to both the 1st and 2nd grade measurements, and observed a significant decrease in BMD ($t = 4.713$, degrees of freedom = 54, $P < 0.01$).

BMD changes in the intervention and non-intervention groups

In the intervention group ($n = 11$), the stiffness measured in July of the 2nd grade (80.0 ± 5.24) and after 12 weeks (82.36 ± 3.85) showed a significant increase ($P < 0.05$). But the difference between July of the 2nd grade and July of the 3rd grade (85.55 ± 7.15) was not significant (Fig. 4). The non-intervention group ($n = 10$) recorded mean stiffness at 98.60 ± 7.29 in July of the 2nd grade and 97.20 ± 9.72 in July of the 3rd grade (Fig. 3).

The mean Ca intake on the previous day of BMD measurement in July of the 3rd grade was 587 ± 258 mg in the intervention group and 592 ± 210 mg in the non-intervention group.

Discussion

We carried out BMD measurements over a 2-year period for college girls, giving them active instructions on life-style, and followed-up the effects of our intervention on their diet.

As for methods of measuring BMD, the literature has reported roentogenography and ultrasound bone densitometry. We calculated levels of stiffness for the present study with the latter method which served as the index for BMD.

BMD and life-style

For the 1st grade, stiffness in 55 girls (aged 18 to 20 years) was higher than the age-matched

mean reported in the literature (Yamazaki et al., 1992) (Fig. 3). The 55 girls responded to our recruitment out of a whole grade of college students consisting of 80 girls. We suppose that the voluntary subjects were concerned with their health condition.

In the present study, we observed that difference in stiffness was not significant in comparing cases with or without any BMD-affecting factor. A significant correlation was reported between continuous sports activity and stiffness of the os calcis of 18- to 20-year-old Japanese women (Hasegawa et al., 1997). We observed no significant difference between stiffness and quantity of exercise in the present study, which may be attributed to the low number of studied subjects. However, the daily mean of Ca intake calculated from personal interviews concerning 1-day meals (404.9 ± 284.4 mg) was 67.5% of the recommended daily level (600 mg). In a study of age-matched students at a domestic science college (Kamezaki and Shimao, 1994), the mean Ca intake was 408 ± 179 mg (68% of necessary level). Both populations presented similar levels. These facts suggest the necessity of nutrition betterment in adolescent Japanese females.

Change in stiffness between the 1st and the 2nd grades

We performed a *t*-test for the data of stiffness matching both the 1st and 2nd grades, and observed a significant decrease in stiffness ($P < 0.01$). The peak of BMD in Japanese females is 15 to 17 years of age (Io et al., 1997). As the present subjects were aged 18 to 20 years, their peak of BMD had passed, which is one reason for the significant decrease we observed. Another presumable factor for BMD decrease is poor eating habits in the population. BMD in July of the 1st grade reflected eating habits administered by their families, but levels measured thereafter were a reflection of poorly self-managed eating habits. Following college entrance as new students, they started to live independently from their family and prepared meals by themselves. Their lack of cooking knowledge, skill and time apparently produced trouble in their diets.

Health guidance to improve and maintain BMD

In the 1st guidance, we delivered the students a booklet on life-style methods for preventing osteoporosis. However, 2nd-grade BMD decreased, which implies a correlation between negative effects and the 1st guidance. To study the individual's subjective state of readiness to take recommended preventive health action, Pender (1996) introduced the illustrated "Health Belief Model," which was a report done by Becker et al. (1977). This model contained the following elements: i) the individual's subjective state of readiness to take action is determined by the individual's perceived likelihood of susceptibility to the particular illness, and ii) the individual's estimate of the action's potential benefits in reducing susceptibility weighs against his perception of barriers involved in the proposed action. As the aim of the present study, we first explained to the subjects as follows: to prevent osteoporosis and bone fracture after menopause which is a high risk in women with low BMD, it is important to increase the maximum BMD in adolescence and for young girls to take measures to reinforce the habit of taking Ca. We lectured them on this at the 1st guidance. Thus, our lecture on the importance of Ca-taking behavior focused on health maintenance after menopause. Presumably, the students hardly recognized such disease-oriented concern as Pender (1996) suggested, and they did not realize the problem to be related to their own possible future condition.

On the other hand, BMD did not change or increase between the 2nd and the 3rd grades (Fig. 4). We supposed that the girls' behavior must have changed during the period: they were shocked by the decrease in BMD between the 1st and the 2nd grades, which was translated as fear and which led them to perceive that strengthening the bone would be their benefit. This is a result of effectively applied knowledge obtained from our explanation.

According to Yamada et al. (1999), establishment of any behavior is the result of forming

motivations through the mutual functioning of biological, psychological and social factors. In the present study, the biological factor was the BMD data, while the psychological factor was students' response to how they accepted the data. The social factors considered were many: the method of getting food, economical problems or encouragement by others. We intervened in the poor-BMD group for 4 weeks by means of appreciating girls' efforts and confirming the following week's goal; our intervention must have contributed to the forming of motivation, which was the social factor in the present study. If intervention had made subjects feel like they were bearing a heavy burden, however, the intervention would have had the opposite effect to what was intended. We performed the above intervention for 12 weeks in a previous study and observed some effects, which lasted temporarily. One year after, during the 2nd-grade measurement, their Ca intake returned to the pre-intervention level (Maeda and Kitagawa, 1997). This fact suggests that the quantity and duration of intervention need to be more fully considered.

Our conclusion is that girl students can and must sustain their efforts to take Ca-rich food, when their knowledge of osteoporosis works together with the recognition that Ca-taking behavior is essential for their future.

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Corresponding author: Prof. Takako Maeda