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Relationship Between Nutrient Intake and Bone Mineral Density in 20～30 Year-old Korean Women

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Abstract

The achievement of maximal peak bone mineral density (BMD) in early life is one of the most important strategies for the prevention of osteoporosis, which is affected by nutritional status. However, it has been reported that young Korean women do not consume the optimal levels of nutrients because of the frequent practice of body weight reduction. Therefore, this study was conducted to investigate the relationship between nutrient intakes and BMD in young Korean women. Bone mineral density was measured at the lumbar spine by dual-energy X-ray absorptiometry. Information on health status, lifestyle and physical activity was obtained by questionnaire. Dietary intake was ascertained from a 3-day dietary record. The study sample included 112 Korean women aged 20～39 yr. In accordance with the energy intake of subjects, individuals who had an energy intake that was greater than 80% of the Korean Dietary Reference Intake (KDRI) were assigned to the control group (Control), while those who had an energy intake lower than 80% of the KDRI were assigned to the low intake group (LI). The intake of all nutrients in the LI group was significantly lower than that of the Control. Control subjects also showed nutrient intakes higher than the KDRI, except for Ca and folate. However, LI subjects showed intakes of energy, fiber, Ca, Fe, K, Zn, vitamin A, vitamin B_1, vitamin B_2 and folate that were lower than the KDRI. The BMD of the lumbar spine in LI subjects was significantly lower than that of the Control subjects. These results suggested that lower nutrient intake has a negative impact on BMD in young women.

Key words: nutrient intake, bone mineral density, osteoporosis, peak bone mass, young women

INTRODUCTION

Osteoporosis is a major public health problem worldwide due to accretion in the elderly population. Recently, osteoporosis, which causes health problems in middle aged and elderly women, has rapidly increased due to the growth of the elderly population. Indeed, the prevalence of osteoporosis in Korean women in their 50s was 26.9%, 55.4% in their 60s, and 77.2% in their 70s (1). The prevalence of osteoporosis was reported to be 26～31% in women aged 55 and older in the 2003～05 Hiroshima Cohort of Japan (2). In the United States, the prevalence of osteoporosis was 10% in subjects in their 50s who had their femoral bone mineral density (BMD) examined between 1988 and 1994 (3).

Although there is no effective treatment for osteoporosis, the best preventative method is to obtain the peak bone mass during the growth period and to reduce the risk factors for bone loss (4). The reported time or period for peak bone mass differs among studies, but it is generally accepted to be the mid-30s for most parts of the body. However, if the intake of energy and calcium are sufficient, the peak bone mass in the lumbar spine or femoral neck can be obtained before reaching 20 years of age (5). Therefore, it is very important to increase and accumulate bone mineral density while aged 20～30 to attain the peak bone mass to maintain bone health and prevent osteoporosis during old age. Factors affecting bone mineral density include nutrition status, exercise, hormonal balance and genetic disposition (6). The bone mass during early adulthood reflects the bone mass obtained during the growth period. However, increases in bone mass after that period are known to be affected by lifestyle factors (7). Thus, proper nutrient intakes during early adulthood can provide a positive influence on attaining peak bone mass.

In Korea, the underweight population has increased, particularly in young women, due to a social atmosphere that prefers women with thin figures. Indeed, a study of urban female college students showed that 55.9%

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were underweight, and that 53.8% of the underweight population had tried weight reduction (8). Decreased food intakes for weight reduction can cause under-nutrition and negatively affect bone health (9). According to the 2005 National Health and Nutrition Survey (10), the ratio of energy intake to the Korean Dietary Reference Intakes (KDRI) was 82.1% in young individuals aged 20～29 years. This was the smallest energy intake among all age groups, and was much smaller than the same age group in the United States, which was 91.5% (National Health and Nutrition Examination Survey).

In the present study, the current status of nutrient intake was investigated in young women aged 20～30 years who preferred to have a thin figure. The bone mineral density was comparatively analyzed by dividing the subjects into a control group who had an energy intake above 80% of the KDRI and a low intake group (LI) who had an energy intake below 80% of the KDRI to examine the influence of energy intake status on bone mineral density.

SUBJECTS AND METHODS

Subjects

This study was conducted from December 2006 to December 2007 on 112 healthy women aged 20～39 years who resided in the suburbs of Seoul, Korea. Subjects who were pregnant or had been ill with thyroid or parathyroid diseases, diabetes, rheumatoid arthritis, forms of bone carcinoma such as myeloma, were hospitalized for over 6 months, had taken estrogen or other medicines for osteoporosis, had used steroids or heparin for a long period of time, or had experienced a non-traumatic fracture were excluded. A dietary intake survey was provided, and the BMD was then measured one week later. Subjects were divided into a control group (Control) that had an energy intake higher than 80% of the Korean Dietary Reference Intake (KDRI) and a low intake group (LI) comprised of individuals with an energy intake lower than 80% of the KDRI. This study was reviewed and approved by the Institutional Review Board (IRB) at the College of Medicine, Kwandong University, and written informed consent was obtained from all subjects.

Dietary intakes

The instructions for the dietary intake survey were explained to the subjects in advance. The subjects filled out the survey to provide a 3-day dietary record that included two weekdays and one weekend day. The survey content was then confirmed by a trained investigator through a one on one interview during the collection period. Nutrient intake was analyzed using the nutrition evaluation program, Canpro 3.0.

Anthropometry and bone mineral status measurements

Height and body weight were measured in light clothing using a fatness measuring system (Mod DL-102, Jenix Co., Ltd., Korea) on the day of the experiment, and this information was then used to calculate the body mass index (BMI). Waist circumference was measured using a tape measure. Bone mineral density was measured at the lumbar spine, which has a higher metabolic rate, using dual-energy X-ray absorptiometry (Mod QDR-4500, Hologic Co., USA). The average value of the BMD from L1-L4 (lumbar 1 to lumbar 4 vertebra) was used to improve the precision of the measurements (11). In addition to the absolute value of the BMD, the T-score and Z-score were measured. The T-score is a standard deviation of the average BMD value of healthy young adults (20～39 years), and a value for comparison to age group with the highest bone mass to present the absolute risk for fracture. According to the diagnostic criteria of the WHO (1999), osteoporosis is defined as a T-score of lower than -2.5 and osteopenia is defined as a T-score of lower than -1.0. Conversely, the Z-score is the number of standard deviations of the average BMD among individuals of the same age and gender. The Z-score can be used to compare the BMD among members of the same age group. A Z-score lower than -2.0 indicates a BMD lower than the mean value.

Statistical analysis

All survey data from this study were statistically analyzed using SPSS (Statistical Package for Social Science version 12.0). The mean and standard deviation of the measurements were calculated for the BMD and nutrient intakes. Significance among groups was verified by a student's t-test, and the relationship between nutrient intake and BMD was evaluated using Pearson's coefficient of correlation. A $p<0.05$ was considered to indicate statistical significance.

RESULTS

General characteristics and BMD of subjects

The general characteristics, anthropometry and BMD values of the subjects are shown in Table 1. The average age of the control group was 31.8, while that of the low intake group was 31.0, which was not significantly different. In addition, there were no significant differences in menarche age depending on energy intake between both groups. The average height and weight of the control group were 161.5 cm and 54.2 kg, respectively, while those of the low intake group were

Table 1. Demographic characteristics, anthropometric data and bone mineral density of the subjects

	Control (N=63)	LI (N=49)	Total (N=112)
Age (yr)	31.81±4.8[1)NS2)]	31.0±4.5	31.5±4.7
Menarche (yr)	13.5±1.2	13.2±1.2	13.2±1.1
Height (cm)	161.5±4.8	160.0±4.2	160.8±4.6
Weight (kg)	54.2±6.4	53.2±5.8	53.8±6.1
BMI (kg/m^2)	20.8±2.4	20.8±2.5	20.8±2.4
Waist (cm)	70.9±4.2	70.9±4.4	70.9±4.4
Spine BMD[3)] (g/cm^2)	1.000±0.104*	0.942±0.089	0.975±0.10
T-score	-0.05±0.91*	-0.56±0.78	-0.27±0.89
Z-score	0.01±0.91*	-0.45±0.75	-0.19±0.87

[1)]Mean±SE.
[2)]NS: Not significant.
[3)]BMD: Bone mineral density. T-score=(measured BMD−young adult BMD)/ standard deviation (young adult BMD). Z-score=(measured BMD−population mean BMD for same age subject)/ standard deviation (BMD at same age).
*Significant difference between the Control and LI groups as determined by a t-test at $p<0.05$.

160.0 cm and 53.2 kg, respectively, which were not significantly different. There were no significant differences in BMI and waist circumference between the control group and the low intake group. Conversely, the average BMD was significantly higher in the control group than the low intake group, as indicated by values of 1.000 g/cm^2 and 0.942 g/cm^2, respectively ($p<0.05$). Furthermore, when the BMD values of individuals in the same age group were compared, the Z-score of the low intake group was significantly lower than that of the control group ($p<0.05$).

Table 2. Comparison of nutrient intakes between control and low intake subjects

	Control (N=56)		LI (N=56)		Total (N=112)	
	Intake	%KDRI[1)]	Intake	%KDRI	Intake	%KDRI
Energy (kcal)	1999.5±349.7[2)]	100.0[3)]	1341.0±187.9*	67.1*	1711.4±437.3	85.6
Protein (g)	81.8±26.0	181.8[4)]	50.3±10.5*	111.8	68.0±26.0	151.1
Plant protein (g)	37.2±18.8		25.4±6.5*		32.0±15.8	
Animal protein (g)	44.7±19.5		25.0±8.0*		36.1±18.4	
Fat (g)	61.5±21.9		37.2±11.4*		50.9±21.7	
Plant fat (g)	28.9±9.9		16.9±5.9*		23.7±10.3	
Animal fat (g)	32.6±19.1		20.3±9.5*		27.2±16.7	
Carbohydrate (g)	281.6±56.2		193.3±37.7*		242.9±65.7	
Fiber (g)	21.4±4.7	93.0[5)]	14.6±4.3*	63.5	18.4±5.6	80.0
Calcium (mg)	554.5±175.6	79.2[4)]	366.4±141.8*	52.3	472.2±186.3	67.5
Phosphorus (mg)	1075.7±239.7	153.7[4)]	702.2±193.3*	100.3	912.3±287.9	130.3
Iron (mg)	14.1±3.0	100.7[4)]	9.6±2.8*	68.6	12.1±3.7	86.4
Sodium (mg)	4628.2±1090.4	308.5[4)]	3191.7±823.3*	212.8	3999.7±1212.3	266.6
Potassium (mg)	2985.3±584.4	63.5[5)]	1971.4±623.6*	41.9	2541.7±783.7	54.1
Zinc (mg)	10.5±6.7	131.3[4)]	6.3±1.6*	78.8	8.6±5.6	108.1
Vitamin A (μg RE)	845.0±315.2	130.0[4)]	566.4±209.0*	87.1	723.1±306.0	111.2
Retinol (μg)	142.6±117.3		72.3±47.8*		111.8±99.6	
Carotene (μg)	3725.0±1662.3		2543.3±942.5*		3208.0±1508.1	
Vitamin B1 (mg)	1.4±0.5	127.3[4)]	0.8±0.2*	72.7	1.1±0.5	100.0
Vitamin B2 (mg)	1.2±0.3	100.0[4)]	0.8±0.2*	66.7	1.0±0.3	83.0
Vitamin B6 (mg)	2.3±0.6	164.3[4)]	1.4±0.4*	114.3	1.9±0.7	135.7
Niacin (mg)	17.9±4.9	127.9[4)]	17.9±4.9*	91.4	15.1±5.3	107.9
Vitamin C (mg)	145.5±78.6	145.5[4)]	84.5±66.5*	100.0	118.8±79.3	118.8
Folate (μg)	277.6±108.0	69.4[4)]	185.3±51.5*	46.3	237.2±98.9	59.3
Vitamin E (mg)	17.4±6.2	174.0[5)]	10.0±3.8*	100.0	14.2±6.4	142.0
Cholesterol (mg)	369.8±168.5		229.0±129.0*		308.2±167.3	

[1)]KDRI: Korean Dietary Reference Intakes.
[2)]Mean±SE.
[3)]EER: Estimated energy requirement.
[4)]RI: Recommended intake.
[5)]AI: Adequate intake.
*Significant difference between the Control and LI groups as determined by a t-test at $p<0.05$.

Table 3. Correlation coefficients between lumbar spine bone mineral density and nutrient intake[1)]

	BMD[2)]	T-score	Z-score
Protein	0.0388	0.0385	0.0359
Fat	-0.1307	-0.1344	-0.7430
Carbohydrate	0.0695	0.0717	0.0311
Fiber	0.2047*	0.2023*	0.2137*
Calcium	0.0616	0.0594	0.0979
Phosphorus	0.0768	0.0735	0.0746
Iron	0.1341	0.1357	0.1387
Sodium	0.0043	0.0090	0.0399
Potassium	0.0809	0.0816	0.0881
Zinc	0.0732	0.0731	0.0757
Vitamin A	0.0715	0.0715	0.0777
Retinol	-0.1207	-0.1184	-0.1738*
Carotene	0.0639	0.0619	0.0788
Vitamin B1	-0.0889	-0.0881	-0.0815
Vitamin B2	-0.1577	-0.1564	-0.1205
Vitamin B6	0.1009	0.0978	0.1030
Niacin	0.1149	0.1165	0.0987
Vitamin C	0.1334	0.1335	0.1470
Folate	0.0318	0.0330	0.0588
Vitamin E	0.0923	0.0904	0.1297
Cholesterol	0.0140	0.0109	0.0349

[1)]Adjusted for energy intake.
[2)]BMD: Bone mineral density. T-score = (measured BMD − young adult BMD)/ standard deviation (young adult BMD). Z-score = (measured BMD − population mean BMD for same age subject)/ standard deviation (BMD at same age).
*Significantly association at $p<0.05$ (Pearson's correlation).

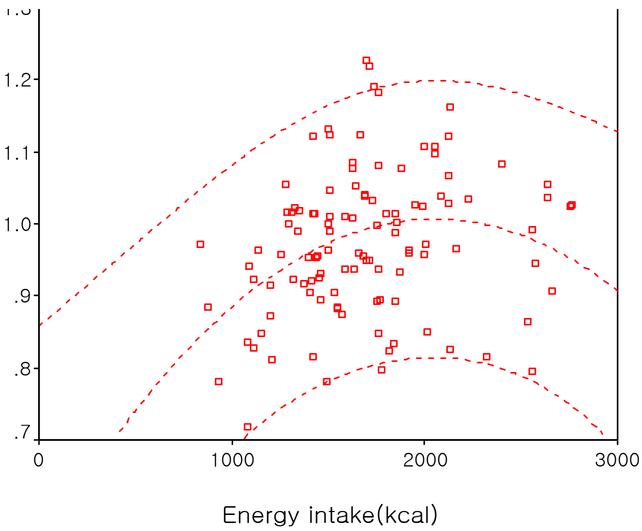

Fig. 1. Relationship between energy intake and bone mineral density.

Nutrient intake status

The energy and nutrient intakes of the subjects are shown in Table 2. The daily energy intake of the control group was 1999.5 kcal, while that of the low intake group was 1341.0 kcal, which was significantly lower than the control group. The energy intake of the control group was 100% of the KDRI, while that of the low intake group was 67% of the KDRI. Subjects in the control group consumed all nutrients at levels higher than the KDRI except for calcium and folate. However, subjects in the low intake group consumed energy, calcium, iron, zinc, vitamin A, vitamin B1, vitamin B2, niacin, and folate at levels below the KDRI. Indeed, the intake of calcium, potassium and folate in the low intake group was only 52.3%, 41.9% and 46.3% of the KDRI, respectively. However, there was no positive correlation between BMD and calcium intake (Table 3). The analysis of the relationship between energy intake and BMD showed that the BMD increased as the energy intake increased (Fig. 1).

DISCUSSION

Recently, nutritional imbalances in Korea have increased due to excessive weight reduction, and such imbalances have primarily occurred in young women due to a social atmosphere emphasizing appearance and preferring thin figures. Therefore, this study was conducted to investigate the effects of nutrient intakes on bone mineral density in young women aged 20～30 years. Subjects were divided into two groups based on the ratio of energy intake to KDRI and then compared. Specifically, the subjects were divided into a control group composed of individuals that consumed nutrients at levels above 80% of the KDRI and a low intake group that included individuals that consumed nutrients at levels below 80% of the KDRI. The average age of all subjects was 31.5 and the average BMD was 0.975±0.10 g/cm^2. The BMD of the lumbar spine was reported to be 1.03 g/cm^2 in a study of Korean women with an average age of 33.6 years that were examined using the same DXA method that was used in the present study (12). However, the BMD of the lumbar spine was 1.16 g/cm^2 in a study of Korean women with an average age of 40.2 conducted by Choi (13). Thus, the BMD of the lumbar spine observed in our study was lower despite the younger age of the subjects. Mazess and Barden (14) evaluated the BMD of 1,472 American women and a total of 9,160 women in England and northern Europe. They found that the BMD of the lumbar spine of 20～29 year-old American women was 1.24 g/cm^2, while that of northern European women was 1.19 g/cm^2, both of which were higher than those of the control and low intake groups observed in our study.

It is generally accepted that the peak bone mass of women is obtained during their mid-30s in most parts of the body, but that this can be attained before age 20 in the lumbar spine or femoral neck if energy and calcium intakes are sufficient (5). We evaluated the BMI and BMD in 322 Korean women aged 20～60 years and found that the lowest BMI was 19.9 in individuals in their 20s, while it was 20.8, 22.2, 23.7 and 23.9 in women in their 30s, 40s, 50s, and 60s, respectively, which indicates that BMI increases with age. The BMD of the lumbar spine and the femur was also found to be lower in women in their 20～30s than in women in their 40s (unpublished data). These results may indicate that Korean women do not reach their peak bone mass in their 20～30s as a result of a lack of the optimal nutrition due to weight reduction. Compston et al. (15) reported that weight reduction decreased bone mass, while an increase in body weight led to increased bone mass. Because body weight provides physical pressure on the entire skeleton, which influences the BMD (16), it is recommended that young women maintain their proper body weight to optimize the BMD.

Kim (17) reported that BMD increased as energy intake increased in a study of Korean female college students. These findings were consistent with the results of our study, which showed that the BMD of the low intake group that consumed 67.1% of the estimated energy requirements (EER) was significantly lower than that of the control group that consumed 100% of the EER. Additionally, the results of the Z-score measurements for comparison of the BMD among individuals of the same age group revealed that they were significantly lower in the low intake group than the control group. Calcium intake, which is directly related to bone health, was 79.2% of the recommended intake in the control group and only 52.3% in the low intake group. In addition, iron intake, which is particularly important to women, was 100.7% of the recommended intake in the control group, but only 68.6% in the low intake group. Woo et al. (18) reported that higher calcium intake in young women was associated with higher BMD, and Bhatia (19) reported that sufficient calcium intake delayed bone loss. Furthermore, the sodium intake in both the control group and low intake group were 2～3 times higher than the tolerable upper intake level, which is a matter of great concern because increased sodium intake can cause increased urinary calcium loss (20). Mizushima et al. (21) reported that the mineral content of the bones of women aged 20～40 years who had high sodium diets was significantly lower than that of women who had a low sodium diet. The results of a recent National Health and Nutrition Survey (10) showed that sodium intake by the Korean population was 1.6 times higher than that of the population of the United States.

According to the 2005 National Health and Nutrition Survey (10), the ratio of women aged 20～30 years who were actively pursuing weight reduction was 55.6%. If young women experience a lack of nutrients due to weight reduction, the incidence of osteoporosis will increase. The low intake group of our study is considered to be at risk of osteoporosis based on the results of a previous study (22) in which a low BMD in 20～30 year-old women led to a higher risk for osteoporosis after menopause. A lack of nutrients in the period critical for obtaining the peak bone mass may have negative influences on bone health.

In conclusion, the low intake group showed lower energy intake and lower calcium and iron intakes when compared to the control group. Additionally, the BMD of the lumbar spine was significantly lower in the low intake group when compared to the control group. Thus, the lower BMD in the low intake group appears to be the result of a low intake of nutrients important to bone health.

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