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Effect of Soymilk and Exercise on Bone Mineral Density and Bone Metabolism Related Markers in Underweight College Women with Low Bone Density*

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ABSTRACT

The objective of this study was to investigate the effect of soymilk and exercise on bone mineral density (BMD) in underweight college women of 19−22 years of age, who had lower bone mass. The BMD of the lumbar spine and femoral neck was measured for 52 underweight college women. Among them, 33 subjects, whose t-score value was below −1, were selected. Questionnaire survey, anthropometrical measurements, dietary recall, analysis of BMD, fasting serum osteocalcin and urinary deoxypyridinoline (DPD) were conducted before and after the 10 week study. The 33 subjects were divided into 2 groups : soymilk group (n=19), and soymilk + exercise group (n=14). The soymilk group was given 400ml soymilk containing 60mg of isoflavones on a daily basis and the soymilk + exercise group exercised three times a week with a daily intake of 400ml soymilk for 10 weeks. The average ages of the soymilk group and the soymilk + exercise group were 21.1 years and 20.4 years, respectively and, there were no significant differences between the soymilk group and the soymilk + exercise group in the areas of height, weight or Body Mass Index (BMI). At the baseline, the mean daily energy intake of the soymilk group and the soymilk + exercise group was 1,597.9kcal (79.43% of RDA) and 1,704.2kcal (85.2% of RDA), respectively. The mean calcium intake of the soymilk group (408.3mg) was not significantly different from that of the soymilk + exercise group (389.4mg). Despite the 400ml soymilk supplementation, there were no significant changes of nutrient intake in either group after treatment. However, there were significant increases in BMD's of lumbar spine and femoral neck in both groups. There were some increases in the serum osteocalcin level and decreases in the urinary deoxypyridinoline level as well. BMD change of the soymilk group was not significantly different from that of the soymilk + exercise group. In conclusion, supplementary intake of soymilk (containing 60mg of isoflavones) resulted in a significant increase in the BMD's of the lumbar spine and femoral neck in underweight college women with low bone mass. However, exercise did not result in any significant changes in the BMD's, implying the necessity for more intensive and specific long-term physical training for any substantial changes. Further investigation is necessary to determine the exercise that most strongly affects BMD. (*J Community Nutrition* 5(3) : 132~140, 2003)

KEY WORDS : soymilk · isoflavones · exercise · underweight · bone mineral density.

Introduction

Underweight population is growing due to stereotyping of obesity and the desire for a lean body shape. This trend is most evident amongst young women and becomes a social issue that threatens women's health. Extreme desire to have a lean body causes these women to develop anemia, growth retardation, irregular menstruation, dietary problems and psychological issues (Comerci 1988 ; Story et al. 1983). In addition to research findings that the lower the weight of women is, the lower the BMD is (Douchi et al 2000 ; Woo 1999), it has been suggested that extreme , there is no treatment for osteoporosis ; therefore, the best way of preventing osteoporosis is to maximize peak bone mass during the growth period and reduce risk factors for bone mass

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loss (Lee et al 1999 ; Lee at al. 1996). Barr et al. (1998) reported that the age prone to bone fracture could be delayed when peak bone mass was higher in earlier years. Nutritional imbalance or inappropriate dietary habits of college women will affect future dietary habits. In addition, the nutritional health status of these young women close to childbearing ages is critical since health and nutritional status of mothers prior to pregnancy can have significant impact on the health of a fetus.

Factors affecting BMD can be divided into two areas : Genetic factors including ethnicity and gender, and environmental factors including body mass index (BMI) (Douchi et al. 1997), diet (New et al. 1997), physical activity (Mayoux-Benhamou et al. 1999), alcohol, smoking, caffeine (Grainge et al. 1998), and hormones (Compston). Amongst dietary factors, nutrients including protein (Kerstetter et al. 1999), calcium (Matkovic et al. 2000), and phosphorus (Heaney et al. 2000), are believed to be closely related to BMD. Recently, intake of a biologically active ingredient, isoflavones is reportedly related to BMD (Alekel et al. 2000 ; Potter et al. 1998). It has been reported that isoflavones in soy foods, similar to estrogens, have a positive impact on BMD (Dalais et al. 1998 ; Messina et al 1996 ; Potter et al. 1998). However, most of these studies were conducted on post-menopausal women, not on pre-menopausal underweight women with high risk of bone mass loss. In this study, isoflavones were provided through soymilk that can be easily found in normal diet. In addition to isoflavones, soymilk is a good source of calcium and vegetable proteins ; therefore, soymilk compared to isoflavones alone will help malnourished underweight college women to further enhance the BMD.

Regular physical activities are known to prevent bone loss and help maintain healthy bones. Good physical activities in early childhood and adolescence can especially contribute to BMD increase in the adulthood (Bailey 2000). In the study by Kemper et al (2000), teenagers of 13−17 years of age and young adults of 21−27 years of age (163 males and 139 females) were monitored for their BMD at age of 32. The study found that the group with higher physical activities had a significantly higher spinal BMD. In addition, benefit of exercise on BMD is known to be greater on pre-menopausal than post-menopausal women (Lee 1996). More studies of exercise benefit are needed on pre-menopausal women in Korea.

In this study, BMD's of underweight college women with BMI of <19 were measured and women whose T-score values were below −1 were chosen. These women were divided into two groups. On a daily basis one group was given 400ml of soymilk (containing 60mg of isoflavones) for 10weeks and the other group was given the same amount of soymilk and exercised for 10weeks. Changes in BMD's and bone metabolism related markers were monitored before and after the treatment. It is hoped that these data are used as a reference in preventing osteoporosis in underweight women with high risk of losing bone mass.

Subjects and Methods

1. Selection of study subjects and study period

The subjects of this study were 33 college women of 19−22 years of age residing in Seoul, Korea. For selection of the subjects, preliminary survey on college women in Seoul area identified 52 underweight women whose BMI's were below 20 and who were willing to participate in the study. Among these women, a total of 33 subjects were chosen, based on the BMD with t-score value below −1. These subjects were divided into two groups : soymilk group (n = 19) and soymilk + exercise (n = 14). The study was conducted from March to June of 2001 after subjects were informed about the study and submitted consent forms on the participation.

2. Study content and methods

Thirty-three subjects were given 400ml (2 packs) of soymilk (containing 60mg isoflavones, Sahmyook Foods) on a daily basis. The level of isoflavones was determined based on previous studies on the effect of isoflavones on BMD and bone metabolism (Alekel et al 2000 ; Morabito et al. 2002 ; Potter 1998 ; Scheiber et al. 2002 ; Uesugi et al. 2002). For the group of soymilk + exercise, in addition to soymilk intake, personalized exercise was conducted at the sports center three times a week for 30min. each time. Dept. of Physical Fitness Test, Sahmyook College Sports Center, first measured their physical abilities. An appropriate exercise program was assigned to each subject. Based on previous studies, aerobic exercise with different forms and intensity and muscular training that can increase lumbar spine and femoral neck BMD's (Nelson et al. 2001 ; Park 1998 ; Teegarden et al. 1996) were conducted.

The exercise protocol included warm-ups (stretching 10 areas), 10min. aerobic exercise (treadmill at 7km/hr for 1.2 km), 3−5min. rest, and light exercise followed by muscle strength training concentrated on areas of waist, hip, and thigh (Table 1). For 1−2 weeks, muscular exercise was conducted at 60% 1RM (2 sets of 12 repeats on each area) and from the third week, at 80% of 1 RM (8−10 repeats on each area). Assigned intensity of exercise was adjusted to their ability in case subjects were unable to handle it. For the third set, maximum numbers of lifts were asked. Once more than 18 repeats were achieved, weights were increased.

1) Anthropometrical measurements

The subjects were measured at the standing position lightly clothed for body weight, body mass Index (BMI = weight (kg)/height (m^2), fat mass, percent body fat, and waist hip ratio (WHR) (Inbody 2.0 Body Composition Analyzer Precision Medical Instrument Biospace Co., Ltd. Korea).

2) Survey

Survey of age, menstruation, weight change, etc. on the subjects was conducted prior to soymilk and exercise treatment through questionnaire. Questionnaires were revised based on the results from preliminary survey conducted during February/March in 2001.

3) Physical examination

The Dept. of Physical Fitness Test at Sahmyook University Physical Center evaluated physical status of the subjects by testing 9 areas : blood pressure, resting heart rate, large muscle strength, vital capacity, grip strength, sitting trunk flexion, sit up, vertical jump, and simple reaction time. These tests were conducted before and after the soymilk and exercise treatment. Data obtained from these tests were used to understand the physical status of subjects and to customize exercise program for the soymilk and exercise group.

Table 1. Muscle groups and exercises

Muscle groups	Exercise methods
Abdomen muscle	Crunch exercise
Back muscle	Dead lift exercise
Gluteus muscles	Half squat exercise
Quadriceps muscles	Leg press exercise
Hip abductor muscles	Abduction machine exercise
Hip adductor muscles	Abduction machine exercise
Hamstring muscles	Leg curl exercise

4) Survey of food and nutrient intake

Food intake for the three previous days was surveyed under the guidance of investigators using a 24-hr recall method. The results were analyzed for overall nutrient intake using Can-Pro, Computer Aided Nutritional Analysis Program for Professionals (The Korean Nutrition Society, 1998). Isoflavones intake was analyzed based on information by Franke et al. (1999) and Lee et al. (2000).

5) Measurement of bone mineral density (BMD)

The BMD's of lumbar spine (L2-L4) and femoral neck areas that have a high rate of bone metabolism and a high correlation with various factors, were analyzed by Dual Energy X-ray Absorptiometry (DEXA, ESLIPSE, Norland). Precision of the measurement was +1.5%. The BMD value of lumbar spine was an average of BMD's of L2 to L4. Differences between BMD's of lumbar spine and femoral neck, and normal BMD's were divided by standard deviations of normal BMD's to obtain t-scores.

6) Blood sampling and osteocalcin analysis

For the sampling at 7−9 am, 20cc of blood was drawn from the subjects fasting 12hours. Samples were left at room temperature for 30min., centrifuged for 15min. at 2,500rpm to separate serum, and stored at −70℃. Serum osteocalcin levels were determined using OSCA test osteocalcin kit (Brahms, Germany) and counter (COBRA 5010 Quantum, USA.

7) Urine sampling and deoxypyridinoline analysis

Urine samples were collected in the plastic containers at the time of blood sampling and stored at −20℃. Deoxypyridinoline (DPD), a biochemical indicator, was analyzed by competitive enzyme linked immunoassay (Pyrilink-D

Table 2. General characteristics in subjects before treatment

Variables	Soymilk (n = 19)	Soymilk + Exercise (n = 14)	t-test[3]
Age (yrs)	21.1 ± 2.2[1]	20.4 ± 4.1	N.S.
Height (cm)	160.9 ± 3.3	161.1 ± 2.9	N.S.
Weight (kg)	49.2 ± 3.3	49.0 ± 3.2	N.S.
BMI (kg/m^2)[2]	19.0 ± 1.2	18.9 ± 1.0	N.S.
Body fat (%)	28.6 ± 4.1	26.7 ± 2.6	N.S.
Age of menarch (yrs)	13.9 ± 1.0	14.3 ± 1.3	N.S.
Duration of menstrual cycle (days)	29.1 ± 2.8	28.2 ± 1.2	N.S.
Duration of menstrual flow (days)	6.0 ± 1.4	5.9 ± 1.2	N.S.

1) Mean ± Standard deviation,
2) Body mass index,
3) Significance as determined by Student t-test

kit, Metra Bio-systems, USA) and calculated as of nmol of DPD per mmol of creatinine (Cr).

3. Statistical analysis

SAS program (version 8.1) was used for statistical analysis. Anthropometrical measurement, food and nutrient intake, BMD and bone metabolism related markers are expressed as means and standard deviation. Significance in differences between two groups was determined by t-test. Paired t-test was used to determine significant changes between before and after treatment. Chi-square test was used to test significance on the distribution rate within the group.

Results and Discussions

1. General characteristics of the subjects before treatment

General characteristics of the subjects are shown in Tables 2 and 3. Average age of the soymilk group (n = 19), and the soymilk + exercise (n = 14) was 21.1 and 20.4 years, respectively with no significant difference between the two groups. Weight and height of the soymilk group and the soymilk + exercise group were 160.9cm and 49.2kg, 161.1 cm and 49,0kg, respectively without significant difference. Compared to Korean Physical Standard set by the Korean Nutrition Society (161cm and 54kg, 2000), heights of the two groups were not significantly different but weights were significantly lower. Body Mass Index's (BMI) of the soymilk (28.6%) and the soymilk + exercise (26.7%) groups were not significantly different. Regarding weight changes of the subject in the previous year (Table 3), 47.4% of the soymilk group and 64.3% of the soymilk + exercise group responded to 'no change during the last one year' and 36.8% of the soymilk group and 28.6% of the soymilk + exercise group responded to 'weight increase' suggesting that majority of subjects has maintained the current underweight during the last one year without resorting to a short period of dieting.

Table 3. Weight change of the subjects in a previous year

N (%)

Variables	Soymilk (n = 19)	Soymilk + Exercise (n = 14)	χ^2 1)
Unchanged	9 (47.4)	9 (64.3)	χ^2 = 1.5828 df = 2, *N.S.*
Gained weight	7 (36.8)	4 (28.6)	
Lost weight	3 (15.8)	1 (7.1)	

1) Significance by χ^2-test

Age of menarch and duration of menstrual cycle in the soymilk group and the soymilk + exercise group were 13.9 years and 29.1 days, and 14.3 years and 28.2 days, respectively. Duration of menstrual flow in the soymilk group and the soymilk + exercise group was 6.0 and 5.9 days, respectively showing no significant difference between the two groups.

2. Effects of treatment on nutrient intake, anthropometrics, physical profiles, BMD, and markers for bone metabolism

1) Intake of nutrients and isoflavones

Daily nutrient intake before and after treatment is shown in Table 4. Prior to the treatment, average calorie intake of the soymilk group and the soymilk + exercise group was 1,597.9kcal (79.4% of the recommended) and 1,704.2kcal (85.2% of the recommended), respectively indicating no significant difference between two groups. These calorie intakes are lower than the average calorie intake of 20–29 years of age (93.6%) according to 2001 survey on Korean Health and Nutrition (Dept. of Health and Welfare, 2003). Protein intake of the soymilk group and the soymilk + exercise group was 59.3g and 63.9g, respectively suggesting sufficient intake higher than the recommended intake. Calcium intake of the soymilk group and the soymilk + exercise group was 408.3mg and 389.4mg, respectively

Table 4. Mean of daily nutrient intakes of the subjects before and after treatment

Variables	Soymilk (n = 19)	Soymilk + Exercise (n = 14)	t-test3)
Energy (kcal)			
Pretreat	1587.9 ± 345.7 1)	1704.2 ± 536.2	N.S.
Posttreat	1752.0 ± 327.0	1626.9 ± 349.9	N.S.
Protein (g)			
Pretreat	59.3 ± 20.5	63.9 ± 21.8	N.S.
Posttreat	65.4 ± 13.3	63.5 ± 21.4	N.S.
Calcium (mg)			
Pretreat	408.3 ± 192.2	389.4 ± 143.2	N.S.
Posttreat	434.9 ± 155.5	397.9 ± 231.2	N.S.
Phosphorus (mg)			
Pretreat	874.2 ± 304.7	909.6 ± 247.0	N.S.
Posttreat	970.6 ± 185.0	907.5 ± 342.7	N.S.
Isoflavone (mg)			
Pretreat	15.2 ± 19.0	20.6 ± 20.6	N.S.
Posttreat	75.0 ± 18.1***2)	80.5 ± 20.4***	N.S.

1) Mean ± S.D.
2) Significance as determined by paired ttest, *** : p<0.001
3) Significance as determined by Student t-test

showing only 60% of the recommended intake and no significant difference between two groups. Phosphorous intake of the soymilk and the soymilk + exercise group was 874.2mg and 906.6mg, respectively showing high intake, without any significant differences between the two groups. When phosphorous intake is too high compared to calcium intake, it is believed to lower calcium absorption and increase bone loss. The intake ratio of calcium and phosphorous was 1 : 2.1 for the soymilk group and 1 : 2.3 for the soymilk + exercise group showing undesirable ratios due to insufficient calcium intake. Isoflavones intake prior to the treatment was 15.2mg and 20.6mg for the soymilk group and the soymilk + exercise group, respectedly, showing no significant difference. These levels of intake were similar to the level (16.9mg) in the pre-menopausal women (Sung et al. 2001).

The treatment (daily 400ml soymilk intake with or without exercise) did not make any significant changes in the intake of calorie, protein, and calcium. It is speculated that due to feeling of full stomach caused by soymilk intake, overall food intake was reduced. However, isoflavones intake after treatment was significantly increased for both the soymilk group (75.0mg) and the soymilk + exercise group (80.5mg) ($p<0.001$).

2) Anthropometric measurement and physical characteristics

Anthropometrical measurements (Table 5) showed that both treatments contributed small but significant decreases in weight ($p<0.05$), BMI ($p<0.05$) and body fat ($p<0.01$) in the soymilk group and body fat ($p<0.01$) in the soymilk + exercise group. Physical examination (Table 6), conducted to prescribe adequate exercise program for each subject before treatment showed that systolic and diastolic blood pressures were 108.8mmHg and 67.3mmHg for the soymilk group and 107.1mmHg and 64.6mmHg for the soymilk + exercise group ; thus showed no significant differences between the two groups. Ictus cordis was 80.1/min for soymilk group and 78.01/min for the soymilk + exercise group. Vital capacity of the soymilk group and the soymilk + exercise group was 2,338.4ml and 2,300.0ml, respectively and grip strength was 26.6kg for the soymilk group and 27.8 for the soymilk + exercise group. Sitting trunk flexion and sit up were 9.3cm and 15.5times for the soymilk group and 12.9cm and 16.7times for the soymilk + exercise

Table 5. Anthropometrical measurements of the subjects before and after treatment

Variables	Soymilk (n = 19)	Soymilk + Exercise (n = 14)	t-test[3]
Weight (kg)			
Pretreat	49.2 ± 3.3[1]	49.0 ± 3.2	N.S.
Posttreat	47.9 ± 2.7*[2]	48.7 ± 3.5	N.S.
BMI (kg/m^2)[4]			
Pretreat	19.0 ± 1.2	18.9 ± 1.0	N.S.
Posttreat	18.6 ± 1.0*	18.7 ± 1.2	N.S.
Body fat (%)			
Pretreat	28.6 ± 4.1	26.7 ± 2.6	N.S.
Posttreat	26.6 ± 3.6**	24.9 ± 2.4**	N.S.

1) Mean ± S.D.
2) Significance as determined by paired ttest * : p<0.05, ** : p < 0.01, *** : p<0.001
3) Significance as determined by Student t-test
4) Body Mass Index

Table 6. Physical examination of the subjects before and after treatment

Variables	Soymilk (n = 19)	Soymilk + Exercise (n = 14)	t-test[3]
Systolic blood pressure (mmHg)			
Pretreat	108.8 ± 14.8[1]	107.1 ± 12.4	N.S.
Posttreat	100.4 ± 13.4*[2]	93.9 ± 9.2***	N.S.
Diastolic blood pressure (mmHg)			
Pretreat	67.3 ± 9.1	64.6 ± 7.8	N.S.
Posttreat	61.7 ± 10.9*	56.4 ± 7.4**	N.S.
Ictus cordis (No./min)			
Pretreat	80.1 ± 11.1	78.0 ± 11.8	N.S.
Posttreat	87.0 ± 14.1*	79.5 ± 11.2	N.S.
Vital capacity (ml)			
Pretreat	2338.4 ± 339.9	2300.0 ± 352.4	N.S.
Posttreat	2377.9 ± 344.5	2523.4 ± 406.1**	N.S.
Grip strength (kg)			
Pretreat	26.6 ± 1.9	27.8 ± 2.9	N.S.
Posttreat	26.6 ± 2.2	28.3 ± 2.8	N.S.
Sitting trunk flexion (cm)			
Pretreat	9.3 ± 5.9	12.9 ± 6.6	N.S.
Posttreat	10.0 ± 6.1	15.9 ± 5.1*	p<0.01
Sit up (No.)			
Pretreat	15.5 ± 3.7	16.7 ± 3.8	N.S.
Posttreat	15.8 ± 3.8	17.1 ± 3.9	N.S.
Vertical jump (cm)			
Pretreat	26.5 ± 4.4	32.7 ± 4.3	p<0.01
Posttreat	28.7 ± 4.8	32.1 ± 5.0	N.S.
Simple reaction time (msec)			
Pretreat	371.0 ± 74.9	348.1 ± 66.5	N.S.
Posttreat	347.0 ± 75.4	301.9 ± 65.6*	N.S.

1) Mean ± S.D.
2) Significance as determined by paired ttest * : p<0.05, ** : p < 0.01, *** : p<0.001
3) Significance as determined by Student t-test

group. Vertical jump and simple reaction time were 26.5cm and 371.0msec. for the soymilk group and 32.7cm and 348.1msec. for the soymilk + exercise group. Except the vertical jump, other measurements showed no difference between two groups suggesting their physical capability is similar to each other. Ten-week treatments showed that both systolic and diastolic blood pressures decreased ($p<0.05$) and ictus cordis increased ($p<0.05$) significantly in the soymilk group. In the soymilk + exercise group, both systolic ($p<0.001$) and diastolic ($p<0.01$) blood pressures decreased and vital capacity ($p<0.01$), sitting trunk flexion ($p<0.05$), and simple reaction time ($p<0.05$) increased significantly. In both groups, blood pressure decreased significantly and the soymilk + exercise group showed more improvement in physical capability than the soymilk group suggesting the positive effect of exercise.

3) BMD and bone metabolism markers

BMD and bone metabolism markers of the subjects were shown in Table 7. Prior to the treatment, BMD's of lumbar spine and femoral neck were $0.87g/m^2$ (t value = −1.41) and $0.80g/m^2$ (t value = −1.21) for the soymilk group and $0.86 g/m^2$ (t value = −1.10) and $0.81g/m^2$ (t value = −1.12) for the soymilk + exercise group showing no significant difference between the two groups. After the treatments, BMD's of lumbar spine and femoral neck significantly increased by $0.02g/m^2$ each in the soymilk group ($p < 0.01$ each). In the soymilk + exercise group, BMD's of lumbar spine and femoral neck significantly increased by 0.2g/m and 0.04g/m, respectively ($p < 0.001$ each). However, overall the BMD's of two groups were not significantly different from each other.

Analysis on the markers of bone metabolism (Table 7) showed that after the treatment, serum ostesocalcin of the soymilk group and the soymilk + exercise group trended higher, but not significantly. Urine deoxypyridinoline (DPD) level in both groups trended lower without statistical significance. Osteocalcin is made in osteoblast and combined with cellular materials and some of it is released into the blood ; therefore, it is considered as a marker for bone formation (Brown et al. 1984). DPD, found in the bone structure and released by osteoclast into urine without degradation, is used as a marker for bone degradation (Kleerekoper 1996 ; Rubinacci et al. 1999). Markers for bone metabolism have been used to understand the bone

Table 7. BMD and markers of bone metabolism of the subjects before and after treatment

Variables	Soymilk (n = 19)	Soymilk + Exercise (n = 14)	t-test[3]
BMD-S[4] (T-score)			
Pretreat	−1.41 ± 0.61[1]	−1.51 ± 0.66	N.S.
Posttreat	−1.26 ± 0.63*[2]	−1.34 ± 0.65***	N.S.
BMD-S (g/cm^2)			
Pretreat	0.87 ± 0.09	0.86 ± 0.09	N.S.
Posttreat	0.89 ± 0.09**	0.88 ± 0.09***	N.S.
BMD-F[2] (T-score)			
Pretreat	−1.21 ± 0.62	−1.12 ± 0.59	N.S.
Posttreat	−0.91 ± 0.97*	−0.84 ± 0.59***	N.S.
BMD-F (g/cm^2)			
Pretreat	0.80 ± 0.09	0.81 ± 0.08	N.S.
Posttre	0.82 ± 0.09**	0.85 ± 0.08***	N.S.
Osteocalcin (ng/ml)			
Pretreat	8.56 ± 3.07	9.80 ± 2.20	N.S.
Posttreat	10.12 ± 3.21	10.59 ± 2.45	N.S.
DPD[6] (nM/mMCr)			
Pretreat	6.27 ± 1.47	7.26 ± 2.58	N.S.
Posttreat	5.88 ± 1.71	6.79 ± 1.25	N.S.

1) Mean ± S.D.
2) Significance as determined by paired ttest, * : $p<0.05$, ** : $p < 0.01$
3) Significance as determined by Student t-test
4) Bone mineral density-spine
5) Bone mineral density-femoral neck
6) Deoxypyridinoline

metabolism ; however, there was no significant change in this study.

In this study, soymilk was used ; therefore, it is not possible to draw a conclusion that a specific compound contributed to increase in the BMD. However, there were no significant changes in the intake of calorie, proteins, calcium etc., which suggested no effects of isoflavones in soymilk. It is known that isoflavones in soymilk are similar to estrogen, and therefore, compete with estrogen for estrogen receptors thereby working as estrogen or anti-estrogen. For pre-menopausal women, they lower the level of intrinsic estrogen; for post-menopausal women, they function as agonists to estrogen (Kurzer 2000). Study by Alekel et al. (2000) on menopausal women showed that 80.4mg/day of isoflavones intake for 24weeks lowered bone loss in lumbar spine, and the study by Potter (1998) on post-menopausal women reported that the daily dose of 90mg isoflavones during a 6-month period caused significant increase in BMD of lumbar spine. Study on the healthy post-menopausal women showed that daily dose of 60mg of isoflavones significantly increases the serum osteocalcine level (Schiber et al. 2001), and the Pansini et al. (1997) and Uesugi et al. (2001) reported that daily intake of 61.8−76mg of isolated soy proteins for 4weeks and 12weeks significantly decreased urinary DPD in post menopausal women. Most of these studies on the positive effect of isoflavones on the bone metabolism are based on the studies on post-menopausal women. The current study also showed the positive effect on the BMD in underweight pre-menopausal women. Exercise is known to increase BMD and the max.bone mass (Kelly 1998 ; Rudberg et al. 2000 ; Suleiman et al. 1997) and the effects are dependent of the exercise type (Gail et al.1998 ; Hong et al. 2001 ; Katie et al.1992). In this study, in consideration of optimum exercise type and intensity for bone formation and exercise, experts prescribed the exercise program including aerobic exercise and muscle strength training. According to pre-study survey and anthropometrical measurements, subjects in this study did not exercise at all before the study, and lack of muscle in the body due to underweight easily caused fatigue with a little exercise; therefore, intensity and duration of the exercise was forced to be reduced. As a result, ten-week exercise of the soymilk + exercise group did not make significant difference in the BMD and markers of bone metabolism compared to the soymilk group without exercise. Intensity and duration of the exercise in the study were considered ineffective as the weight bearing exercise to affect the bone structure. Therefore, more studies on the exercise program, and intensity and duration of the exercise are needed to increase the BMD in underweight college women lacking physical endurance.

Summary and Conclusion

Effect of soymilk and exercise on bone mineral density (BMD) and bone metabolism was studied on 33 underweight college women with reduced bone mass. They were divided into two groups : daily intake of 400ml soymilk (containing 60mg isoflavones) was given to the soymilk group and exercise was additionally prescribed to the soymilk group + exercise. The results of the study on the changes of BMD and markers for bone metabolism are summarized as the following.

1) Age and body mass index (BMI) were 21.1 years and 19.0kg/m^2 for the soymilk group and 20.4 years and 18.9 kg/m^2 for the soymilk + exercise group. Subjects in both groups were underweight. Age, height, weight, BMI, and body fat of the two groups were not significantly different from each other.

2) Prior to the treatment, average calorie intake of the soymilk group and the soymilk + exercise group was 1,597.9 kcal (79.4% of the recommended) and 1,704.2kcal (85.2% of the recommended), respectively indicating no significant difference between two groups. Calcium intake of the soymilk group and the soymilk + exercise group was 408.3mg and 389.4mg, respectively showing no significant difference between two groups. The ten-week treatment (daily 400ml soymilk intake with or without exercise) did not make significant changes in the intake of calorie, protein, and calcium. Isoflavones intake prior to the treatment was 15.2mg and 20.6mg for the soymilk group and the soymilk + exercise group showing no significant difference. Isoflavones intake after treatment was significantly ($p<0.001$) increased for both the soymilk group (75.0mg) and the soymilk + exercise group (80.5mg).

3) Prior to treatment, BMD's of lumbar spine and femoral neck were 0.87g/m^2 (t value = −1.41) and 0.80g/m^2 (t value = −1.21) for the soymilk group and 0.86 g/m^2 (t value = −1.10) and 0.81 g/m^2 (t value = −1.12) for the soymilk + exercise group showing no significant difference between two groups. After the treatments, BMD's of lumbar spine and femoral neck significantly increased by 0.02g/m^2 each in the soymilk group ($p < 0.01$ each). In the soymilk + exercise group, BMD's of lumbar spine and femoral neck significantly increased by 0.2g/m and 0.04g/m, respectively ($p < 0.001$ each). However, overall the effect on BMD increase in two groups was not significantly different from each other.

4) After treatment, markers of bone metabolism were analyzed. Serum ostesocalcin of the soymilk group and the soymilk + exercise group trended higher, but not significantly. Urine deoxypyridinoline (DPD) level in both groups trended lower without statistical significance.

Based on findings of this study, isoflavones intake in soymilk significantly increases the BMD of the lumbar spine and femoral neck in underweight college women. Therefore, nutrition education on underweight women with high risk of bone loss should include isoflavones. On the other hand, exercise did not significantly increase the BMD compared to soymilk diet alone. As found from physical profiles of the subjects in this study, lack of muscle in the body due to underweight easily caused fatigue with a little exercise ; therefore, intensity and duration of the exercise were forced to be reduced. Intensity and duration of the exercise in the study were considered not effective as the weight bearing exercise to be able to affect the bone structure. Therefore, more studies on the exercise program, and intensity and duration of the exercise along with intake of foods containing isoflavones, and attitude of the subjects toward exercise and physical activity are highly desired.

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