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# Effects of Exercise on Bone Mineral Density and Bone Mineral Content in Postmenopausal Women

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## ABSTRACT

This study investigated associations between exercise habit and bone mineral density (BMD) and bone mineral content (BMC) in postmenopausal women. The BMD and BMC of the spinal skeleton was measured by dual energy x-ray absorptiometry. Exercise and energy expenditure of physical activity were estimated by questionnaire. For exercise activities, subjects were asked to identify all exercises they have participated in. The subjects were further asked to estimate the number of years of participation, the number of weeks per year, the number of times per week, and the number of hours per time. Subjects were then categorized into exercise (more than 3 times/wk, more than 30min per session exercise (n = 47) and nonexercise group (n = 72). Results indicated that there were no significant differences in BMD and BMC when comparisons were made between subjects in exercise habit, a general exercise group and a nonexercise control group. However, when exercise subjects were divided into weight-bearing and nonweight-bearing groups, significant differences were found. These results suggest that weight-bearing exercise positively influences bone mineral density and bone mineral content in postmenopausal women. Sedentary women should be encouraged to adopt a weight-bearing exercise to maintain the health of their skeletons. Exercise interventions are practical and feasible for healthy women and should be encouraged at the earliest possible age. Our findings lend support to recommendations for physical activity and weight-bearing exercise as a means of osteoporosis prevention. (*J Community Nutrition* 7(2) : 93~99, 2005)


KEY WORDS : weight-bearing exercise · postmenopausal women · bone mineral density.

## Introduction

Osteoporosis is a serious public health problem because of the increasing population of elderly people. In the Korea in 2000, 7.0% of Koreans were aged over 65 years and it is expected that these figures will rise in 2020 to about 14.0% for age over 65 (Kim 2001). Therefore, poor bone health is an increasingly common medical, social, and economic problem and its prevention or amelioration is of major importance for maintenance of health in elderly people. This disease is of particular concern for postmenopausal women. A low bone mass can be the result of an increased rate of bone loss during aging, especially in women after menopause. Exercise has been recommended as a nonpharmacological approach for maximizing bone mineral density during the younger years as well as improving bone density by increasing and/or preventing the loss of bone during the older years. Increased activity has been suggested as a way of preserving bone health in older women. Numerous reports indicate that physical activity is positively related to bone density and may, therefore, be an important factor in the prevention or treatment of osteoporosis. Some longitudinal studies report that excercise, as an intervention technique, has slowed or reversed losses in bone mineral content (Dalsky et al. 1988). Whereas, other longitudinal studies have not found significant results (Miriam et al. 1991).

It appears the types of exercise have a significant effect on bone density while others do not (Bassey, Ramsdale 1995). Whereas, some studies demonstrate that bone loss in exercising postmenopausal women is similar to that in controls. A large number of studies have attempted to define the role of physical activity and exercise patterns across the lifespan on bone density. Physical activity has been linked to reduced osteoporotic fracture prevalence or incidence as well as

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higher bone density in older adults. A variety of prospective studies have examined the effects of exercise on postmenopausal bone loss (Cavanaugh, Cann 1988 ; Dalsky et al. 1988 ; Smith et al. 1989). However, the results of these studies vary, probably because of differences in exercise protocols and measurement techniques used (Dalsky et al. 1988). In the few studies little attention has been given to understand the type, intensity, duration, and frequency of exercise that are optimal for bone. The present study was to examine the effects of a regular basis exercise habit and physical activity at the daily basis in postmenopausal bone mineral density. The goal of the present study was to determine whether modifiable factors, such as physical activity and regular basis exercise habits influence the bone mineral density and bone mineral content in postmenopausal women.

## Subjects and Methods

One hundred and nineteen postmenopausal women aged 46 – 56 years were voluntarily recruited from the Daegu area for the study. The examination included measurements of height, weight, and nutrient intake. Body mass index (BMI), which is a weight to height index, was derived from the formula : [(weight (kg)/height (m)$^2$). Energy intake and nutrient intakes were estimated by the convenient method (Moon et al. 1980). The convenient method is categorized into the seven food groups (fish, meat, eggs and soy bean products, milk and dairy products, vegetables, fruits, cereals and potatoes, and sugar and candies) and further categorized into the number of eatings per day and the quantity of food per eating.

For daily basis physical activity, subjects were asked to identify energy expenditure. Energy expenditure was calculated from the Korean RDA (Recommended Dietary Allowances for Koreans 2000). The energy expenditure is calculated from the numbers of hours in a 24-h period spending doing very heavy, a little heavy, heavy, moderate, moderate light, light, or very light activities and the numbers of hours in the same period spent sleeping or resting in bed. Physical activity is normally defined as the ratio of overall daily energy expenditure to BMR. Seated work that allows or requires a person to move around, but with little or no strenuous activity, is consistent with a physical activity level of 1.4 – 1.7, and standing work (eg, that of a housewife or salesclerk) is consistent with physical activity level of 1.9.

For exercise activities, subjects were asked to identify all exercises they have participated in. The subjects were further asked to estimate the number of years of participation, the number of weeks per year, the number of times per week, the number of hours per time, and type of exercise. It is well documented that bone remodeling is estimated to take a minimum of 4 to 6 months (Smith, Raab 1986). Subjects were then categorized into exercise (more than 3 times/wk, more than 30 min per session exercise, lasting more than 1 year) and nonexercise group. Also subjects were categorized into weight-bearing exercise (jogging, climbing, walking, running aerobic dancing) and non weight-bearing exercise (swimming) Bone mineral density and bone mineral content of the lumbar spine (L2 – L4) were measured by dual-energy absorptiometry (Lunar Radion Corp. Madison, WI). The degree of bone formation was estimated by measuring serum alkaline phosphoatase (ALP). Calcium in serum was measured.

### 1. Statistical analysis

Pearson correlation coefficients were calculated to test for associations among weight, bone mineral density, energy expenditure, and age. Statistical significance was set a $p < 0.05$ for all tests. All data were analyzed by SAS system. All values are expressed as means ± SD.

## Results and Discussion

### 1. Subjects characteristics.

Comparisons between exercise and sedentary subjects were made to determine the extent to which self-monitored physical activity influences bone mineral density and bone mineral content of postmenopausal women. The demographic characteristics of the study subjects are described in Table 1. The

**Table 1.** Descriptive characteristics of exercise and non-exercise group of the study subjects

| Variable | Exercise (N = 47) | Nonexercise (N = 72) | p |
|---|---|---|---|
| Age (yr) | 55.3 ± 5.4[1] | 53.2 ± 6.9 | NS[4] |
| Weight (kg) | 56.4 ± 5.3 | 57.9 ± 8.2 | NS |
| Height (cm) | 153.8 ± 4.4 | 154.0 ± 5.1 | NS |
| BMI (kg/m$^2$)[2] | 23.9 ± 2.8 | 24.3 ± 3.1 | NS |
| RBW[3] | 117.6 ± 11.8 | 118.9 ± 12.4 | NS |
| Menarche (yr) | 16.3 ± 1.6 | 16.6 ± 1.9 | NS |
| Menopause (yr) | 49.2 ± 3.4 | 48.1 ± 5.4 | NS |

1) Mean ± SD
2) BMI : Body Mass Index (weight (kg)/height (m$^2$))
3) RBW (Relative Body Weight) : [weight (kg)/{height (cm) – 100} × 0.9] × 100
4) NS : Not significant difference between two groups at $p < 0.05$ by t-test

mean age of exercise and nonexercise women was 55.3 ± 5.4 years and 53.2 ± 6.9 years, respectively. The mean BMI exercise and nonexercise women was 23.9 ± 2.8 and 24.3 ± 3.1, respectively. No significant differences were found between the exercise and nonexercise groups.

## 2. Dietary intake and energy expenditure

Dietary intake data from the convenient method are presented in Table 2. There were no significant differences between groups in any of the nutrient measured and energy expenditure. However, energy intake and expenditure were not significantly different between the groups, as shown in Table 2, the women who exercise had energy intake values that were slightly lower than those of the women who do not exercise and the women who exercise had energy expenditure values that were slightly higher than those of the women who do not exercise. A recent study reported that more leisure-time activity is associated with a lower risk of hip fractures in postmenopausal women (Feskanich et al. 2002).

Smith and Raab (Smith, Raab 1986) recently summarized the positive effect of physical activity on bone mineral density. Tennis players show one-third more cortical thickness of bone in the dominant than in the nondominant arm (Jacobson, Beaver 1984). Further evidence for a positive role of physical activity in bone status of Japanese women shows how environmental factors and be confounded. Japanese have fewer hip fractures and less osteoporosis than American whites have, which is considered to result at least in part from differences in their lifestyle patterns. Even though Japanese women consume significantly less calcium than American white women consume, they have lower fracture rates of the hip which are thought to result from increased sitting and rising activities whereas their higher vertebral fracture rates considered to relate to low calcium intakes.

The exercise women consumed 694mg/day of calcium which is 99.1% of RDA and nonexercise women consumed 665 mg/d of calcium which is 95.0% of RDA. The calcium intake is very high as compared to the mean intake of Korean adult women (Korean Health and Welfare Ministry 2003). The usual intakes of dietary calcium in Korea are far below

**Table 2.** Nutrients, energy intake, and energy expenditure of exercise and nonexercise group

| Variable | Exercise (rs) (N = 47) | % RDA[1] | Nonexercise (rs) (N = 72) | % RDA | p |
|---|---|---|---|---|---|
| Protein (g) | 66.8 ± 20.6 | 121.4 | 65.3 ± 178.3 | 118.7 | NS[3] |
| Fat (g) | 43.0 ± 17.6 | NA[2] | 42.0 ± 17.6 | NA | NS |
| Carbohydrate (g) | 260.3 ± 48 | NA | 275.8 ± 42.2 | NA | NS |
| Vitamin A (R.E) | 12063 ± 95 | 172.2 | 1187 ± 100 | 169.5 | NS |
| Vitamin $B_1$ (mg) | 0.97 ± 0.20 | 97 | 1.01 ± 0.15 | 101 | NS |
| Vitamin $B_2$ (mg) | 1.15 ± 0.38 | 95.8 | 1.10 ± 0.28 | 91.6 | NS |
| Niacine (mg) | 16.1 ± 3.41 | 123.8 | 16.8 ± 2.79 | 129.2 | NS |
| Vitamin C (mg) | 139 ± 27 | 198.5 | 149.0 ± 25 | 212.8 | NS |
| Iron (mg) | 14.3 ± 4.9 | 119.1 | 14.5 ± 4.1 | 120.8 | NS |
| Calcium (mg) | 694 ± 251 | 99.1 | 665 ± 166 | 95.0 | NS |
| Energy intake (kcal) | 1696 ± 325 | 89.2 | 1749 ± 285 | 92.0 | NS |
| Energy expenditure (kcal) | 1987 ± 587 | NA | 1920 ± 424 | NA | NS |
| PAEE (kcal)[4] | 956 ± 279 | NA | 931 ± 295 | NA | NS |

1) RDA : Recommended Dietary Allowances for Korean, 2000
2) NA : Not applicable
3) NS : Not significant difference between two groups at $p < 0.05$ by t-test
4) PAEE : Physical activity energy expenditure

**Table 3.** Effects of regular exercise on spine bone mineral density, spine bone mineral content and ALP in postmenopausal women

| | Total | Exercisers (N = 47) | Nonexercisers (N = 72) | p |
|---|---|---|---|---|
| BMD (g/cm$^2$) | 0.98 ± 0.16[1] | 0.99 ± 0.13 | 0.97 ± 0.17 | NS[2] |
| BMC (g) | 39.2 ± 8.2 | 39.6 ± 7.09 | 39.1 ± 8.6 | NS |
| ALP (u/l) | 75.7 ± 27.1 | 74.6 ± 33.8 | 76.4 ± 36.7 | NS |
| Blood Ca (mg/dl) | 9.21 ± 2.01 | 9.24 ± 0.36 | 9.19 ± 0.44 | NS |
| Blood P (mg/dl) | 3.89 ± 0.48 | 3.88 ± 0.38 | 3.90 ± 0.52 | NS |

1) Mean ± SD
2) NS : Not significant difference between exercise and nonexercise groups at $p < 0.05$ by t-test

recommended amounts for most postmenopausal women. The significance of calcium intake will be studied in the next study.

### 3. Bone mineral density and bone mineral content

The bone-status data, such as spine bone mineral density, spine bone mineral content, and bone formation marker (ALP), and blood calcium concentration for two groups are shown in Table 3. No significant differences were found in spine BMD, spine BMC, ALP, and serum Ca. The BMD of the lumbar spine was 0.98 ± 0.13 in exercise women (n = 47) and was 0.97 ± 0.17 in nonexercise women (n = 72). And spine BMC was 39.2 ± 7.09 in exercising women and 39.1 ± 8.6 in nonexercise women. There was no significant bone mineral density and bone mineral content effect involving exercise. Physical activity has been linked to reduced osteoporotic fracture prevalence or incidence as well as higher bone density in older adults. The benefits of exercise, particularly of moderate levels, for postmenopausal women appear to be primarily preventative, as opposed to therapeutic, in nature with respect to bone loss. However, results of the present study involving a regular basis in exercise activity provide an exception to the above findings. Participation in regular exercise, such as those defined in this study, appear not to have a positive effect on the bone mineral density and bone mineral content in postmenopausal women. A potential confounding factor is a calcium intake ; in this study calcium intake was similar between groups. However, both groups were below the 700mg/day recommended intake for postmenopausal women. We do not know whether an adequate calcium intake would have effected the bone loss in the exercise. In Korean adults, about 80% of the calcium intake is supplied by non dairy products (Korea Health and Welfare Ministry 2003), so we have to investigate the quality of calcium intake as well as the quantity of calcium intake. A need to further investigate degrees of intensity and duration of physical activity was suggested. The physical activity was determined from self-reported. The level of exercise performed by the exercise subjects, based on these self-reported, was high enough to distinguish them from the sedentary group. As bone mineral density of the study subjects was not affected by exercise habit, other possibilities must be considered. First, the level of exercise did not significantly high enough from the nonexercise group. And, in the present study, we did not see exercise intervention in bone mineral density and bone mineral content ; we compared the self-monitored exercise habit. We did not find a higher trend of bone mineral density and bone mineral content in the exercise group. The results of this study was similar to the result of one recent study by Cavanaugh and Cann (Cavanaugh, Cann 1988). A group of postmenopausal women aged 49 – 64 years walked briskly for 15 – 40min/day for 3 day/week for 12mo failed to show a difference in the rate of bone loss between exercising and control subjects. However, in the study of osteoporotic fractures, women who reported walking for exercise had a significant 30% reduction in hip fra-

**Table 4.** Nutrients, energy intake, and energy expenditure in weight-bearing and nonweight-bearing exercise groups

| Variable | Weight-bearing exercise (rs) (N = 20) | % RDA[1] | Nonweight-bearing exercise (rs) (N = 27) | % RDA | p |
|---|---|---|---|---|---|
| Protein (g) | 67.6 ± 18.6 | 122.9 | 64.9 ± 15.6 | 118.0 | NS[3] |
| Fat (g) | 42.7 ± 14.3 | NA[2] | 43.3 ± 16.4 | NA | NS |
| Carbohydrate (g) | 259.0 ± 37 | NA | 260.3 ± 41.0 | NA | NS |
| Vitamin A (R.E) | 1216 ± 99 | 173.7 | 1200 ± 95 | 171.4 | NS |
| Vitamin $B_1$ (mg) | 0.96 ± 0.19 | 96.0 | 1.01 ± 0.13 | 101.0 | NS |
| Vitamin $B_2$ (mg) | 1.15 ± 0.33 | 95.8 | 1.14 ± 0.29 | 95.0 | NS |
| Niacine (mg) | 16.3 ± 3.01 | 125.4 | 16.0 ± 2.80 | 123.0 | NS |
| Vitamin C (mg) | 146 ± 30 | 208.5 | 143.0 ± 27 | 204.2 | NS |
| Iron (mg) | 14.2 ± 4.7 | 118.3 | 14.4 ± 4.0 | 120.0 | NS |
| Calcium (mg) | 697 ± 241 | 99.5 | 682 ± 211 | 97.4 | NS |
| Energy intake (kcal) | 1664 ± 352 | 87.5 | 1721 ± 265 | 90.5 | NS |
| Energy expenditure (kcal) | 1997 ± 497 | NA | 1959 ± 398 | NA | NS |
| PAEE (kcal)[4] | 969 ± 279 | NA | 932 ± 295 | NA | NS |

1) RDA : Recommended Dietary Allowances for Korean, 2000
2) NA : Not applicable
3) NS : Not significant difference between two groups at $p < 0.05$ by t-test
4) PAEE : Physical activity energy expenditure

cture risk compared to women who did not walk for exercise (Cummings et al. 1995). However, a longitudinal study report that excercise, as an intervention technique, has slowed or reversed losses in bone mineral content (Dalsky et al. 1988). The differences in the effect may be due to the intensity or type of the exercise. Our exercise group included any regular exercise, whereas the Dalsky et al. (Dalsky et al. 1988) study included jogging, stair climbing, weight training, rowing, and cycling. Thus, the disparity between our study and the studies of others (Cavanaugh, Cann 1988 ; Dalsky et al. 1988) may be due to the exercise protocol employed, duration or type of the exercise, age group chosen, and the site used to determine bone status. Based on accumulated evidence for all health outcomes, at least 30 minutes to 1 hour of moderate intensity exercise on most days of the week is recommended for adults (Institute of Medicine 2002).

We initially hypothesized that the types of exercise have a different effect on the bone. Several cross-sectional studies have reported positive correlations between walking and spine bone mineral density (Coupland et al. 1999 ; Krall, Dawson-Hughes 1994 ; Nelson et al. 1991). So the exercise subjects were classified by weight-bearing and nonweight-bearing groups. The lumbar spine BMD was 1.09 ± 0.13 in weight bearing-exercise women (n = 27) and 0.96 ± 0.12 in non weight-bearing exercise women (n = 20). There were no significant differences in energy intake, calcium intake, and energy expenditure between non-weight bearing and weight-bearing exercise groups (Table 4).

As shown in Table 5, the women who were weight-bearing exercise had spine BMD and BMC values that were significantly higher than those of the women who were non weight-bearing exercise. The bone formation marker, ALP activities did not differ by exercise type. In a study involving postmenopausal women aged 55 – 70 years, it was found that weight-bearing exercise, such as walking, jogging, or stair climbing, over a period of 9 or 20mo led to significant increases in lumbar spine BMD by 9 months the exercise group had a 5.2% increase in spine BMD and the sedentary control group had a 1.4% decrease. Because mechanical loading contributes to subsequent bone mass (Martin, McCulloch 1987), weight-bearing exercise is suggested as a therapy to increase BMD. Compared with spine BMD and BMC in the non weight-bearing exercising subjects, spine BMD and BMC in the weight-bearing exercising subjects were significantly higher.

The elderly are at risk for vitamin D deficiency because of poor dietary vitamin D intake and decreased exposure to sunlight. Very few foods naturally contain vitamin D. Without vitamin D, the small intestine absorbs no more than 10 – 15% of dietary calcium. In a person with vitamin D sufficiency, the small intestine absorbs, on average 30% of dietary calcium ; during growth, lactation, and pregnancy, the efficiency increases to 80% (Holick 2004). The study reported that 30%, 42%, and 84% of free-living white, Hispanic, and black elderly were vitamin D deficient (25 (OH) D < 50nmol/L) at the end of August in Boston (Holick 2002). It was recently recognized that 42% of African American women aged 15 – 49 years throughout the United States were vitamin D deficient (25 (OH) D < 40nmol/L) at the end of winter (Nesby-O'Dell et al. 2002) Unfortunately, 1,25 $(OH)_2D$

**Table 5.** Effects of kind of exercise on spine bone mineral density, spine bone mineral content and ALP in postmenopausal women

| | Nonweight-bearing exercise (rs) (N = 20) | Weight-bearing exercise (rs) (N = 27) | p |
|---|---|---|---|
| Age (yr) | 53.1 ± 6.9[1)] | 54.0 ± 3.5 | NS[2)] |
| Weight (kg) | 58.3 ± 5.7 | 59.5 ± 6.2 | NS |
| Height (cm) | 153.0 ± 5.89 | 156.9 ± 3.6 | NS |
| BMD ($g/cm^2$) | 0.958 ± 0.129 | 1.089 ± 0.132 | *[3)] |
| BMC (g) | 37.59 ± 7.35 | 45.68 ± 6.40 | * |
| ALP (u/l) | 74.0 ± 29.8 | 68.2 ± 16.7 | NS |

1) Mean ± SD
2) NS : Not significant difference between exercise and nonexercise groups at p < 0.05 by t-test
3) * : p < 0.05

**Table 6.** Correlation coefficients of each variable on BMD and BMC in postmenopausal women

| Variables | Total | | Exercise (rs) | | Nonexercise (rs) | |
|---|---|---|---|---|---|---|
| | BMD | BMC | BMD | BMC | BMD | BMC |
| Age (yr) | −0.61*** | −0.18 | −0.36 | −0.01 | −0.65*** | −0.18 |
| Weight (kg) | 0.36* | 0.19* | 0.53** | 0.37 | 0.32* | 0.18 |
| Height (cm) | 0.39*** | 0.27* | 0.32 | 0.21 | 0.40** | 0.31** |
| ALP (u/l) | −0.28* | −0.31* | −0.41* | −0.25 | −0.24* | −0.31* |
| Years since menopause (yr) | −0.32* | −0.06 | −0.46 | −0.43 | −0.26 | 0.04 |
| Menarche age (yr) | −0.28* | −0.12 | −0.01 | −0.07 | −0.36** | −0.13 |

* : p < 0.05, ** : p < 0.01, *** : p < 0.001

was not measured.

Thus it is reasonable to conclude that increased exposure to sunlight leads to higher BMD, because it was reported that higher 25(OH)D concentrations correlated with higher BMD(Jones, Dwyer 1998). This is the likely one explanation for why exercise with weight-bearing had higher BMD. The weight-bearing exercises in the subjects were jogging, walking, climbing and aerobic. And non weight-bearing exercise in the subjects was swimming. Swimming time was spent indoors. However, jogging, walking, and climbing were spend in the day time with exposure to sunlight. Vitamin D is the most important regulator of calcium absorption and bone mineralization. Allen explains that vitamin D status of the body depends on ultraviolet light and dietary source of vitamin $D_2$(ergosterol) and vitamin $D_3$(calciferol) (Allen 1982). Current study suggests that the bone density observed was affected by physical activity patterns, and furthermore, exposure to sunlight.

### 4. Correlation coefficient of variables

Correlation coefficient for age, weight, and ALP with exercise habits are shown in Table 6. A significant correlation was observed between age, weight, height and ALP, and years since menopause, and menarche age in bone mineral density in total subjects. Correlation analysis revealed that the weight was positively associated with BMD in postmenopausal women, while ALP was negatively associated with BMD. Greater weight is associated with a reduced risk of hip fracture, likely due to its weight-bearing effect on bone, the protection supplied by padding around the hips in the event of a fall, and the conversion of androgens to estrogen in fatty tissues(Longcope et al. 1981). Body weight is partly determined by nutrition and physical activity. Further, it may be determined by bone mass. Women who are obese have a higher bone mineral mass and a lower fracture risk than thin women. Also, a greater body weight may be associated with higher peak bone mass achieved in early adulthood.

Within the non exercise group, we observed that body weight and height were positively correlated with the spine BMD in non exercise women. And the spinal BMD was negatively associated with age, ALP, and menarche age in nonexercise women. However, neither age nor the age of menarche were associated with spinal BMD in exercise women. The fact that exercise is an inexpensive, nonpharmacological approach that is available to most of the general public makes this form of good bone appealing, however, it is important to realize that about 70% of Korean adults do not regularly participate in adequate amounts of physical activity(Kim et al. 2004).

## Summary and Conclusion

The goal of the present study was to determine whether physical activity and regular exercise habits influence the bone mineral density and bone mineral content. We found that weight-bearing activity was an excellent contributor of BMD in postmenopausal women. The results of the present correlation study indicate that older women in the non exercise group tend to have a lighter BMD than younger women, but the same is not true in the exercise women. The effect of age is negated when an exercise habit is involved. And the women who did weight-bearing exercise had spine BMD and BMC values that were significantly higher than those of the women who did non weight-bearing exercise. As the elderly population continues to rise, so does the need to investigate the effectiveness of exercise as preventive therapies for postmenopausal bone loss. Overall, the data represented by this study seems to support the current findings of a positive and significant association between BMD and weight-bearing exercise habit. Osteoporosis is an age-related disease with a multitude of factors contributing to the prevalence of its existence. The effects of exercise on BMD need to be further investigated.

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