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The Relationship between Exercise, Bone Mineral Density and Antioxidant Enzyme Activity of Postmenopausal Women

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Abstract

This study was carried out to elucidate the relationship among exercise, bone mineral density and antioxidant enzyme activity of postmenopausal women. 60 women residing in the Iksan, Korea area were recruited. The questionnaires were designed to find out exercise habits. Bone mineral density (BMD) was measured by dual energy X-ray absorptiometry. Parameters of antioxidative capacity, including the activities of superoxide dismutase (SOD), glutathione peroxidase (GPx), catalase (CAT) and total antioxidant capacity (TA) were analyzed in fasting blood. The mean age, height, weight, and BMI of subjects were 65.0 years, 151.1 cm, 59.5 kg 26.0 m/kg^2, respectively. The mean BMDs of subjects were 0.85 g/cm^2 (lumbar spine), 0.6 g/cm^2 (Femoral neck), 0.49 g/cm^2 (trochanter), and 0.40 g/cm^2 (Ward's triangle). There was a significant difference in BMD among different age groups (50's, 60's and 70's) showing lower value with increasing age ($p<0.05$). The mean SOD, GPx, and CAT activities were 138.5 U/mL, 1,273.8 U/mL and 314.3 kU/L respectively, and TA was 1.16 mmol/L. TA of the group which exercised 3~4 times a week was significantly higher than those of the other exercise groups ($p<0.05$). The subjects with higher SOD activity also have a higher the T values in the lumbar spine, femoral neck, trochanter, and Ward's triangle. In conclusion, this study revealed that the levels of antioxidant enzyme activity were closely associated with the exercise status and bone mineral density in postmenopausal women.

Key words: bone mineral density, superoxide dismutase, catalase, total antioxidant capacity

INTRODUCTION

Osteoporosis, the decrease of bone density, is an increasingly important problem as the population ages.

The list of leading causes of mortality causes for Korea shows that 2.1 persons per one hundred thousand persons in the population in 1989 had diseases of the musculoskeletal system and conexus substanita. This figure has increased to 4.4 persons in 2001. For women, the rate was tripled from 2.5 to 7.5 persons per one hundred thousand at this time (1).

It is estimated that a number of chronic diseases, including aging, have a loose relationship with oxidative stress in the body. Some studies on anti-oxidative factors (2-5) are being conducted.

These investigate the relationship between osteoporosis and oxidative damage, on the assumption that oxidative stress affects osteoporosis caused by aging. They suggest free radicals as the major cause of osteoporosis (6-9). Osteoporosis is caused by various factors, such as genetic factors, menopause and nutritional status (10, 11). There are few studies on the activation of anti-oxidative enzymes by general nutrition conditions, except for antioxidant vitamin and minerals. According to the studies of Datta et al. (6) and Garrett et al. (9), Reactive Oxygen Species (ROS) may directly affect the process of bone resorption through destruction of the collagen in the bone, or facilitating the secretion of protease by osteoclasts. Osteoclasts reacts with parathormone, interleukin-1, tumor necrosis factor (TNF) and 1,25-$(OH)_2$ vitamin D_3 and creates superoxide. This superoxide facilitates bone resorption by increasing the creation and activation of osteoclasts. Also, Veille et al. (12) reported that estrogen increased oxide synthase activity and decreased the activity of SOD in the womb of lambs. Damoulis and Hauschka (13) and Ralston et al. (14) reported nitric oxide increased the activation of osteoblasts at low levels, while it hindered its activation or toxicity at high levels. Therefore, in the decrease of bone density after menopause caused by lack of estrogen, the creation

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of free radicals may affect the creation and activation of osteoclasts and be the major cause of decreasing of bone mineral density, caused by inharmonious remodeling.

Limited study has been conducted on the possible effect of the "free radicals" on bone mineral density, especially among postmenopausal women. Research on the relationship between bone density and antioxidant enzyme activity is greatly needed.

This study focused on the relationship between the anthropometric measurement, lifestyle, bone mineral density, and activity of the antioxidant enzyme of postmenopausal women.

MATERIALS AND METHODS

Subjects

60 postmenopausal women an age 50～77, attending a seniors' college and living at Iksan, Jeon-buk in July 2002 were selected as the main subjects. The subjects experienced natural menopause without hysterectomy, except those who had thyroid and kidney problems. We studied anthropometric measurements, collected blood and details of food intake for three days.

Questionnaire interview

Each participant completed a questionnaire conducted by investigators. The questionnaire included the participant's age, health status, past and current use of medication (including estrogen), lifestyle factors such as sleeping hours and exercise status.

Anthropometric measurements

The subjects took their heights and weight in an upright position without shoes using an automatic physical measuring machine (DS-102, JENIX, Korea). The BMI {body mass index=weight (kg)/height $(m)^2$} was calculated based on height and weight. The percentage of body fat (body fat %) was calculated based on age and height using a body fat measuring instrument (TBF-105 TANITA, Japan). Waist and hips were measured with a measuring tape. On the basis of this, WHR (waist hip ratio) was calculated. Systolic blood pressure (SBP) and Diastolic blood pressure (DBP) were measured using an automatic sphygmomanometer (BP-750A, NISSEI, Japan). The survey was designed to measure the age, maternal factors, the lifestyle, the frequency of the exercise, and the exercise hours.

Measurement of the bone mineral density

The age, height and weight of the participants were recorded. The bone mineral density was measured in the following areas: the lumbar spine (L2～L4), femoral neck, trochanter, intratrochanter and Ward's triangle using dual energy X-ray absorptiometry (DEXA, Hologic, USA).

Analysis of antioxidant enzyme activity

Superoxide dismutase: The activity of SOD was measured using heparin-treated plasma 1.0 mL based on Floh method (15). Xanthin created superoxide by xanthine oxidase. This superoxide radical forms Formazan dye through reacting with I.N.T (2-[4-iodophenyl]-3-[4-introphenol]-5phenyl-tetrazolium chloride). We measured the degree of suppression of this reaction as an indicator of SOD activity.

Glutathione peroxidase: GPx activity was determined by a spectrophotometric method using heparin-treated 0.05 mL plasma based on Paglia and Valentine's method (16). We measured the degree of decrease in optical density at 340 nm when glutathione is reduced by GR and NADPH.

Serum catalase: Serum catalase activity was determined according to Aebi's method (17). We placed 50 mmol/L Na-K phosphate buffer (pH 7.0) and a substrate, 1.0 mL H_2O_2, into 0.2 mL serum and activated it at 37°C for 1 minute. Then 32.4 mmol/L ammonium molydate solution was added and held at 37°C for 1 minute. Optical density then measured at 405 nm using a spectrophotometer (Photometer 4020, Japan).

Total antioxidant capacity: We cultivated ABTS [2,2′-Azino-dl-(3-ethylbinzthiazoline sulphonate)] with peroxidase and H_2O_2, and measured the appearance of a positive ion at 600 nm, which forms a stable bluish green molecule creates by ABTS.

Statistical analysis

Statistical comparisons were performed using SAS software (Version 8.2). Significance of differences among three groups was conducted with Duncan's multiple range test at a $p<0.05$ level minimum after ANOVA.

RESULTS AND DISCUSSION

Anthropometric measurements

Sixty subjects (Table 1) were divided into 3 age groups of 20 (age group, 50～59), 21 (age group, 60～69) and 19 (age group, 70～77). The average age, height and weight of all subjects were 65.0, 151.1 cm and 59.5 kg, respectively; which was a little shorter, but relatively heavier for their age than the 154 cm and 54 kg suggested by Korean physical standards for citizens aged 65～74 (18). Therefore, average BMI was 26.0, which was higher than the 22.8 suggested for the age group by Korean physical standards (18). The content of body fat was also higher at 38.4%. WHR was within a normal range (75～90%) at an average of 87.4%. The average

Table 1. Anthropometric measurements in postmenopausal women

Variables	Total (n=60)	50～59 yrs (n=20)	60～69 yrs (n=21)	70～77 yrs (n=19)
Height (cm)	151.1±5.5[1)]	152.2±5.7[a2)]	152.3±5.1[a]	148.7±5.1[b]
Weight (kg)	59.5±8.6	60.3±89.0	61.2±7.7	56.8±9.0
BMI (kg/m^2)[3)]	26.0±3.2	26.1±3.6	26.3±2.7	25.6±3.1
Waist (cm)	85.8±8.9	82.9±9.1	87.3±6.6	87.1±10.5
Hip (cm)	98.0±6.6	96.5±6.4	98.8±5.9	98.8±7.6
WHR[4)]	87.4±5.8	85.7±5.8	88.3±3.3	88.1±7.7
Body fat (%)	38.4±7.3	38.6±8.0	38.4±5.2	38.1±8.8
SBP[5)] (mmHg)	145.5±21.4	133.3±17.6[b]	151.1±20.9[a]	152.2±21.1[a]
DBP[6)] (mmHg)	77.7±10.0	76.7±9.7	79.5±9.0	76.7±11.6

[1)]Mean±standard deviation.
[2)]Means with different superscripts within a row are significantly different at α=0.05 as determined by Duncan's multiple range test.
[3)]Body mass index. [4)]Waist hip ratio. [5)]Systolic blood pressure. [6)]Diastolic blood pressure.

SBP and DBP were 145.5 mmHg and 77.7 mmHg, respectively, lower than the 160 mmHg hypertension standard of WHO for SBP, higher than the Korean standard for normal SBP of under 140 mmHg.

There were no differences in height between the fifties, 152.2 cm and sixties, 152.3 cm. But the seventies age group was shorter at 148.7 cm ($p<0.05$). The SBP of the fifties group was significantly lower at 133.3 mmHg, compared with the sixties and seventies groups at 151.1 mmHg and 152.2 mmHg, respectively ($p<0.05$).

Lifestyle

The exercise survey reveled that (Table 2) 51.7 percent (31 people) said they exercised once a month. There was a significant effect of age on exercise frequency. The reported time spent exercising per session was divided into three groups, 1) less than 30 minutes, 2) 30～60 minutes, and 3) 60 minutes and over. Less than 30 minutes exercise was preferred by 28 subjects (46.7%). Lee et al. (19) pointed out that the intensity of physical activity was the main factor affecting the density of the bone in the lumbar spine after menopause. Lee (20) also concluded that the group who engaged in more physical activity exhibited better skeletal condition. The average sleep time of the participants was 7.8 hours, and there was no difference among ages. Twenty-seven participants (45.0%) reported sleeping less than 7 hours, 20 people (33.3%) 8～9 hours, and 13 people (21.7%) 10 hours or more.

Table 2. Daily activity, sleeping hours and frequency of exercise in postmenopausal women N (%)

	Variables	Total (n=60)	50～59 yrs (n=20)	60～69 yrs (n=21)	70～77 yrs (n=19)	x^{2*}
Exercise	Mean of exercising hours (min/one time)	52±51[1)]	48±51	55±33	52±67	
	Frequency					
	once/day	16 (26.7)	7 (35.0)	5 (23.8)	4 (21.1)	x^2=17.5722
	3～4/week	2 (3.3)	1 (5.0)	1 (4.8)	0 (0.0)	df=8,
	1～2/week	5 (8.3)	5 (25.0)	0 (0.0)	0 (0.0)	$p<0.0247$
	2～3/month	6 (10.0)	0 (0.0)	4 (19.1)	2 (10.5)	
	once/month	31 (51.7)	7 (35.0)	11 (52.4)	13 (68.4)	
	Exercising hours groups					
	≤ 30 mins	28 (46.7)	11 (55.0)	8 (38.1)	9 (47.4)	x^2=3.5334
	30～60 mins	20 (33.3)	4 (40.0)	8 (38.1)	8 (42.1)	df=4,
	60 mins ≥	12 (20.0)	5 (15.0)	5 (23.8)	2 (10.5)	$p<0.4728$
Sleeping	Mean of sleeping hours (hour/day)	7.8±2.1	7.8±2.2	8.0±1.7	7.4±2.4	
	Sleeping hours groups					
	≤ 7 hours	27 (45.0)	9 (45.0)	8 (38.1)	10 (52.6)	x^2=2.3819
	8～9 hours	20 (33.3)	8 (40.0)	8 (38.1)	4 (21.1)	df=4,
	10 hours ≥	13 (21.7)	3 (15.0)	5 (23.8)	5 (26.3)	$p<0.6659$

[1)]Mean± standard deviation.
[*]Significance by x^2-test.

Table 3. Bone mineral density in postmenopausal women (g/cm^2)

Skeletal sites	Total (n=60)	50～59 yrs (n=20)	60～69 yrs (n=21)	70～77 yrs (n=19)
Lumbar spine 2	0.81±0.17[1)]	0.89±0.17[a3)]	0.82±0.09[a]	0.71±0.18[b]
Lumbar spine 3	0.86±0.18	0.95±0.20[a]	0.87±0.10[a]	0.75±0.19[b]
Lumbar spine 4	0.88±0.18	0.94±0.21[a]	0.90±0.09[ab]	0.80±0.18[b]
LS[2)] (L2～L4)	0.85±0.17	0.93±0.19[a]	0.86±0.08[a]	0.75±0.18[b]
Femoral neck	0.60±0.10	0.68±0.09[a]	0.60±0.08[b]	0.52±0.07[c]
Trochanter	0.49±0.10	0.56±0.11[a]	0.49±0.07[b]	0.42±0.08[c]
Intratrochanter	0.87±0.15	0.96±0.16[a]	0.89±0.12[a]	0.77±0.13[b]
Ward's triangle	0.40±0.14	0.50±0.12[a]	0.40±0.13[b]	0.30±0.06[c]

[1)]Mean±standard deviation. [2)]Lumbar spine.
[3)]Means with different superscripts within a row are significantly different at α=0.05 as determined by Duncan's multiple range test.

Fig. 1. Mean of bone mineral density by age in postmenopausal women.
[1)]Means with different superscripts are significantly different at α=0.05 determined by Duncan's multiple range test.

Bone mineral density

Bone mineral density (BMD) was measured in the following: the 3 areas of the lumbar spine (L2～L4), the femoral neck, intratrochanter, trochanter and Ward's triangle.

The mean BMD of the lumbar spine was 0.85 g/cm^2. Ward's triangle showed the lowest density of 0.40 g/cm^2 (Table 3, Fig. 1). Age was significantly related to lower BMD. Lee and Lee (21) demonstrated that bone mineral density tended to worsen in the order of lumber spine >femoral neck>trochanter>Ward's triangle for women 60 years and over. Mazess et al. (22) also mentioned that women 70 years and over showed the lowest bone mineral density in the Ward's triangle. All these studies support that aging is the main risk factor for decreased bone mineral density (23).

Participants were classified into 1) normal group (T value≥-1), 2) osteopenia group (-2.5<T value<-1), and 3) osteoporosis group (T value≤-2.5) according to the standard of the osteoporosis prescribed by WHO (Table 4). For Ward's triangle, 81.7 percent of the participants turned out to have osteoporosis. For the lumbar spine, 46.7 percent of the subjects had the osteoporosis. Lee and Lee (21) studied women 60 years and over for bone mineral density. According to the report, nearly 46 percent of the participants showed the osteoporosis in the lumbar spine and thigh bone, and only nine percent of the participants maintained normal density of bones. These findings all clearly indicate the prevalence of the osteoporosis among the aged.

Effects of lifestyle and activity of the antioxidant enzymes

The antioxidant enzyme activities of the participants according to frequency of exercise, sleep hours, and coffee intake are shown in the Table 5. The subjects were divided into three groups: 1) less than 7 hours, 2) 8～9 hours, and 3) 10 hours and over. For sleep hours, there was no significant difference in the activity of antioxidant enzyme. Exercise time had no significant effect among the groups of less than 30 minutes, 30～60 minutes, and 60 minutes and over. However, respondents who exercised 3～4 times a week showed the highest TA level of 1.35 mmol/L ($p<0.05$).

According to the Ji's study (24), vigorous muscle exercise helps to generate the ROS in the mitochondrial electronic conveyance gauge, xantine oxidase, and polymorphonuclear cells, as exhibited by increased oxygen uptake. These changes then lead to a disturbance of the prooxidant-antioxidant homeostasis, which contributes to the peroxidation of lipids in adipocytes. In doing so, vigorous exercise can impede the antioxidant defense system in the body. On the other hand, regular modest exercise enhances the immune and antioxidant defense systems in the body (25).

Antioxidant enzyme activity and exercise hours were not significantly related in this study. However, respondents who exercised 3～4 times a week showed the

Table 4. Status of bone health in postmenopausal women N (%)

Status of bone health		Total (n=60)	50～59 yrs (n=20)	60～61 yrs (n=21)	70～77 yrs (n=19)	x^{2*}
Lumbar spine	Osteoporosis[1)]	28 (46.7)	7 (35.0)	7 (33.3)	14 (73.7)	x^2=14.5291 df=4, p<0.0058
	Osteopenia	20 (33.3)	6 (30.0)	12 (57.1)	2 (10.5)	
	Normal	12 (20.0)	7 (35.0)	2 (9.5)	3 (15.8)	
Femoral neck	Osteoporosis	41 (68.3)	8 (40.0)	16 (76.2)	17 (89.5)	x^2=13.3737 df=4, p<0.0096
	Osteopenia	17 (28.3)	10 (50.0)	5 (23.8)	2 (10.5)	
	Normal	2 (3.3)	2 (10.0)	0 (0.0)	0 (0.0)	
Intratrochanter	Osteoporosis	20 (33.3)	4 (20.0)	5 (23.8)	11 (57.9)	x^2=17.2231 df=4, p<0.0017
	Osteopenia	30 (50.0)	8 (40.0)	14 (66.7)	8 (42.1)	
	Normal	10 (16.7)	8 (40.0)	2 (9.5)	0 (0.0)	
Trochanter	Osteoporosis	33 (55.0)	6 (30.0)	12 (57.1)	15 (79.0)	x^2=14.5737 df=4, p<0.0057
	Osteopenia	23 (38.3)	10 (50.0)	9 (42.9)	4 (21.0)	
	Normal	4 (6.7)	4 (20.0)	0 (0.0)	0 (0.0)	
Ward's triangle	Osteoporosis	49 (81.7)	13 (65.0)	17 (81.0)	19 (100)	x^2=8.8350 df=4, p<0.0654
	Osteopenia	10 (16.7)	6 (30.0)	4 (19.0)	0 (0.0)	
	Normal	1 (1.7)	1 (5.0)	0 (0.0)	0 (0.0)	

[1)]Osetoporosis: T-score≤-2.5, Ostoepenia: -2.5<T-score≤-1, Normal: -1<T-score.
[*]Significance by x^2-test.

Table 5. Antioxidant enzyme activities by life style factors

Variables		n	SOD (U/mL)	GPx (U/mL)	CAT (kU/L)	TA (mmol/L)
Sleeping hours (hr)	≤7	27	133.6±16.8[1)]	1234.3±308.2	308.9±198.0	1.17±0.16
	8～9	20	145.9±17.7	1338.4±247.1	289.1±176.7	1.15±0.14
	10≤	13	139.3±12.3	1274.4±252.1	365.0±229.5	1.17±0.11
Period of exercise hours (min)	<30	28	138.9±11.0	1210.7±289.8	351.6±196.3	1.14±0.12
	30～60	20	136.1±24.0	1323.2±248.3	257.1±195.1	1.21±0.17
	60<	12	141.3±15.7	1351.3±276.9	322.4±195.3	1.15±0.13
Frequency of exercise (times)	once/day	16	138.5±13.6	1246.1±341.3	367.5±157.2	1.15±0.12[b2)]
	3～4/week	2	148.0±26.6	1094.7±179.7	305.3±352.9	1.35±0.46[a]
	1～2/week	5	140.0±9.0	1320.2±210.8	245.7±130.5	1.09±0.09[b]
	2～3/month	6	131.5±10.5	1294.2±242.3	400.1±318.5	1.19±0.06[ab]
	once/month	31	139.3±19.5	1292.2±271.8	285.1±185.2	1.16±0.14[ab]

[1)]Mean±standard deviation.
[2)]Means with different superscripts within a column are significantly different from each other at α=0.05 as determined by Duncan's multiple range test.

highest TA in terms of the antioxidant enzymatic activity. This again indicates that modest exercise is the key to enhancing the antioxidant enzymatic activity. It also confirms a study on middle aged men by Kang and Park (26). People who engaged in regular modest exercise showed notably higher GPx and total radical-trapping antioxidant potential (TRAP) than the non-exercisers. Uusi-rasi et al. (27) studied 422 female in their 20's, 40's and 60's. The group who exercised in the form of jogging or aerobics for 20 minutes twice a week showed higher bone mineral density (5%) in their femoral necks compared to the non-exerciser. This result also confirms that a moderate degree of proper exercise affects both bone density and antioxidant enzyme activity.

Bone mineral density and the antioxidant enzyme activity

The participants were divided into three groups by T scores of each bone (Table 6, Fig. 2): less than -2.5, -2.5～-1 and over -1. The over -1 group for the intratrochanter showed notably higher level of SOD of 152.7 U/mL compared to other two groups who were -2.5～-1, and less than -2.5 showed 138.9 and 132.5 U/mL respectively ($p<0.05$). The higher the SOD activity was also associated with higher T scores in the lumbar spine, femoral neck, trochanter, and Ward's triangle.

These findings support the result of a cell study by Datta et al. (6) and Garrett et al. (9). First, the reactive oxygen species might destroy the collagen of the bone

Table 6. Antioxidant enzyme activities by status of bone health by T-score

Status of bone health		n	SOD (U/mL)	GPx (U/mL)	CAT (kU/L)	TA (mmol/L)
Lumbar spine	Osteoporosis[1)]	28	139.2±18.1[2)]	1292.0±301.1	334.5±198.2	1.16±0.13
	Osteopenia	20	136.7±12.1	1238.9±261.9	320.4±188.5	1.18±0.13
	Normal	12	140.7±22.3	1300.2±262.0	256.4±212.4	1.16±0.19
Femoral neck	Osteoporosis	41	135.7±17.0	1265.5±283.0	302.7±199.7	1.16±0.16
	Osteopenia	17	143.6±13.8	1283.0±278.1	336.5±198.5	1.17±0.11
	Normal	2	–[3)]	–	–	–
Intrat-rochanter	Osteoporosis	20	132.5±15.7[b4)]	1264.1±302.3	329.4±182.6	1.11±0.13
	Osteopenia	30	138.9±16.5[b]	1285.4±273.8	310.0±226.3	1.19±0.15
	Normal	10	152.7±12.1[a]	1247.7±263.6	296.0±105.7	1.19±0.12
Trochanter	Osteoporosis	33	135.2±18.3	1279.8±272.6	289.9±175.7	1.13±0.13
	Osteopenia	23	141.5±12.8	1271.4±295.1	340.5±233.6	1.21±0.15
	Normal	4	156.7±10.1	1213.6±307.3	365.5± 41.9	1.14±0.10
Ward's triangle	Osteoporosis	49	136.8±16.7	1279.5±273.4	306.3±202.4	1.16±0.14
	Osteopenia	10	145.1±13.5	1218.3±326.1	345.0±182.1	1.18±0.15
	Normal	1	–	–	–	–

[1)]Osteoporosis: T-score≤-2.5, Osteopenia: -2.5<T-score≤-1, Normal: -1<T-score
[2)]Mean±standard deviation.
[3)]It is exempted in analysis, due to lack of numbers.
[4)]Means with different superscripts within a column are significantly different at α=0.05 as determined by Duncan's multiple range test.

Fig. 2. Comparison of superoxide dismutase activities by T-score groups.
[1)]Means with different superscripts are significantly different at α=0.05 determined by Duncan's multiple range test.
[2)]No subject.

and affect the process of the bone's absorption directly by facilitating the secretion of the protease. Second, the osteoclast generates superoxide in response to parathyroid hormone, interleukin-1, tumor necrosis factor (TNF) and 1,25-$(OH)_2$ vitamin D_3, and the generation and activity of the precursor osteoclast increases these production of superoxides.

This study also relates to other results of Burton and Ingold (28) who found that due to the lack of estrogen after the menopause, phenolic hydroxyl group of the estrogen itself is transferred to the lipid peroxyradical and act as a direct antioxidant by preventing the chain reaction of the free radical. Another related study was conducted by Chamber and Hall (29). They found that the generation of ROS increases the activity of nuclear factor kappa B (NF-kB) which guides the expression of antioxidant enzymes such as glutathione synthetase, SOD and CAT in the osteoclast as a defense mechanism against ROS. The estrogen receptor then combined with NF-B blocks the activity of the NF-kB as an indirect antioxidant.

Ko (30) studied the relationship between antioxidant enzyme activity and skeletal muscle such, evaluating GR, GPx and GST using estrogen and glutathione in the skeletal muscle of ovariectomized white mice. The activities of GR and GPx were lower in the soleus muscle, among the skeletal muscles of the tested. The mice that received estrogen treatment after ovary removal also had higher activities of the GR and GPx. These findings all suggest a further need to explore the relationship between the bone mineral density and the activity of SOD through the clinical tests.

CONCLUSION

In short, the participants who exercised 3～4 times a week showed the highest TA, This indicates that regular moderate exercise enhances the activities of the antioxidant enzymes. Higher bone mineral density is associated with higher SOD activities. Among the antioxidant indices, SOD and TA were the most affected by bone mineral density.

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