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Original research

Effect of Yi Jin Jing exercise plus Elastic Band Resistance exercise on overall bone mineral density in postmenopausal women

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ABSTRACT

Objectives: This work aimed to study the effects of Yi Jin Jing plus Elastic Band Resistance exercise on bone mineral density at all parts of the body and bone metabolism index levels in postmenopausal women.
Design: Randomized controlled trial.
Methods: Forty postmenopausal women were randomly assigned equally to the exercise or to the control group. The control group maintained their lifestyle behaviors unaltered, whereas the exercise group received Yi Jin Jing plus Elastic Band Resistance exercise. The primary outcome was overall bone mineral density at each part, and the secondary one was bone metabolism indicator levels and bone mineral density on both sides.
Results: The results after six months showed increased bone mineral density at all parts of the body in the exercise group (spine, $P = 0.002$; thighs, lumbar, and whole body, $P < 0.05$) and decreased bone mineral density in the control group (trunk, pelvis, and spine, $P < 0.01$). In particular, the decrease and increase were greater on the non-preferred (left) side than on the right side. As for bone metabolism indexes, β-Crosslaps levels reduced ($P = 0.016$) and a significant increase in 1,25-(OH)2-D3 ($P < 0.001$) can be observed in the exercise group.
Conclusions: The results suggested that Yi Jin Jing plus Elastic Band Resistance exercise could delay the overall decrease of bone mineral density in postmenopausal women, especially on the non-preferred side. It also increased bone formation metabolite levels and inhibited bone resorption metabolite levels.

Practical implications

- The decline in bone mineral density was more severe on the non-preferred side in postmenopausal women.
- Yi Jin Jing plus Elastic Band Resistance exercise could delay the decrease in bone mineral density.
- Bone mineral density on the non-preferred side was better improved by exercise.
- Levels of bone turnover markers were also affected.

1. Introduction

Osteoporosis (OP) is a metabolic disease characterized by reduced bone mineral density (BMD) per unit volume, altered bone tissue microstructure, and bone metabolic disorder.[1,2] With a rapidly aging population, OP has increasingly become a serious public health problem, imposing a significant medical, economic, and social burden.[3] The risk of OP is usually higher in women than in men, especially among postmenopausal women.[4] The decline of ovarian function in postmenopausal women induces disruptions in sex hormone levels in the body, reducing osteoblast activity and accelerating the rate of bone resorption and bone loss.[5] Pharmacological (calcium and vitamin D) and hormone therapy (HT) are the commonly chosen prevention and treatment measures. However, pharmacological treatments are long, expensive, and involve reliance on patient persistence and compliance.[6] HT is not suitable for patients who have been menopausal for more than 10 years, and it also increases cardiovascular risk.[1] Given that, searching for a more economical, safe, and effective way to prevent and delay bone loss is of great value.

Exercise is widely recognized as an important way to develop and maintain optimal bone strength throughout the lifespan. Current evidence indicates that the effects of exercise on bone depend on modes, intensity, and timing.[7,8] Acute exercise alone strongly activates bone resorption [as estimated by C-telopeptide of type I collagen (CTX)],[9] but this acute effect usually diminishes after 24 h.[10] Walking and other forms of low-impact or non-impact aerobic exercise have been shown

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to have little effect on bone loss,[8] while acute aerobic exercise alone increases CTX in middle-aged and older adults.[11] In contrast, long-term chronic exercise training appears to increase bone formation [as estimated by procollagen of type 1 n-terminal propeptide (PINP)].[9] Bone responds positively to impact exercise and progressive resistance training (PRT),[7] but loading impact sports (e.g. vertical jumps) are prone to strains of the femoral neck and its surrounding muscles, with a higher risk of injury.[12] Though PRT causes rare adverse events,[13] optimizing muscle strength, balance, and mobility may be more suitable for people at high risk of osteoporotic fractures.[7] Therefore, there is growing evidence to support multimodal exercise programs as they have been shown to positively impact on multiple skeletal (spine and femoral neck BMD) and fall-related risk factors (dynamic balance, muscle strength).[14,15]

Qigong, an indispensable part of traditional Chinese medicine, can play a significant role in the physical and mental health of postmenopausal women. Qigong consists of two forms: Qigong dynamics (external) or Qigong meditation (internal). External qigong involves movements of whole body or limbs, while internal qigong requires maintaining posture and subtle body movements when performing exercises that involve breathing and thought.[16] Dao Yin, Ba Duan Jin, Tai Chi, Yi Jin Jing and Liu Zi Jue are all types of qigong. Ba Duan Jin can enhance bone strength by strengthening tendons and bones.[17] It also systematically mobilizes active joints and muscles, and improves balance, cardiorespiratory function, while improving cognitive impairment and mental status, ultimately unifying the mind and body.[17] Tai Chi has a mitigating effect on the loss of BMD in the lumbar spine and proximal femoral neck region in special populations, such as the elderly and peri- and post-menopausal women.[2] Similarly, Yi Jin Jing has potential healing effects on bone diseases and the physical and mental functions.[18]

Resistance training (RT) is one of the main forms of exercise to increase bone mass in older adults and also an essential component of multi-component exercise undertaken to provide therapeutic benefits.[19] It can increase various loads exerted on the bones through the direct pulling action of the muscles and/or through the gravitational action acting on the bones when they support heavier weights.[8] For people at high risk of fractures such as OP, PRT is effective in improving BMD and reducing pain safely, which is beneficial to their life quality.[13] Among the resistance equipment, elastic bands have the advantages of being economical, easy to carry, and not limited by the site. In addition, elastic band RT can achieve similar results in terms of changing muscle strength and quality of life and have a better effect on functional movement capacity than RT with conventional resistance equipment.[20]

Yi Jin Jing is a branch of Dao Yin developed in the Qing Dynasty. “Yi” means change, and “Jin” is the soft tissues of the muscles of the trunk and extremities. Yi Jin Jing can strengthen the body by stretching muscles and tendons to improve soft tissue flexibility and agility, and enhance bone and joint mobility. In traditional Chinese medicine, it is believed that Yi Jin Jing can affect the corresponding meridians and internal organs to bring about comprehensive health benefits.[21] In a study of human tendons and bones, Yi Jin Jing has achieved good efficacy on OP.[18] Nevertheless, the former study mainly focused on individual parts, and did not conduct research on the effect of BMD on multiple parts. Considering the above factors, this study hypothesized that the combination of Yi Jin Jing and Elastic Band Resistance exercise could improve BMD and related bone metabolic marker levels at various sites in postmenopausal women.

2. Methods

This randomized, controlled trial used the randomized number table method to assign all participants equally to the control or exercise group. Participants in the control group maintained their lifestyle behaviors (diet and exercise habits) unaltered, whereas participants in the exercise group received progressive-intensity Yi Jin Jing plus Elastic Band Resistance exercise. The researchers measured participants' anthropometric indicators, bone metabolism indices, and BMD by part within one week before and after the study. Supplementary Fig. S1 provides a flow chart of the recruitment and assignment of participants in this study.

The study was approved by the Ethics Committee of Shanghai University of Sport (102772021RT066) and registered at the Chinese Clinical Trial Registry (ChiCTR2000039049). We followed the Declaration of Helsinki, and all participants voluntarily signed the informed consent prior to the experiment.

Participants were recruited through Shanghai University of Sport together with Shidong Hospital in Shanghai, and they were all postmenopausal women aged 50–70 years who met the diagnostic criteria for bone loss. They all underwent a complete medical examination before the start of the trial and met the following inclusion and exclusion criteria. The inclusion criteria were (a) women aged between 50 and 70 years; (b) confirmed to be menopausal by medical examination; (c) diagnosed with total body bone loss by BMD testing; (d) right-handed; (e) without exercise habit; (f) long-term stable community residents living in Yangpu District, Shanghai; and (g) fully understood the purpose and significance of the study and agreed to sign the informed consent form.

Diagnostic criteria for osteopenia and OP: BMD was measured by dual-energy X-ray absorptiometry, with $-2.5 < \text{T value} < -1$ as low bone mass (osteopenia); $\text{T value} \leq -2.5$ as OP.[1]

The exclusion criteria were (a) patients with polycystic ovary syndrome, hyperthyroidism, and other endocrine diseases; (b) history of fractures; (c) using hormonal drugs or calcium and phosphorus supplements; (d) poor compliance (including those with severe cognitive impairment); (e) suffer from severe cardiac, pulmonary, hepatic, renal, and gastrointestinal diseases affecting activity; and (f) suffer from other diseases affecting bone metabolism.

2.1. Exercise protocol

All participants in the exercise group were taught by professional athletes to perform Yi Jin Jing and RT. Yi Jin Jing is widely recommended and supported.[22] The 12 movements included Wei Tuo Presenting the Pestle (three movements), Plucking a Star and Exchanging a Star Cluster, Pulling Nine Cows by Their Tails, Displaying Paw-Style Palms like a White Crane Spreading Its Wings, Nine Ghosts Drawing Swords, Three Plates Falling on the Floor, Black Dragon Displaying Its Claws, Tiger Springing on Its Prey, Bowing Down in Salutation, and Swinging the Tail (Supplementary Fig. S2). The details of the operation of Yi Jin Jing exercise are shown in Supplementary Table S1. All the actions were completed in 13 min. Elastic Band Resistance exercise was designed by professional researchers and consisted of five movements, namely, elastic band side pull, left and right bowing stance and straightening up, elastic band around the knee squat, reverse flying bird and elastic band weighted squat (Supplementary Fig. S3). The full set of movements was completed in about 8 min. Researchers let women (25 lb: $1500 \times 150 \times 0.4$ mm) and men (35 lb: $1500 \times 150 \times 0.5$ mm) exercise with different loads of elastic bands, considering the difference in exercise effect caused by the strength disparity between genders.

2.2. Exercise arrangement

The exercise time (Monday to Friday at 8:00–9:30 a.m.) and place (Gongnong Park in Yangpu District, Shanghai) were uniform and fixed. The exercise frequency was three times per week, with no more than 2 days between training sessions for a total of 6 months.

2.3. Exercise load

According to the exercise guidelines for women with postmenopausal OP,[8] the volume and intensity of the exercise group increased progressively. Each exercise included 5 min of warm-up and finishing activities. The first 2 months was spent repeating Yi Jin Jing and Elastic Band Resistance exercises twice a day, with eight repetitions of each resistance movement, for about 47 min. In the third to fourth months, the participants performed repeated Yi Jin Jing and Elastic Band Resistance exercises three times a day and 10 repetitions of each resistance movement for up to 68 min. In the next two months, Yi Jin Jing and Elastic Band Resistance exercises were repeated three times a day, with 12 repetitions of each resistance movement, reaching 76 min.

The exercise amount and intensity were controlled in the moderate intensity range. The participants felt warm and reported slight sweating, and the maximum heart rate (HRmax) was calculated by $207 - 0.7 \times age$. The expected exercise intensity was 60 %–70 % of the HRmax, and the target heart rate was calculated by $(HRmax - resting\ heart\ rate) \times intensity\ percentage + resting\ heart\ rate$. The entire intervention was observed by professionals to ensure the exercise quality and safety of the participants.

Anthropometric data were collected at the Shi Dong Hospital in Shanghai. General information about the participants (including name, age, medical history, and lifestyle habits) was recorded in detail by researchers. Height, weight, and BMI were measured using a physical examination scale (OMRON, HNH-318).

Blood samples were collected, tested, and analyzed at the Shi Dong Hospital in Shanghai. All participants were notified the time 3–4 days ahead and requested to fast for 8–16 h after dinner the day before the blood collection. Early in the morning of the collection day, the endocrinology nurse drew blood from the anterior elbow and sent it within 30 min to the in-hospital laboratory for uniform testing and analysis. Bone metabolism indices β-Collagen Special Sequence (β-Crosslaps), osteocalcin (OCN), 1,25 hydroxyvitamin D3 (1,25-(OH)2-D3), and serum calcium (SCa) were analyzed by using a Siemens IMMULITE 2000 analyzer.

The BMD of each part of the participants was measured using a dual-energy X-ray absorption scanner (GE Medical System, Lunar Prodigy) in the Fitness Science Center of Shanghai University of Sport. Before the test, the researcher calibrated the instrument first and entered general information about the participants (including gender, age, and date of birth). The test site was positioned, and the participant was instructed to remove all metal objects from the body and to lie flat on the test table to be scanned after ensuring that they had no interfering foreign objects. The scanned areas included the whole body, upper limbs, trunk, thighs, pelvis, spine, and lumbar spine. When scanning the lumbar spine, the researchers used a square pad to raise the participant's legs to stretch the lumbar spine.

According to the results of a previous study of combined exercise on BMD in older women,[23] the spinal BMD was (0.891 ± 0.155) g/cm^2 and (1.059 ± 0.082) g/cm^2 in the control and exercise groups, respectively, after the intervention. By using the PASS 15.0 software, after accounting for a twenty-five percent dropout rate, the trial required thirty-two participants (sixteen in each of the two groups, 50 % each) to be able to test for a statistical difference in clinical effectiveness between the two groups at an alpha significance level of 5 % with 85 % power.

All data were expressed as mean ± SD. The paired sample *t*-test (normal distribution) and Wilcoxon rank sum test (skewed distribution) were used to compare within-group differences before and after. Differences between groups were then compared by the independent sample *t*-test (normal data distribution) and Mann–Whitney *U* test (skewed distribution). Results were considered statistically different at $P < 0.05$ and significantly different at $P < 0.01$. Statistical analyses were processed with the SPSS 25.0 software (IBM SPSS Inc., Chicago, IL, USA).

3. Results

A total of forty-two participants were recruited, and forty participants were assigned equally to the control or exercise group. Eight participants dropped out during the trial. Two participants in the control group refused to cooperate and two people withdrew from the trial for personal physical reasons. Four people in the exercise group withdrew from the trial for personal physical reasons. A total of thirty-two participants completed the trial (exercise = control, n = 16) and were included in the analysis (Supplementary Fig. S1). As shown in Table 1 the baseline data were balanced and comparable, and there were no statistical differences between the two groups for all indicators.

Table 1
Characteristics of participants at baseline.

Characteristics	Exercise (n = 16)	Control (n = 16)	*P* value
Age (years)	63.11 ± 4.59	62.47 ± 4.79	0.669
Height (cm)	158.11 ± 6.13	157.70 ± 6.10	0.830
Weight (kg)	62.83 ± 8.25	61.11 ± 8.09	0.677
BMI (kg/m^2)	24.45 ± 3.87	24.80 ± 8.00	0.746
BMD (g/m^2)			
Whole body	1.020 ± 0.079	1.030 ± 0.077	0.768
Upper limbs	0.745 ± 0.083	0.743 ± 0.072	0.408
Trunk	0.830 ± 0.069	0.829 ± 0.070	0.791
Thighs	1.055 ± 0.086	1.074 ± 0.102	0.414
Pelvis	0.989 ± 0.075	0.987 ± 0.102	0.438
Spine	0.966 ± 0.107	0.978 ± 0.107	0.655
Lumbar	0.918 ± 0.125	1.027 ± 0.104	0.655
Bone metabolism index			
β-Crosslaps (ng/mL)	0.62 ± 0.22	0.59 ± 0.28	0.216
OCN (ng/mL)	19.26 ± 6.46	20.80 ± 6.77	0.343
1,25-(OH)2-D3 (ng/mL)	17.65 ± 9.70	18.94 ± 4.76	0.095
SCa (mmol/L)	2.41 ± 0.07	2.42 ± 0.07	0.531

Differences between groups were not significant (all $P > 0.05$). BMD = bone mineral density, β-Crosslaps = β-Collagen Special Sequence, OCN = osteocalcin, 1,25-(OH)2-D3 = 1,25 hydroxyvitamin D3, SCa = serum calcium.

Table 2 shows the changes in the values of BMD and bone metabolism indexes. BMD increased at all parts in the exercise group but decreased in the control group (Fig.1A). The BMD change values at the remaining parts varied significantly between groups except for the upper limbs (0.0002 ± 0.0008 vs. −0.0165 ± 0.0069 g/cm^2; $P = 0.192$) and trunk (0.0032 ± 0.0008 vs. −0.0127 ± 0.0063 g/cm^2; $P = 0.013$). The exercise group showed a significant increase in BMD of the spine (0.954 ± 0.112 vs. 0.986 ± 0.120 g/cm^2; $P = 0.002$) and a statistically significant increase in BMD of the thighs and lumbar region. Little to no change in BMD was seen in the upper limbs. BMD of the trunk (0.816 ± 0.053 vs. 0.804 ± 0.049 g/cm^2; $P = 0.007$), pelvis (0.968 ± 0.082 vs. 0.948 ± 0.085 g/cm^2; $P = 0.003$), and spine (0.960 ± 0.084 vs. 0.934 ± 0.081 g/cm^2; $P < 0.001$) was significantly lower in the control group compared with baseline (Table 2).

The increase in BMD (except for the whole body) was greater on the (non-preferred) left side of the exercise group, but none of the differences were statistically significant ($P < 0.05$). The decrease in BMD was greater on the (non-preferred) left side than on the right side in the control group except for the trunk. Only the difference in whole-body (−0.035 ± 0.004 vs. −0.008 ± 0.002 g/cm^2; $P = 0.039$) BMD change between the two sides was statistically significant (Fig. 1B).

Significant differences were found in the changed values of β-Crosslaps ($P < 0.001$), OCN ($P = 0.001$), and 1,25-(OH)2-D3 ($P < 0.001$) between groups (Table 2). Moreover, 1,25-(OH)2-D3 levels in the exercise group were significantly different after 6 months compared to the control group (28.96 ± 12.74 vs. 18.38 ± 6.26 ng/mL; $P = 0.009$) and baseline (17.65 ± 9.70 vs. 28.96 ± 12.74 ng/mL; $P < 0.001$). β-Crosslaps levels decreased in the exercise group but increased in the control group, and the difference was statistically significant after 6 months (0.49 ± 0.21 vs. 0.74 ± 0.38 ng/mL; $P = 0.029$) (Fig. 1C).

4. Discussion

This experiment was the first to investigate the effects of Yi Jin Jing plus resistance exercise on BMD at multiple sites and on both sides in postmenopausal women. The results showed that the six-month

Table 2
Results of baseline, 6-month, and mean change values of BMD (g/cm^2) and bone metabolism indexes.

Parameter	Exercise				Control			
	Baseline	6-month	Change	*P* value	Baseline	6-month	Change	*P* value
BMD at all parts								
Upper limbs	0.715 ± 0.064	0.716 ± 0.064	0.0002 ± 0.0008	0.949	0.738 ± 0.072	0.722 ± 0.066	−0.0165 ± 0.0069	0.181
Thighs	1.038 ± 0.087	1.047 ± 0.088[#]	0.0092 ± 0.0025[**]	0.013[#]	1.059 ± 0.103	0.986 ± 0.247	−0.0730 ± 0.0083	0.258
Trunk	0.828 ± 0.076	0.830 ± 0.074	0.0032 ± 0.0008[*]	0.473	0.816 ± 0.053	0.804 ± 0.049[##]	−0.0127 ± 0.0063	0.007[##]
Pelvis	0.986 ± 0.081	1.005 ± 0.088	0.0197 ± 0.0064[**]	0.055	0.968 ± 0.082	0.948 ± 0.085[##]	−0.0196 ± 0.0017	0.003[##]
Spine	0.954 ± 0.112	0.986 ± 0.120[##]	0.0312 ± 0.0084[**]	0.002[##]	0.960 ± 0.084	0.934 ± 0.081[##]	−0.0261 ± 0.0046	<0.001[##]
Lumbar	0.912 ± 0.136	0.991 ± 0.172[#]	0.0792 ± 0.0301[**]	0.046[#]	1.037 ± 0.104	0.979 ± 0.112[#]	−0.0579 ± 0.0224	0.020[#]
Whole body	1.005 ± 0.082	1.020 ± 0.086[#]	0.0148 ± 0.0031[**]	0.027[#]	1.022 ± 0.067	1.010 ± 0.064	−0.0258 ± 0.0086	0.395
BMD on both sides								
Left upper limb	0.710 ± 0.067	0.726 ± 0.094	0.016 ± 0.011[*]	0.194	0.739 ± 0.069	0.705 ± 0.048[†]	−0.026 ± 0.005	0.035[#]
Left thigh	1.043 ± 0.084	1.055 ± 0.085	0.011 ± 0.008[**]	0.027[#]	1.054 ± 0.096	1.023 ± 0.079	−0.030 ± 0.015	0.016[#]
Left trunk	0.829 ± 0.071	0.832 ± 0.075	0.014 ± 0.005[**]	0.377	0.815 ± 0.049	0.801 ± 0.049	−0.014 ± 0.007	0.004[##]
Left whole body	1.004 ± 0.089	1.015 ± 0.089	0.011 ± 0.007[**]	0.019[#]	1.017 ± 0.066	0.982 ± 0.067[†]	−0.035 ± 0.004[†]	0.003[##]
Right upper limb	0.731 ± 0.079	0.738 ± 0.083	0.007 ± 0.002	0.219	0.746 ± 0.077	0.732 ± 0.086	−0.014 ± 0.007	0.395
Right thigh	1.033 ± 0.094	1.045 ± 0.169	0.005 ± 0.003[*]	0.173	1.065 ± 0.110	1.052 ± 0.108	−0.012 ± 0.002	0.068
Right trunk	0.823 ± 0.076	0.828 ± 0.076	0.005 ± 0.003[**]	0.456	0.817 ± 0.059	0.798 ± 0.055	−0.018 ± 0.002	0.091
Right whole body	1.007 ± 0.082	1.022 ± 0.090	0.016 ± 0.003[**]	0.030[#]	1.023 ± 0.069	0.922 ± 0.066	−0.008 ± 0.002	0.130
Bone metabolism index								
β-Crosslaps (ng/mL)	0.55 ± 0.25	0.49 ± 0.21[*]	−0.073 ± 0.099[**]	0.016[#]	0.60 ± 0.29	0.74 ± 0.38	0.116 ± 0.141	0.013[#]
OCN (ng/mL)	19.26 ± 6.45	21.92 ± 6.08	1.709 ± 2.699[**]	0.028[#]	20.80 ± 6.77	17.52 ± 5.45	−2.538 ± 2.288	0.001[##]
1,25-(OH)2-D3 (ng/mL)	17.65 ± 9.70	28.96 ± 12.74[**,##]	10.233 ± 4.515[**]	<0.001[##]	18.94 ± 4.76	18.38 ± 6.26	−0.991 ± 2.621	0.180
SCa (mmol/L)	2.41 ± 0.07	2.46 ± 0.06[*]	0.039 ± 0.071[*]	0.066	2.42 ± 0.07	2.37 ± 0.14	−0.051 ± 0.119	0.129

BMD = bone mineral density, β-Crosslaps = β-Collagen Special Sequence, OCN = osteocalcin, 1,25-(OH)2-D3 = 1,25 hydroxyvitamin D3, SCa = serum calcium.
[#] Significant differences from baseline ($P < 0.05$).
[##] Significant differences from baseline ($P < 0.01$).
[*] Significant differences between groups ($P < 0.05$).
[**] Significant differences between groups ($P < 0.01$).
[†] Significant differences between the left and right sides within groups ($P < 0.05$).

exercise intervention increased BMD at all parts of the body and the non-preferred side (left side) generally increased more than the preferred side (right side). Exercise increased the levels of metabolites involved in osteogenesis and decreased the levels of metabolites associated with bone resorption simultaneously.

Bone loss begins after the age of 40 and the rate of loss peaks after menopause. New or different loading patterns may be particularly important to this vulnerable group of people who have difficulty with high-intensity impact exercise.[24] BMD is closely related to exercise patterns, and combined exercise can expose bones to unfamiliar loading one.[7] According to the principle of initial value and the principle of diminishing returns, if the skeleton maintains a fixed load after adaptation to the initial load, it means that it is under less stress, so the loading stimulus must be gradually increased as the skeleton adapts.[8] The results of this study support the above principles well. At the same time, skeletal adaptation to load is site-specific rather than systemic.[8] Thus it could explain why, although participants in the exercise group showed improvements in BMD at all parts, there were differences in the degree of improvement.

A long-term joint exercise with traditional Qigong may be a hope. The previous study[25] found that Tai Chi combined with RT significantly improves physical function and muscle strength in older adults. The combination of Liu Zi Jue with conventional therapy had better efficacy for improving trunk control and breathing function than the combination with other training.[15] This may be related to the physiological benefits generated by its effectiveness.[26] The gentle movements of Yi Jin Jing, repeated left and right, can coordinate the movement of muscles and ligaments throughout the body.[18] Moreover, the movements were mostly accompanied by back flexion and extension, improving long-term back muscle strength associated with higher spinal BMD,[27] which was consistent with the study results. The new finding was that in most parts, the change in BMD was greater on the non-preferred side. The reasons for more severe density loss may be related to less frequent use in daily life, less external stimulation of the bones, and slightly lower mineralization.[28] However, the general impact of motion also acted more on the dominant side, with low improvement on the non-dominant side.[28] In contrast, the design of Yi Jin Jing and resistance movements has a symmetrical concept to compensate for the lack of strength training on the non-preferred side and to achieve a balanced BMD, while this feature is also supported by the results of the study.

In addition, traditional Chinese medicine clinicians believe that Yi Jin Jing can affect bone metabolic marker levels by activating the meridians and blood vessels associated with the kidneys.[21] The exercise program in this study showed that the bone metabolic profile favors bone formation. According to Dolan et al.[29] and Sarah et al.[9], the amount of exercise (frequency and duration of exercise) may be more important in the process of bone remodeling than the mode of exercise. The cycle of bone remodeling is 3 to 4 months, so chronic adaptive exercise may indeed be an effective way to facilitate the observation of changes in osteogenic markers.

The results of this study also have some limitations. The sample size was limited and concentrated in one geographic area, so it was not possible to evaluate more objectively the group effects of Yi Jin Jing plus Elastic Band Resistance exercise on postmenopausal women. To complete this, the sample size and recruitment area can be increased in the future to reduce the geographical effects and limitations.

5. Conclusion

We concluded that 6 months of Yi Jin Jing plus Elastic Band Resistance exercise delayed the decline of BMD levels in postmenopausal women at all parts, especially on the non-preferred (left) side. It also increased the levels of metabolites related to bone formation and inhibited the levels of bone resorption metabolites.

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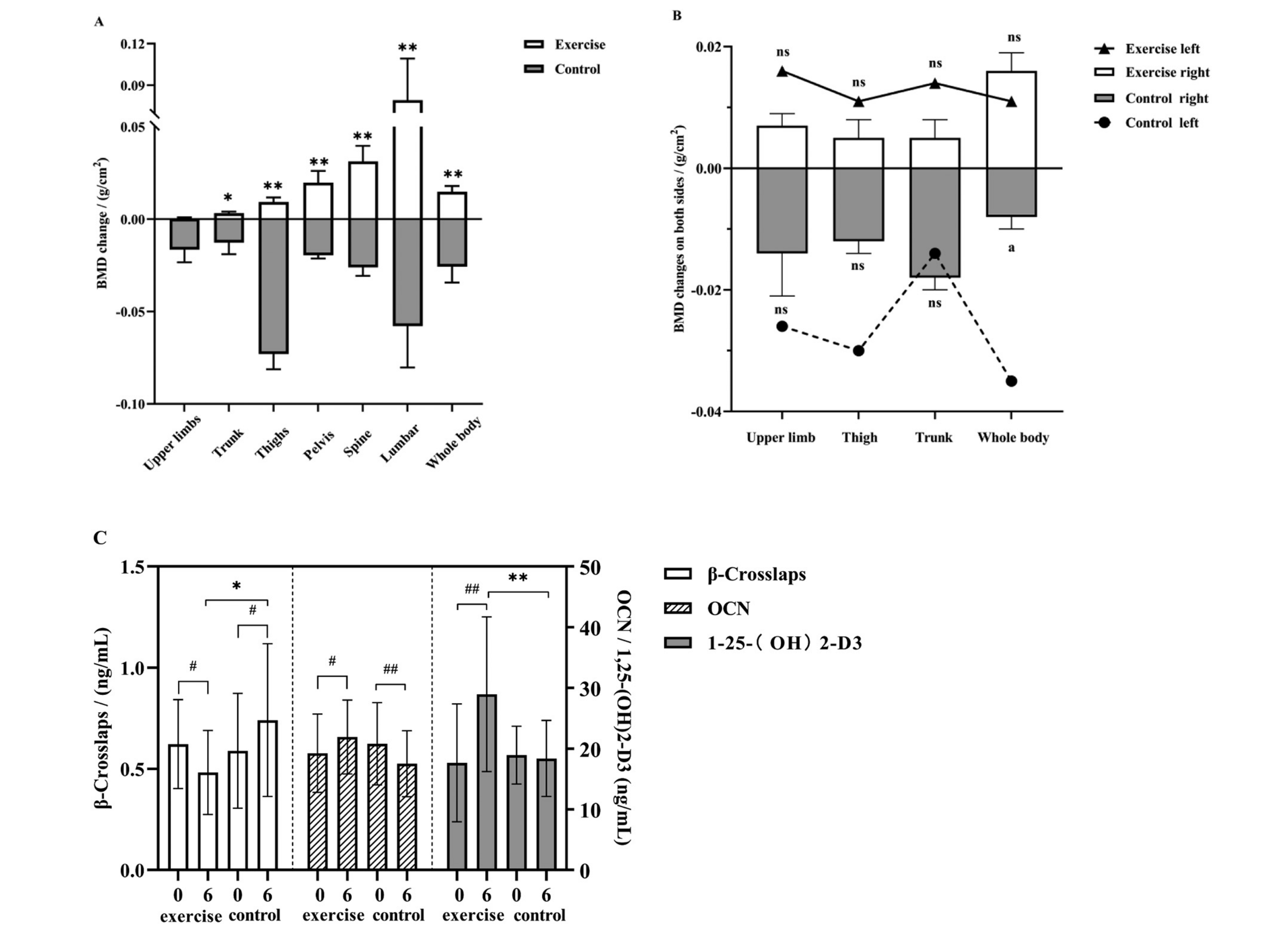

Fig. 1. Comparison of BMD change values at all parts (A) and both sides (B) between exercise and control groups. Changes in β-Crosslaps, OCN, and 1,25-(OH)2-D3 levels in the exercise and control groups after 6 months of exercise intervention (C). BMD = bone mineral density, β-Crosslaps = β-Collagen Special Sequence, OCN = osteocalcin, 1,25-(OH)2-D3 = 1,25 hydroxyvitamin D3, SCa = serum calcium. [#]Significant differences from baseline ($P < 0.05$). [##]Significant differences from baseline ($P < 0.01$). [*]Significant differences between groups ($P < 0.05$). [**]Significant differences between groups ($P < 0.01$). [a]Significant differences in change value of BMD on both sides within group ($P < 0.05$). [ns]No significant differences in change value of BMD on both sides within group.

and Technology Committee of Shanghai outstanding academic leaders plan (21XD1403200).

Confirmation of ethical compliance

The study was approved by the Ethics Committee of Shanghai University of Sport (102772021RT066) and registered at the Chinese Clinical Trial Registry (ChiCTR2000039049). We followed the Declaration of Helsinki, and all participants voluntarily signed the informed consent prior to the experiment.

CRediT authorship contribution statement

Jingyuan Li and Qing Gu have contributed equally to this work.

Jingyuan Li: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Supervision, Project administration, Writing - Original draft. **Qing Gu:** Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Supervision, Project administration, Writing - Original draft. **Ruixue Li:** Visualization, Formal analysis, Writing - Original draft. **Ru Wang:** Methodology, Project administration, Writing - Review & editing. **Yanwei Cai:** Investigation, Writing - Review & editing, Supervision. **Yunda Huang:** Investigation, Writing - Review & editing, Supervision. **Shasha Wang:** Investigation, Writing - Review & editing, Supervision. **Suijun Wang:** Conceptualization, Project administration, Resources, Writing - Review & editing, Funding acquisition. **Xiangyun Liu:** Conceptualization, Resources, Project administration, Methodology, Writing - Review & editing.

All authors read and approved the final version of the manuscript.

Declaration of interest statement

The authors declare no financial or other conflicts of interests.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jsams.2023.01.006.

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