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RESEARCH

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Effects of resistance training, Yijinjing and Baduanjin exercise with oral caltrate D on bone mineral density and bone metabolism in older women: a randomised controlled trial

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Abstract

Background The literature lacks studies comparing the effects of traditional Chinese exercises, Qigong Yijinjing (YJJ) and Baduanjin (BDJ), with resistance training (RT) on bone mineral density (BMD) and bone metabolism in older adults.

Objective This study investigated the effects of regular RT, YJJ, and BDJ exercises training, combined with oral Caltrate D supplementation, on lumbar spine and proximal femur BMD and serum bone metabolism indices in older women.

Methods Eighty-four older women were randomly divided into the RT group (RG, $n=21$), YJJ group (YG, $n=22$), BDJ group (BG, $n=21$) and control group (CG, $n=20$). These groups performed the assigned exercises for 24 weeks (3 times/week, 60 min/time). The BMD of the lumbar L_2-$_4$ and proximal femur, as well as serum bone metabolism indices, were measured using dual-energy X-ray absorptiometry and an automatic chemiluminescence apparatus, respectively.

Results At week 24, compared to the CG, the RG, YG, and BG had significantly higher BMD and procollagen type I N-terminal propeptide (PINP) levels in the lumbar $L_{2–4}$ region (BMD: $p=0.049$, $p=0.016$, $p=0.040$; PINP: $p=0.026$, $p=0.029$, $p=0.020$), and lower β-carboxy-terminal cross-linked telopeptide of type 1 collagen (β-CTX) levels ($p=0.001$, $p=0.012$, $p=0.042$). Intragroup comparison between baseline and week 24 data revealed that in RG, YG, and BG, lumbar $L_{2–4}$ BMD (RG: $p=0.036$, YG: $p=0.002$, BG: $p=0.022$) and PINP (RG: $p=0.020$, YG: $p=0.001$, BG: $p=0.001$) increased, whereas β-CTX (RG: $p=0.003$, YG: $p<0.001$, BG: $p=0.008$) decreased.

Conclusions RT, YJJ and BDJ combined with Caltrate D for 24 weeks can increase lumbar BMD, increase the bone formation marker PINP and decrease the bone resorption marker β-CTX in older women but had no significant effect

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on the BMD of the proximal femur. YJJ and BDJ had the same effect on improving BMD in the older adults as RT with the same exercise cycle and frequency.

Keywords Resistance training, Yijinjing, Baduanjin, Older women, Bone mineral density

Introduction

Older adults are at a high risk of developing osteoporosis, which is a serious public health issue [1, 2]. Regular exercise training has been proven to be effective in preventing osteoporosis to a certain extent [3, 4]. Besides regular exercise training, calcium and vitamin D supplementation, like Caltrate D, is crucial for managing osteoporosis. This supplement, containing calcium carbonate and vitamin D3, addresses deficiencies that can lead to conditions such as osteoporosis, fractures, and rickets, and supports skeletal health by enhancing intestinal absorption of calcium and phosphorus [5]. Exercise training can stimulate the bones and affect bone mineral density (BMD) by inducing hormonal changes, regulating bone metabolism signalling pathways and generating mechanical stress [6, 7]. Older adults can choose to engage in resistance training (RT) [7, 8] or aerobic exercise (Tai Chi or brisk walking) [4, 6] as physical activity. RT is a form of exercise training that focuses on improving muscle strength and bone density through the use of resistance, such as weights or elastic bands. It has been widely recognized for its effectiveness in enhancing muscle strength, increasing bone mineral density, and improving overall physical function in the older adults. RT can significantly impact bone metabolism and bone mineral density, making it a potential therapeutic option for the prevention and treatment of osteoporosis [7, 8]. Despite its established benefits, the comparative effectiveness of RT with traditional Chinese exercises like Yijinjing (YJJ) [9, 10] and Baduanjin (BDJ) [11, 12] remains understudied, particularly in the context of bone health in older women. They involve slow and gentle movements that are simple to learn and are suitable for collective practice by the older adults [13].

Meta-analyses [14–16] and studies [17–21] highlight the impact of regular RT, YJJ, and BDJ on BMD in older adults. Progressive RT is effective for BMD enhancement [14], with specific benefits to the lumbar spine and hip [15], and similar effects for high- and low-intensity RT over 24 weeks [16]. YJJ increases proximal femur BMD [17] and delays BMD decline when combined with elastic band RT [18]. BDJ significantly raises overall BMD in middle-aged women [19] and femoral neck BMD in older women [20], with combined treatment showing substantial improvements [21]. Despite a wealth of RT data, YJJ and BDJ research is limited, primarily focusing on osteoporotic patients, and direct comparisons among these exercises are sparse.

The innovation of this study is that we not only confirmed the positive impact of YJJ and BDJ, two traditional Chinese fitness methods, on bone density and metabolism in older women, but also directly compared their effects with RT for the first time under the same experimental conditions. This direct comparison provides a new perspective for understanding the relative benefits of different exercise training in enhancing bone density and metabolism. Moreover, our results highlight YJJ and BDJ as safe and effective treatment options, comparable to traditional resistance training, providing new scientific evidence for exercise choices among older women. Our study also specifically focuses on older women, which is significant for developing targeted exercise training and osteoporosis prevention plans. This study aims to compare the effects of the above three exercise training combined with Caltrate D supplementation on BMD in older adults. The primary focus is on the changes in BMD at the lumbar $L_{2\text{-}4}$ and proximal femur, as well as serum bone metabolism indices. Especially the bone formation marker - Procollagen Type I N-terminal Propeptide (PINP) and the bone resorption marker -β-C-terminal telopeptide of type I collagen (β-CTX). The hypothesis of this research is that YJJ and BDJ have similar effects on BMD in older women as RT. Although RT was employed in our study design, it should be noted that the intensity and frequency of RT in this study did not fully comply with the current recommendations for RT in older adults for bone health. This was due to our consideration of the participants' physical conditions and compliance when designing the experiment, leading to a more moderate training program. Therefore, the results of this study should be regarded as a preliminary exploration of the effects on bone density and metabolism under specific training conditions, rather than a validation of the optimal training regimen.

Materials and methods

Participants

This study was approved by the Human Research Ethics Committee of Chengdu Sport University (No: 20236). This study underwent retrospective clinical registration due to administrative delays in the initial registration process. However, all experimental procedures strictly adhered to the ethical guidelines of the Declaration of Helsinki. This study underwent retrospective clinical registration (7/25/2024), with the Clinical Trial Number: NCT06529172. The complete experimental protocol for this study can be found at the following URL. https://ichgcp.net/clinical-trials-registry/NCT06529172.

Recruitment of willing older women for fitness activities in Chengdu was conducted through community and nursing home visits, advertisements, informational sessions, direct contact, and local media outreach. Females who (1) were aged 60–70 years, (2) recently expressed willingness to engage in fitness activities, (3) passed a health examination, (4) signed an informed consent form in accordance with the Helsinki Declaration were included and (5) no osteoporosis diagnosis (BMD T-score ≥ -1.0). Females with (1) heart disease, (2) mobility impairments, (3) history of severe lower limb injury, (4) currently taking antiosteoporosis medication, (5) currently taking hormone replacement therapy, (6) engaging in other regular forms of exercise were excluded and (7) regular practice of YJJ/BDJ/RT in the past 6 months.

G-power software was used to calculate the minimum number of participants required. Calculation was performed on the basis of previous studies on the effect of three exercise training on BMD in older adults [14, 17, 18] and in consideration of the 4 (number of groups) × 2 (measurement times) experimental design of this study, a sample loss of approximately 10% sample loss, an effect size of 0.3, a power of 0.8 and an α of 0.05. The calculation revealed that a minimum number of 80 participants was required. Initially, we recruited 92 participants by using random digit assignment and allocated them to the RT group (RG, $n = 23$), YJJ group (YG, $n = 23$), BDJ group (BG, $n = 23$) and control group (CG, $n = 23$). At the beginning of the experiment, one participant from RG, one from YG, two from BG and three from CG dropped out due to personal or other reasons, resulting in a sample loss rate of 7.6%. Ultimately, a total of 84 participants completed the entire experiment (Fig. 1). No statistically significant differences in age, height and weight amongst the groups were found ($p > 0.05$, Table 1). Participants were not required to be completely sedentary but were expected not to engage in other organized exercise programs during the study period. A health examination, including blood tests for calcium levels, was conducted at the beginning of the study to assess any potential calcium deficiency, which could be addressed through dietary adjustments or supplementation if necessary.

Exercise training

The initial exercise training was provided as follows: throughout the entire intervention period, the four groups of participants were administered Caltrate D tablets (produced by Wyeth Pharmaceuticals; specification: 600 mg per tablet; National Medicine Permission No. H10950029, Products, Suzhou, China, twice daily, one tablet each time) [5] before lunch and dinner. During the intervention period, dietary habits were specifically regulated to include calcium-rich foods and appropriate protein intake while prohibiting smoking and consuming alcohol, coffee, strong tea and carbonated drinks. On the above basis, the RG, YG and BG groups underwent exercise interventions. The CG group maintained their original lifestyle without engaging in regular exercise training. The intervention period lasted for 24 weeks with a frequency of three times per week. Each session lasted for 60 min and included approximately 10 min of preparatory activities, warm-up and relaxation. Exercise training

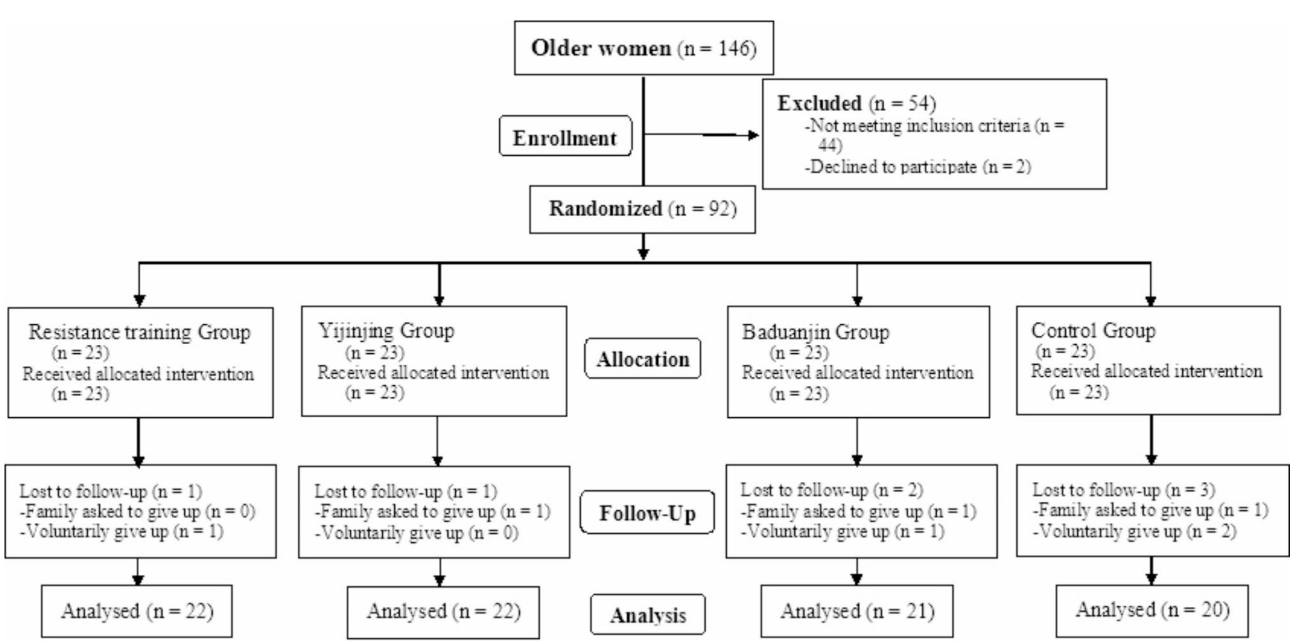

Fig. 1 Participant selection flow diagram

Table 1 Basic information of the study participants

Group	Resistance training group	Yijinjing group	Baduanjin group	Control group	F	*p*
n	21	22	21	20	-	-
Age (years)	65.2 ± 2.8	64.8 ± 2.2	65.1 ± 3.2	64.7 ± 2.6	0.163	0.921
Height (cm)	157.9 ± 5.7	157.7 ± 6.0	157.6 ± 5.3	157.2 ± 7.1	0.052	0.984
Weight (kg)	59.2 ± 7.0	58.8 ± 8.8	58.7 ± 7.2	58.9 ± 8.5	0.019	0.996
PINP (μg/L)	55.6 ± 10.8	53.2 ± 9.3	2.7 ± 8.7	53.1 ± 11.2	0.072	0.975
OC (ng/mL)	15.6 ± 6.12	16.2 ± 5.73	15.9 ± 5.36	15.8 ± 6.30	0.029	0.993
β-CTX (μg/L)	0.48 ± 0.16	0.45 ± 0.13	0.43 ± 0.10	0.45 ± 0.09	0.447	0.720
25(OH)D3 (μg/L)	18.32 ± 3.26	17.96 ± 3.60	18.11 ± 3.12	18.50 ± 3.10	0.130	0.942
Lumbar vertebrae $L_{2\text{-}4}$ (g/cm^2)	0.92 ± 0.21	0.90 ± 0.15	0.91 ± 0.16	0.92 ± 0.23	0.598	0.618
Femoral neck (g/cm^2)	0.82 ± 0.19	0.80 ± 0.16	0.81 ± 0.20	0.84 ± 0.18	0.146	0.932
Greater trochanter (g/cm^2)	0.68 ± 016	0.66 ± 0.13	0.65 ± 0.22	0.69 ± 0.16	0.406	0.749
Wards triangle (g/cm^2)	0.66 ± 0.15	0.68 ± 0.14	0.65 ± 0.19	0.68 ± 0.20	0.150	0.930

Note: PINP: Procollagen type I N-terminal propeptide; OC: Osteocalcin; β-CTX: β-carboxy-terminal cross-linked telopeptide of type 1 collagen

25(OH)D3: 25-Hydroxyvitamin D3

intensity was based on the research method by Cheng et al. [22]. with the heart rate controlled at (220 – age) × (55–70%). To accurately control exercise intensity, we employed a heart rate monitoring method. Each participant was equipped with a heart rate monitor to ensure that the heart rate remained within the target range during exercise training. Participants were advised to consume calcium-rich foods (e.g., dairy products ≥ 300 mL/day, leafy greens) and protein (1.2 g/kg body weight/day). Compliance was monitored through weekly dietary logs and monthly 24-hour dietary recall interviews.

RG performed RT with an elastic band (yellow, force of 9–11 pounds when stretched twice the original length). They performed eight movements. Each movement was performed for 3–5 sets at 8 times/sets with 30 s of rest between groups. The movements included upright row, reverse crunch, standing external shoulder rotation, behind-the-neck elbow extension with bent elbows, lunge with downward press, standing leg raise, side-lateral raise, standing kickback (Fig. 2A1-A8) [23]. All participants completed the RT movements according to the regular rhythm (1-2-1) provided by the experimenter, which ensured that all participants had similar movements completion rates.

YG performed 12 movements (Fig. 2B1-B7) [9, 10]. These movements included extending the hands upwards and slowly lowering them; extending the torso by stretching the hands straight up and bending the body to the left or right; squatting with the hands on the knees and standing up slowly; bending the body to the left or right side, extending the arms and waist; getting down on the knees, leaning forward, extending the hands forward and slowly pulling them back; bending forward, placing the hands around the knees and standing up slowly; placing the hands on the hips; and leaning back to stretch the back and waist.

BG performed eight movements (Fig. 2C1-C8) [11, 12]. These movements included holding the hands straight up, slowly bringing the hands down and turning the waist while in a standing position; bending the body to the left or right side and extending the arms; extending one hand straight up, placing the other hand on the waist, then switching arms and repeating the movement; tilting the head back and looking back while stretching the neck and back; squatting the body, swinging the head and hips from side to side and moving the spine and waist; bending the body forward, touching the hands to the toes and standing up slowly; making fists with the hands and moving the arms and shoulders; and gently bouncing the body to relax the whole body in a standing position. A study tested 120 older adults, while performing YJJ, the mean metabolic equivalent and HR were 3.18 ± 0.96 MET and 106.5 ± 14.1 b.p.m, while performing BDJ, the mean metabolic equivalent and HR were 3.96 ± 1.17 MET and 113.8 ± 21.3 b.p.m [24]. Indicating that YJJ [25] and BDJ are moderate intensity aerobic activity.

The first 4 weeks of YG and BG were the learning period, and weeks 5–24 weeks were the consolidation and strengthening period. During the consolidation and strengthening period, the participants were required to practise six sets of movements each time with a gap of approximately 30 s. With the increase in intervention weeks, the participants can appropriately adjust the stretching length of the elastic band and increase the number of sets to control the load in accordance with their own condition. Every week, the experimenter interviewed the participants in person or by telephone to record information about their living conditions. The recorded information mainly involved the participants' eating habits (diet variety and amount), working and resting patterns (sleep quality, sunshine amount and residence area) [3, 4], whether the participants took other

Fig. 2 Resistance training, Yijinjing and Baduanjin exercise. Note: **A**: Resistance training, A1: Upright Row, A2: Reverse Crunch, A3: Standing External Shoulder Rotation, A4: Behind-the-Neck Elbow Extension with Bent Elbows, A5: Lunge with Downward Press, A6: Standing Leg Raise, A7: Side-Lateral Raise, A8: Standing Kickback; **B**: Yijinjing, B1: extending the hands upwards and slowly lowering them, B2: extending the torso by stretching the hands straight up and bending the body to the left or right, B3: squatting with the hands on the knees and standing up slowly, B4: bending the body to the left or right side, extending the arms and waist, B5: getting down on the knees, leaning forward, extending the hands forward and slowly pulling them back;, B6: bending forward, placing the hands around the knees and standing up slowly, B7: placing the hands on the hips; and leaning back to stretch the back and waist; **C**: Baduanjin, C1: holding the hands straight up, slowly bringing the hands down and turning the waist while in a standing position, C2: bending the body to the left or right side and extending the arms, C3: extending one hand straight up, placing the other hand on the waist, then switching arms and repeating the movement, C4: tilting the head back and looking back while stretching the neck and back, C5: squatting the body, swinging the head and hips from side to side and moving the spine and waist, C6: bending the body forward, touching the hands to the toes and standing up slowly, C7: making fists with the hands and moving the arms and shoulders, C8: gently bouncing the body to relax the whole body in a standing position

regular exercise training and whether the participants took drugs that affected BMD.

Dual-energy X-ray bone densitometry testing

A Norland XR-46 dual-energy X-ray BMD tester was used a Norland XR-46 dual-energy X-ray bone densitometer to measure the BMD of the lumbar L_{2-4} and proximal femur of the dominant side (femur neck, greater trochanter and Ward's triangle). Five non-re-entrant scans were performed at each measurement site. The error coefficients of the measurement location were 1–2% in the lumbar $L_{2–4}$, femoral neck and greater trochanter and 2.5–5% in Ward's triangle [3, 4]. The coefficient of variation in the lumbar vertebrae and the proximal femur was 1.1% and 1.85%, respectively [4].

Serum bone metabolism test

The bone formation markers PINP and osteocalcin (OC) in the blood and bone resportion marker β-CTX have been designated as reference bone turnover markers for osteoporosis by the International Osteoporosis The Foundation and International Federation of Clinical Chemistry and Laboratory Medicine [25]. After 24 weeks, 5 ml of fasting venous blood was drawn (7 a.m. – 8 a.m.) and centrifuged at 3000 r/min for 5 min. Serum PINP and OC and β-CTX were detected by using an automatic chemiluminescence apparatus (Liaison, Italian). The kit required for the experiment was purchased from Nanjing Jiancheng Bioengineering Institute and utilised in strict accordance with its instructions.

Statistical analysis

SPSS 20.0 was used to determine the mean ± standard deviation of all the measurement data of the four groups of participants. The Shapiro-Wilk test was used to determine whether or not the data were normally distributed; Two-way ANOVA was performed with time as the main effect to determine whether group (4) and time (2) interacted. If group and time interacted, whether time or group had a separate effect was determined. In the absence of interaction, whether group or time had a main effect was determined. Bonferroni's post hoc test was used for post hoc comparison to ensure that the overall type I rate of each ANOVA did not exceed 0.05 [26]. The significance level was set as $\alpha = 0.05$.

Results

The baseline and week 24 data of the four groups of participants are shown in Figs. 3 and 4. The Shapiro-Wilk test showed that all test data conformed to a normal distribution. Two-way ANOVA indicated no significant interaction between time and group for any test indicators ($p > 0.05$). However, main effects were observed. For the group main effects, significant differences were found for lumbar L_{2-4} ($F = 2.391$, $p = 0.041$, $\eta^2 = 0.080$) and β-CTX ($F = 3.058$, $p = 0.030$, $\eta^2 = 0.054$). Time main effects were significant for lumbar L_{2-4} ($F = 12.336$, $p = 0.001$, $\eta^2 = 0.072$), PINP ($F = 27.907$, $p < 0.001$, $\eta^2 = 0.149$), β-CTX ($F = 32.403$, $p < 0.001$, $\eta^2 = 0.168$), and OC ($F = 5.316$, $p = 0.022$, $\eta^2 = 0.032$).

At baseline, no significant differences were found among the four groups for any indices ($p > 0.05$). At week 24, compared to the CG, the RG, YG, and BG exhibited significantly higher BMD at lumbar L_{2-4} ($p = 0.049$, $p = 0.016$, $p = 0.040$) and higher PINP levels ($p = 0.026$, $p = 0.029$, $p = 0.020$), and lower β-CTX levels ($p = 0.001$, $p = 0.012$, $p = 0.042$). No statistically significant differences in OC levels were observed among groups ($p > 0.05$).

All exercise interventions (RT, YJJ, BDJ) significantly increased lumbar BMD and PINP levels while reducing β-CTX compared to the control group ($p < 0.05$). Group comparison between the data at baseline and week 24 revealed that in RG, the BMD ($p = 0.036$, $\eta^2 = 0.070$) and PINP ($p = 0.020$, $\eta^2 = 0.129$) of lumbar L_{2-4} increased, whereas β-CTX ($p = 0.003$, $\eta^2 = 0.203$) decreased. In YG, the BMD ($p = 0.002$, $\eta^2 = 0.211$) and PINP ($p = 0.001$, $\eta^2 = 0.241$) of lumbar L_{2-4} increased, whereas β-CTX ($p < 0.001$, $\eta^2 = 0.284$) decreased. In BG, the BMD ($p = 0.022$, $\eta^2 = 0.124$) and PINP ($p = 0.001$, $\eta^2 = 0.247$) of lumbar L_{2-4} increased, whereas β-CTX ($p = 0.008$, $\eta^2 = 0.165$) decreased. No significant changes in OC levels were observed within or between groups ($p > 0.05$). The

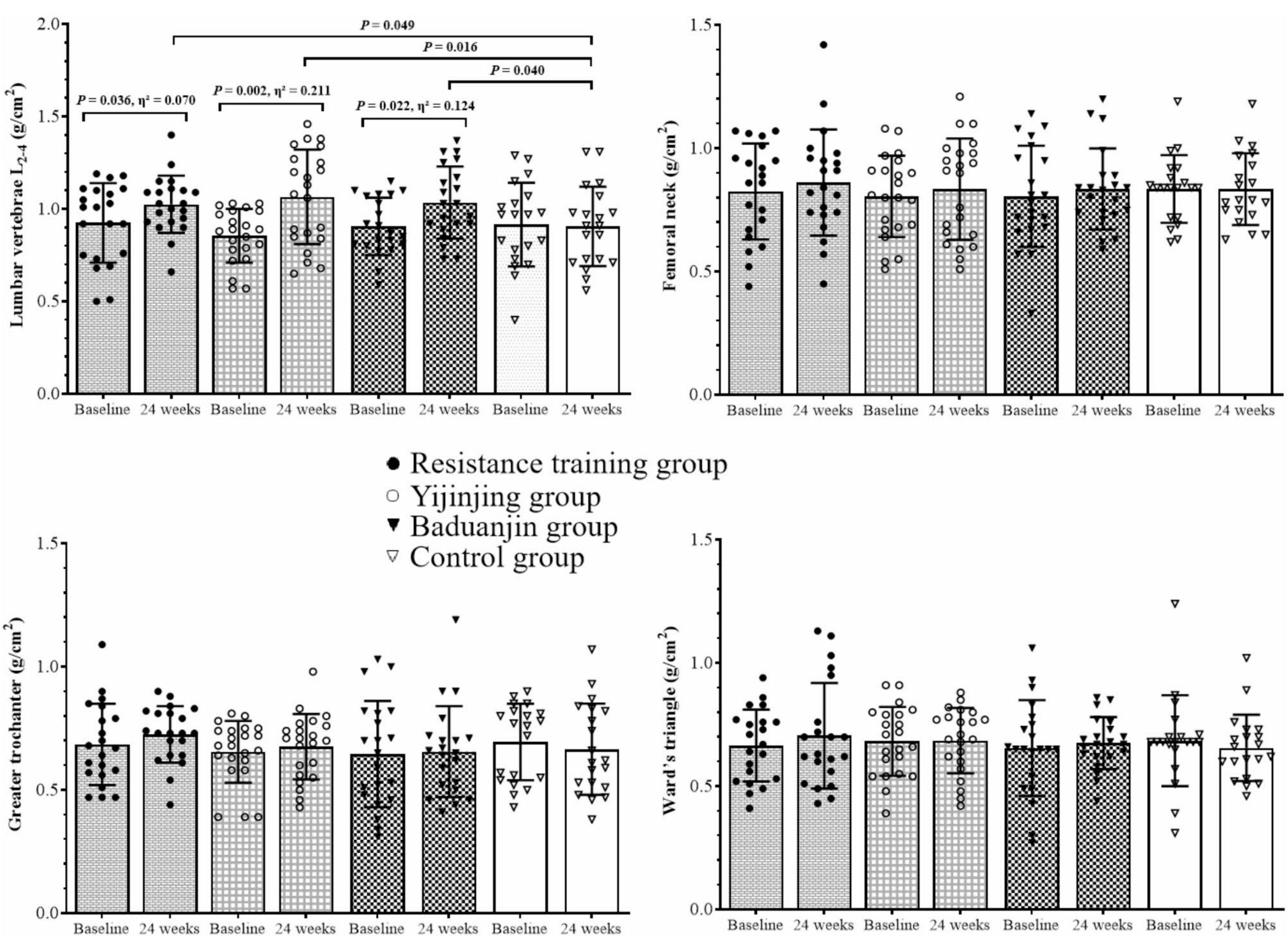

Fig. 3 Results of the bone mineral density. **Note**: PINP: procollagen type I N-terminal propeptide; OC: osteocalcin; β-CTX: β-carboxy-terminal cross-linked telopeptide of type 1 collagen

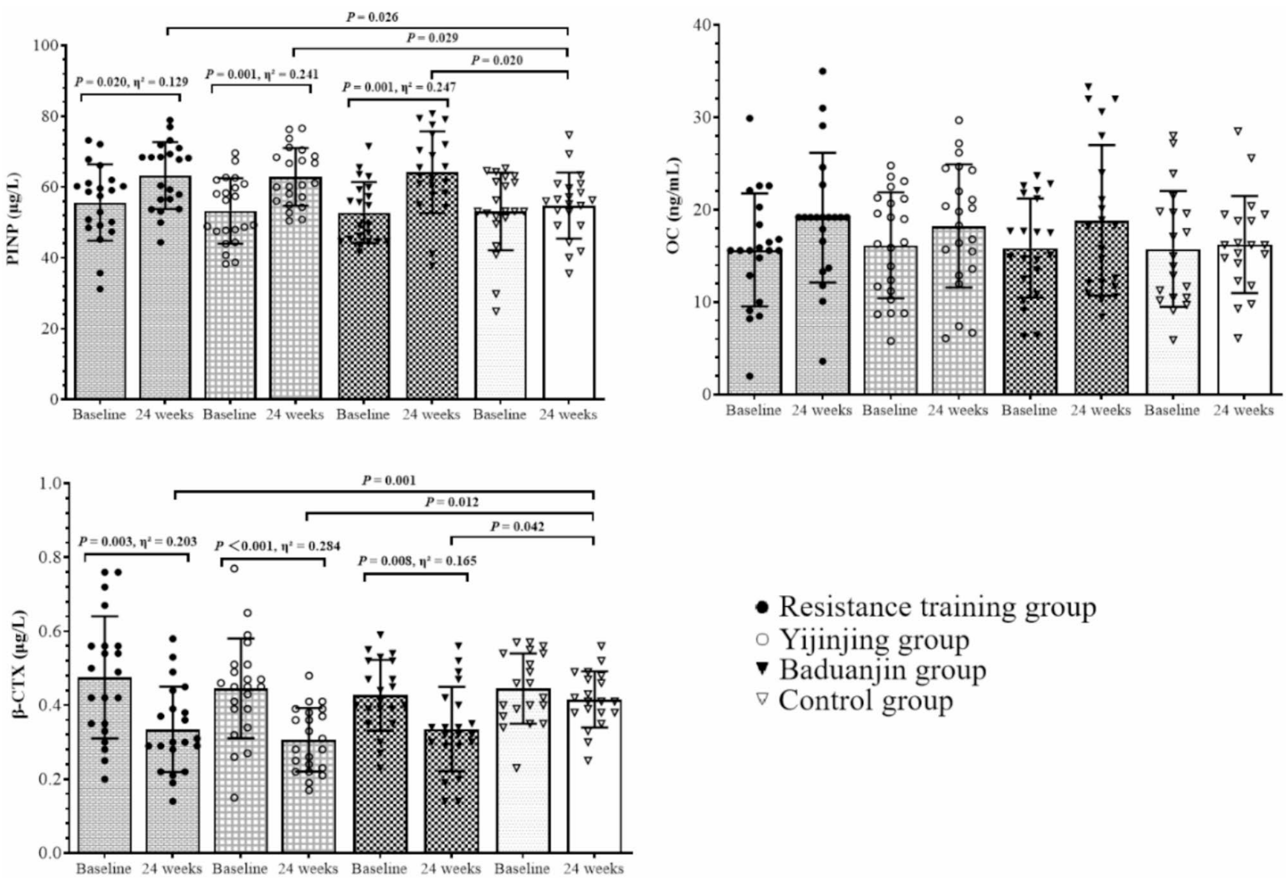

Fig. 4 Results of the bone metabolism measurements

changes in CG indices were not statistically significant ($p > 0.05$).

Discussion

After 24 weeks of RT, this study observed a significant increase in lumbar BMD, while the proximal femur BMD increase was not statistically significant. This contrasts with a previous meta-analysis [14], which found no significant change in lumbar BMD after RT, possibly due to the seated exercise training posture that fails to exert sufficient load on the lumbar spine to trigger an osteogenic response [14]. Another meta-analysis [15] supported our findings, showing no significant effect of RT on femoral neck BMD but a positive impact on lumbar BMD in older adults, suggesting that RT sites affect BMD changes. The use of elastic band resistance in RT may stimulate waist muscle groups more than lower limb muscles, as the intensity is not significantly higher than daily activities, thus not enhancing proximal femoral BMD within 24 weeks. Serum PINP, a bone formation marker, and β-CTX, a bone resorption marker, significantly increased and decreased, respectively, after 24 weeks of RT. Elevated PINP in osteoporotic patients suggests increased osteoblast viability and bone formation capacity [27, 28], while increased β-CTX levels reflect enhanced osteoclast activity and bone resorption [29, 30]. This study found that 24 weeks of RT in older women increased bone formation markers and decreased bone resorption markers, positively affecting BMD.

The mechanism by which RT improves BMD in older adults involves mechanical stimulation, promoting osteoblast activity and bone formation [31], enhancing bone mineral deposition [8], and increasing muscle strength, which raises bone pressure through muscle contraction, promoting bone formation [32]. Additionally, RT can increase testosterone and estrogen levels in older adults, further promoting bone formation [33]. These findings suggest that RT has a positive effect on bone metabolism and BMD in older women, with implications for osteoporosis management and prevention.

This study revealed a significant increase in lumbar BMD after 24 weeks of YJJ, with a non-significant rise in proximal femur BMD, contrasting with Shen et al.'s [17] finding of improved proximal femur BMD but not lumbar spine BMD in osteoporotic patients. Consistent with studies on healthy older adults [18, 34]. This study showed that 24 weeks of YJJ, combined with elastic band resistance training, slowed BMD decline at various sites and improved bone metabolism markers [18]. Li [34] also reported increased lumbar L_{2-4} BMD in older women after 24 weeks of YJJ, without significant changes in proximal femur BMD. These discrepancies may relate to variations in participant characteristics and YJJ practice regimens. Notably, the current study demonstrated that 24 weeks of YJJ led to increased serum PINP and decreased β-CTX in older women, aligning with previous findings [18] and indicating that YJJ enhances bone formation and reduces bone resorption, thus positively impacting BMD.

Participants in YJJ must concentrate on joint and muscle stretching, with a focus on full-range movements and large-scale trunk and lower limb flexion, extension, and torsion. Unlike daily activities, YJJ prompts multiangle movements of bones, muscles, tendons, ligaments, and joint capsules, enhancing blood and lymphatic flow and nutritional metabolism at the exercise site [34]. The lack of significant proximal femur BMD improvement may stem from inadequate lower limb stimulation or intervention duration. The notable increase in lumbar L_{2-4} BMD could be attributed to participants' adeptness at spinal flexion and rotation, a key aspect of YJJ, leading to effective lumbar adjustment and improved BMD in this region.

After 24 weeks of BDJ, this study found a significant increase in lumbar BMD, with no significant change in proximal femur BMD, aligning with Li's [34] findings of improved lumbar L_{2-4} BMD in postmenopausal women. Similar to another study [35], BDJ combined with a Chinese herbal diet enhanced bone formation and reduced resorption in osteoporotic patients. Cheng et al. [36] reported greater lumbar spine BMD improvement than femoral neck after a year of BDJ in perimenopausal women. The varying results may relate to differences in intervention duration and frequency.

After 24 weeks of BDJ, serum PINP rose and β-CTX fell, indicating BDJ's positive impact on bone formation and resorption markers in older women and its contribution to BMD enhancement [19, 36]. BDJ's combination of breath regulation, and static exertion is believed to boost visceral function, joint mobility, and overall blood circulation, thereby strengthening bones. The exercise's specific movements, such as chest expansion and diaphragm engagement, along with the waist movements in the horse-walking posture, may particularly affect lumbar L_{2-4} BMD.

This study, with a standardized 24-week intervention at 3 times/week for 60 min, revealed no significant differences in lumbar and proximal femur BMD and serum bone markers among RT, YJJ, and BDJ in older women. The increases in lumbar BMD and PINP, and decrease in β-CTX in the intervention groups mirrored those of the Caltrate D-only control group, indicating similar effects of YJJ, BDJ, and RT on bone health. Despite BDJ being more intense than YJJ according to a previous study [24], this study found no significant difference in their impact on BMD and bone metabolism, suggesting equivalent training effects.

RT, BDJ, and YJJ positively influenced lumbar L2–4 BMD. Muscle contraction during these exercises likely contributes to bone formation by exerting local stress on bones [2]. However, none significantly altered proximal femur BMD, possibly due to insufficient intervention time, low resistance in RT, lack of progressive overload in RT, and inadequate lower limb stimulation from YJJ and BDJ. For optimal BMD improvement, older adults should maintain and standardize YJJ and BDJ exercises over time, and for RT, gradually increase the load as the intervention progresses.These results suggest that exercise training may influence bone density and metabolism through various mechanisms. Exercise training increases mechanical loading on the skeleton, activating osteoblasts and promoting bone formation [4]. It also improves blood circulation, providing more nutrients to bone tissue and optimizing bone metabolism [6]. Furthermore, exercise training can elevate estrogen and testosterone levels in the body, hormones that play a crucial role in maintaining bone density [37]. These biological effects likely act in concert to result in the increased lumbar BMD and improved bone metabolism indicators observed in our older female participants.

This study has several limitations. First, although RT was employed in the study, its intensity and frequency did not fully comply with the current recommendations for older adults' bone health. This may have limited our observations regarding the effects on proximal femur BMD. Second, we did not measure changes in vitamin D levels in the subjects, which restricts our ability to assess the individual effects of vitamin D supplementation. Additionally, the absence of a control group receiving only vitamin D supplementation prevents us from directly discerning its independent effects from those of the exercise training interventions. Furthermore, the participants in this study were ordinary older women recruited from the same region with similar living backgrounds, so the results may not be universal. Multicentre interventions should be considered in future studies. Lastly, although YJJ and BDJ have similar exercise training intensity, we did not measure whether the RT used in this study had similar exercise training intensity (we only measured the heart rate during exercise training as the evaluation standard). Moreover, the elastic band was used in this study, which provides relatively small stimulation to the lower limb load.

Conclusion

This study showed that 24 weeks of RT, YJJ, and BDJ combined with Caltrate D supplementation significantly increased lumbar spine BMD, increased the bone formation marker PINP, and decreased the bone resorption marker β-CTX in older women. However, these interventions did not significantly affect proximal femur BMD. Nevertheless, the results of this study still provide preliminary evidence for the potential of YJJ and BDJ in improving bone density in older adults. Future studies need to further explore optimal training parameters and longer-term intervention effects to better optimize exercise training programs for older adults' bone health.

Abbreviations

RT	Resistance training
YJJ	Yijinjing
BDJ	Baduanjin
BMD	Bone mineral density
YG	Yijinjing group
BG	Baduanjin group
CG	Control group
PINP	Procollagen type I N-terminal propeptide
β-CTX	β-carboxy-terminal cross-linked telopeptide of type 1 collagen
OC	Osteocalcin
RG	Resistance training group

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Author contributions

YY and HL: designing this study, writing initial draft and revision, revising language and content, supervision, project administration, and funding acquisition. YY and HL: making figure and table. YY and HL: rechecking the manuscript and putting forward suggestions for amendment. All authors contributed to the article and approved the submitted version.

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Data availability

The raw data supporting the results of this study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

This study was approved by the Human Research Ethics Committee of Chengdu Sport University (No: 20236). The complete experimental protocol for this study can be found at the following URL. https://clinicaltrials.gov/study/NCT06529172. All participants provided their consent to participate and signed written informed consent forms. Their agreement to participate was confirmed by selecting the "I agree" option before filling out the questionnaires. All procedures were conducted in compliance with the ethical standards of the responsible committee on human experimentation (both institutional and national) and adhered to the Helsinki Declaration of 1975, as revised in 2008 (5).

Consent for publication

Not applicable.

Consent to participate

Informed consent was obtained from all subjects. No participants were under the age of 16.

Competing interests

The authors declare no competing interests.

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