Abstract:

Introduction: Osteoporosis is common among postmenopausal women, and can affect their health and quality of life. However, it can be managed by physical activity. The present study aims to investigate the combined effect of core stability and dynamic resistive exercises on bone mineral density (BMD) in postmenopausal women.

Material and methods: Sixty postmenopausal women diagnosed with osteoporosis, age 50 to 60, BMI < 30 kg/m^2, were randomly divided into two equal groups: the study group received core stability and dynamic resistance exercise (two sessions per week) in addition to 70 mg Alendronate (one tablet) per week for four months, while the control group only received 70 mg Alendronate (one tablet) per week (n = 30 each group). Both groups were assessed for BMD (dual-energy x-ray absorptiometry; DEXA), and quality of life (Oswestry Disability Index; ODI), both pre- and post-treatment.

Results: Both groups demonstrated a significantly greater bone mineral density in the lumbar spine and left femoral neck and improved quality of life post-treatment compared to pre-treatment (p < 0.001). However, comparing groups, the study group demonstrated significantly higher lumbar spine (Z value = -5.588) and left femoral neck bone mineral density (Z value = -4.794), and significantly lower ODI score (F value = 243.686), compared to the control group (p < 0.001).

Conclusions: Core stability and dynamic resistance exercise appear to be safe and effective methods in the treatment of osteoporosis in post-menopausal women.

Keywords: bone density, core stability, post menopausal osteoporosis, resistance training
Osteoporosis is deemed a fracture risk factor in a similar way to how hypertension predisposes individuals to strokes. While it impacts a considerable portion of the population, irrespective of sex or population type, it typically remains asymptomatic until fractures appear, causing serious secondary health issues and potentially fatal outcomes [3]; in the absence of such fractures, osteoporosis often remains asymptomatic. Nevertheless, its prevalence is likely to rise as the population ages, and it has been estimated that one-third of postmenopausal women in the West will suffer from an osteoporotic fracture during their lives [4-6].

Several studies report a relatively high prevalence of osteoporosis among the Egyptian population, which has been attributed to multiple risk factors and health conditions. According to estimates, 53.9% of postmenopausal women in Egypt are osteopenic, and 28.4% are osteoporotic [7,8].

Estrogen deficiency at menopause impairs the normal cycle of bone turnover, possibly due to the presence of estrogen receptors in both osteoclast progenitor cells and multi-nucleated osteoclasts. Higher osteoclastic resorption combined with lower osteoblastic activity causes more bone to be broken down than formed, leading to overall bone loss. The rise in bone resorption occurs because of the decreased availability of estrogen, leading to increased osteoclast genesis and function [9]. In this way, osteoporosis lowers quality of life (QoL) and results in increased disability-adjusted life years. However, early diagnosis through BMD assessment before fractures occur, coupled with early management, can prevent the onset of osteoporosis [1].

The primary treatment for osteoporosis involves the use of medications that target BMD; such treatments decrease fracture risk by about 20-60% according to the specific medication, patient demographic and degree of medication adherence [10]. However, despite treatment, approximately 80% of postmenopausal women with fragility fractures do not receive adequate follow-up care. Moreover, these treatments do not address significant risk factors for falling and fractures such as muscular strength, muscular power, dynamic balance, coordination or functional capacity [11].

Strategies aimed at preventing and ameliorating osteoporosis include regular physical exercise, especially weight-bearing activities, together with proper nutrition, particularly regarding calcium and vitamin D intake, avoiding detrimental lifestyle habits like smoking and alcohol consumption, and the use of hormone replacement therapy aimed at maintaining optimal bone mass [12,13]. Among these recommendations, regular exercise has shown particular promise in enhancing osseous strength among elderly women and is regarded as the cornerstone of non-pharmacological fracture prevention in postmenopausal women [12,14].

The core muscles are those that provide spinal support and force transmission, such as those attached to the vertebral column, pelvic girdle and hips. Core stabilization exercises employ closed-chain movements in unstable conditions to enhance neuromuscular control, strengthen nerve-muscle feedback, increase deep spinal stabilizer strength, and improve overall balance and movement control. Studies have indicated that core stabilization training is superior to conventional training in strengthening and stabilizing spinal muscles [15]. Hence, core stability exercises play a crucial role in ensuring adequate muscle strength and postural control within the trunk-hip complex, and in enabling safe and efficient motion [16].

Moreover, the Mechanostat theory proposed by Frost indicates that high mechanical-load exercises can enhance a range of bone characteristics, such as mass, structure, and strength. Significantly, bone tissue exhibits a superior response to high-intensity and high-magnitude exercises [17].

Multiple studies and systematic reviews show that progressive resistance exercise (RE), whether as a stand-alone intervention or combined with others, can positively impact bone health in adults [18]. Among these interventions, RE stands out as particularly effective in preserving or enhancing bone mass and density [19]; this has been attributed to the potential of RE to stimulate an osteogenic response by applying various levels of muscular loads to the bone [20].

To date, little or no research has been performed on the effect of these exercise modalities on bone density. Therefore, the aim of the present study is to determine the effect of combined core stability and dynamic resistance exercise training on BMD in postmenopausal women. It is hypothesised that this programme will yield positive effects on bone density.

Materials and methods

Participants

A total of 70 women with osteoporosis were referred to the study by a gynecologist (Figure 1). Of these, 10 were excluded: three by choice and seven due to ineligibility. The remaining 60 postmenopausal women were randomly assigned to two groups using a closed envelope method. The inclusion criteria comprised the following: age range 50-60, body mass index (BMI) not exceeding 30 kg/m$^2$, minimum one year after cessation of menses, and absence of consistent physical exercise for half a year previously. The participants were excluded if they had taken bone metabolism-altering drugs (including calcium supplements, multivitamins with calcium and vitamin D), smoked or consumed alcohol in the previous three months, or had previously experienced fractures, surgeries, or severe injuries.
Procedures

Sample randomization was accomplished using the closed envelope method. The participants were evenly divided into two groups of 30 each through simple random allocation. Sixty sealed envelopes were prepared, with half labelled ‘Group A’ and the other half ‘Group B’. Each participant selected one envelope and was assigned to the corresponding group indicated inside. Before the study began, all procedures were explained to the patients, who then gave their informed consent in writing. The study design adhered to the ethical guidelines for human research as stipulated in the Declaration of Helsinki [21]. Approval for this study was granted by the Ethical Research Committee of the Faculty of Physical Therapy, Cairo University, Egypt [No: P.T.REC/012/003867]. The sample size was calculated using G*Power software (version 3.0.10). The value was determined by assessing the mean difference in ODI (pre-treatment minus post-treatment values) between the control (16.60 ± 2.22) and study (26.50 ± 4.09) groups in an earlier pilot study; the comparison was performed using a two-tailed unpaired t-test (G*Power version 3.0.10). Assuming an alpha level of 0.05, a desired power of 80%, and an effect size of 0.74, the calculated minimum sample size was 30 participants per group. Anticipating a possible 15% dropout rate, the final number of participants was raised to 35 per group.

Outcome measures

Dual-energy x-ray absorptiometry (DEXA)

All participants underwent BMD testing (A & B) before and after treatment using Dual-energy X-ray absorptiometry (DEXA). DEXA uses X-rays to analyze body composition based on the differences in mass attenuation coefficients among various body tissues. It has been found to be reliable in assessing BMD in the neck of femur and distal thigh regions [22] and can identify vertebral fractures with good sensitivity and specificity [23]. As such, it is considered the global gold standard for measuring BMD [24].

Participants maintained their usual eating habits on the examination day and refrained from consuming calcium supplements for a minimum of 24 hours prior to the examination. They chose to wear loose, comfortable attire, avoiding clothing with metal zippers, belts, or buttons. Additionally, they removed any metal objects or attire

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Fig. 1. Flow chart indicating numbers of participants
that could potentially disrupt the scanning process, such as keys, wallets, eyeglasses, removable dental appliances and jewelry. If necessary, the participants wore a gown for the examination.

Subsequently, each participant lay down on a cushioned table, with an X-ray generator below and an imaging detector above. For spinal assessment, the patient’s legs were rested on a cushioned box to flatten the pelvis and lumbar spine; to detect the BMD of the femoral neck, the participant kept the femur straight on the table, with 15–25° of internal rotation. The detector was then moved gradually over the area, and the images were displayed on a computer monitor. The woman was instructed to remain very still and some were asked to hold their breath momentarily while the technologist captured a clear X-ray image. The technologist operated the X-ray machine remotely from behind a protective wall or in an adjacent room. Typically, the bone density test was completed within 10 to 30 minutes.

Oswestry disability index (ODI)

The QoL was assessed in all patients (A & B) before and after treatment using the ODI, which consists of 10 questions focusing on how low back pain impacts daily functioning. The accuracy and validity of the ODI have been confirmed by Miyagi, who used it to assess QoL due to osteoporotic pain [25]. As a condition-specific assessment tool, the ODI demonstrates validity, reliability, and responsiveness, rendering it appropriate for clinical use [26]. It assesses functional limitations through 10 domains, viz. pain severity, self-care, lifting, work, sitting, standing, sleeping, sexual activity, social engagement, and ability to travel. Each criterion is scored from 0 to 5, with a maximum cumulative score of 50. A lower score indicates less severe disability, with 0 to 4 indicating no disability, 5 to 14 mild disability, 15 to 24 moderate, 25 to 34 severe, and 35 to 50 complete disability [27].

Interventions

Group A (control group) included 30 postmenopausal women who received medication only (70 mg Alendronate, i.e. one tablet weekly) for four months, while group B (study group) included 30 postmenopausal women who received both medication (70 mg Alendronate per week) plus core stability and dynamic resistance exercises twice weekly for four months. Each exercise intervention was performed under the supervision of the physical therapist at the outpatient clinic of El Kasr El-Einy University Hospital, Cairo University.

Medication

All patients in both groups (A&B) received 70 mg Alendronate, i.e. one tablet, per week for the four months. Core stability and dynamic resistive exercises

All patients in group B were treated with core stability and dynamic resistance exercises twice weekly, for four months. Each session lasted 60 minutes, and comprised a 5-minute warm-up and a 5-minute cool-down in the form of stretching. All core stability exercises were executed for three sets of 15 seconds, with a 10-second rest interval between each set. Throughout these exercises, the intensity was systematically increased from lesson to lesson based on the principle of gradual progression. Additionally, participants performed breathing exercises, comprising three sets of 10 repetitions, with a one-minute rest interval between sets. The women completed two sets of dynamic resistance exercises with a 90-second rest interval between sets; the number of repetitions gradually increased from 8 to 12 as the study progressed.

The core stability exercises included forearm plank exercise (from kneeling position, elbows bent to 90 degrees, toes tucked under to press into the plank) and side plank exercise (from lying on the side with bent knees, lifting the hips upwards while supporting the upper body on the elbow). In addition, the participants performed a weight transfer exercise: from reclining on the back with flexed knees and feet on the floor, the participant held a weight or pillow overhead with arms extended, in line with her ears, keeping the head and shoulders on the floor; she then raised her arms and brought her knees up over her hips, placed the weight between her knees, then lowered her arms and legs to the floor without arching her back. Other exercises included squatting, prone opposite arm/leg raise exercise, supine bridge, single leg bridge, quadruped-arm/leg raise, pelvic floor exercise, diaphragmatic breathing exercise.

The dynamic resistance exercises included the following: seated hip abduction, seated back extension, standing hip flexion, standing hip extension, seated hip adduction, horizontal leg press, prone hamstring curls, seated knee extension, and bicep curls. These were accomplished using an elastic band. Seated hip abduction emphasizes gluteus medius and gluteus minimus activation, while standing hip flexion engages the iliopsoas and quadriceps femoris muscles, specifically the rectus femoris. Standing hip extension exercises are effective for gluteus maximus strengthening, while seated hip adduction primarily focuses on the adductor magnus, adductor longus, and adductor brevis muscles. Prone hamstring curls activate the biceps femoris, semitendinosus, and semimembranosus muscles, while horizontal leg press exercises target the gluteus maximus, quadriceps femoris, and triceps surae muscles. Seated knee extension entails a specific movement that emphasizes the knee joint, effectively working the quadriceps femoris muscle. Bicep curls are beneficial for strengthening the muscles located on the anterior aspect of the arm and forearm, with a particular emphasis on
the biceps brachii, brachialis, and brachioradialis. Seated back extension enhances the back muscles, involving the erector spinae (iliocostalis, longissimus, and spinalis), supported by the quadratus lumborum and latissimus dorsi; this exercise was chosen for its ability to strengthen the back extensors, aiding in maintaining proper posture.

Statistical analysis

Results were presented as mean ± standard deviation. To assess the distribution of data at pre-treatment, a normality test (Kolmogorov-Smirnov test) was conducted. For normally-distributed variables, an unpaired t-test was used to compare the two groups. Baseline and post-treatment measures were compared between groups using analysis of covariance (ANCOVA), while controlling for initial differences, and within groups using a paired t-test. For non-normally distributed data, intergroup comparisons were performed using the Mann-Whitney U-test, and within-group comparisons using the Wilcoxon Signed Ranks test. Data analysis was performed using the Statistical Package for Social Sciences (SPSS) software (version 19 for Windows). A significance level of p ≤ 0.05 was considered statistically significant.

Results

No statistically significant difference was observed between the two groups (p < 0.05). The general characteristics of the two studied groups are given in Table 1.

Tab. 1. Demographic data of participants in both groups

<table>
<thead>
<tr>
<th>Demographic data</th>
<th>Group (A) X ± SD</th>
<th>Group (B) X ± SD</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>56.70 ± 3.00</td>
<td>55.70 ± 3.44</td>
<td>1.202</td>
<td>0.234</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>27.67 ± 1.31</td>
<td>27.35 ± 1.35</td>
<td>0.923</td>
<td>0.360</td>
</tr>
</tbody>
</table>

BMI- Body Mass Index, p- probability, SD- standard deviation, X- mean

The intergroup and within-group differences in T-scores for lumbar spine and left femoral neck BMD are given in Table 2, Figures 2 and 3. The effect of different treatment modalities in the two studied groups, i.e. the difference in mean values, was evaluated using the Wilcoxon Signed Ranks test and Mann-Whitney U test. Significantly greater mean differences in T-score of lumbar spine and left femoral neck BMD were noted in Group B compared to Group A.

Tab. 2. Mean ± SD of DEXA score, pre and post treatment, of both groups

<table>
<thead>
<tr>
<th>BMD (t-score of spine L1-4)</th>
<th>Group (A) X ± SD</th>
<th>Group (B) X ± SD</th>
<th>Z# value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-treatment</td>
<td>-2.94 ± 0.57</td>
<td>-2.96 ± 0.55</td>
<td>-0.171</td>
<td>0.864</td>
</tr>
<tr>
<td>Post-treatment</td>
<td>-2.85 ± 0.56</td>
<td>-2.40 ± 0.69</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean difference</td>
<td>-0.09 ± 0.05</td>
<td>-0.56 ± 0.50</td>
<td>-5.588</td>
<td>0.001</td>
</tr>
<tr>
<td>% of improvement</td>
<td>3.06% ↑↑</td>
<td>18.92% ↑↑</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Z## value</td>
<td>-4.669</td>
<td>-4.639</td>
<td></td>
<td></td>
</tr>
<tr>
<td>p-value</td>
<td>0.001*</td>
<td>0.001*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BMD (t-score of left femoral neck)</th>
<th>Group (A) X ± SD</th>
<th>Group (B) X ± SD</th>
<th>Z# value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-treatment</td>
<td>-2.20 ± 1.19</td>
<td>-2.56 ± 1.06</td>
<td>-0.845</td>
<td>0.398</td>
</tr>
<tr>
<td>Post-treatment</td>
<td>-2.10 ± 1.18</td>
<td>-2.12 ± 1.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean difference</td>
<td>-0.10 ± 0.07</td>
<td>-0.44 ± 0.50</td>
<td>-4.794</td>
<td>0.001</td>
</tr>
<tr>
<td>% of improvement</td>
<td>4.55% ↑↑</td>
<td>17.19% ↑↑</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Z## value</td>
<td>-4.520</td>
<td>-4.802</td>
<td></td>
<td></td>
</tr>
<tr>
<td>p-value</td>
<td>0.001*</td>
<td>0.001*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

BMD- Bone mineral density, DEXA- Dual-energy x-ray absorptiometry, p- probability; SD- standard deviation, X- mean, Z# value- Mann-Whitney U test, Z## value- Wilcoxon Signed Ranks test, *- significant with p < 0.05.
The intergroup and within-group comparisons of the pre- and post-treatment ODI values are given in Table 3 and Figure 4. Regarding the post-treatment data, a more significant decrease in ODI score during the programme was noted for Group B than Group A.

**Tab. 3. Mean ± SD of ODI score pre and post-treatment of both groups**

<table>
<thead>
<tr>
<th></th>
<th>Group (A)</th>
<th>Group (B)</th>
<th>F value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ODI score</td>
<td>X ± SD</td>
<td>X ± SD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-treatment</td>
<td>35.73 ± 2.96</td>
<td>36.27 ± 2.61</td>
<td>0.548</td>
<td>0.462</td>
</tr>
<tr>
<td>Post-treatment</td>
<td>18.40 ± 2.66</td>
<td>9.23 ± 3.24</td>
<td>243.686</td>
<td>0.001</td>
</tr>
<tr>
<td>Mean difference</td>
<td>17.33</td>
<td>27.04</td>
<td>-5.588</td>
<td>0.001</td>
</tr>
<tr>
<td>% of improvement</td>
<td>48.50% ↓↓</td>
<td>74.55% ↓↓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>t-value</td>
<td>43.733</td>
<td>52.467</td>
<td></td>
<td></td>
</tr>
<tr>
<td>p-value</td>
<td>0.001*</td>
<td>0.001*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

F value- ANCOVA test, ODI score- Oswestry disability index, SD- standard deviation, t-value- paired t test, X = mean, *- significant with p < 0.05.
The aim of the study was to determine how the combination of core stability exercises with dynamic resistance training impacts BMD in women after menopause. The findings indicated significant improvements in BMD and reductions in ODI scores within both study and control groups following the intervention. However, Group B demonstrated significantly greater increases in lumbar and left femoral neck BMD compared to Group A. These findings highlight the efficacy of combining core stability and dynamic resistance training to enhance BMD and QoL in women after menopause.

Our findings on core stability are in line with those of a number of previous studies. For example, Riahi et al. [28] demonstrated that a four-month core stability regimen significantly enhanced lower limb muscular strength (hip flexors and external rotators) in postmenopausal women (p < 0.05). Well-designed exercise programs have also been found to maintain femoral neck BMD or promote annual bone mass increases of up to 1% in pre- and postmenopausal women [29]. Similarly, Yung et al. [30] report a notable enhancement in proximal femur BMD among postmenopausal women aged 55 and older following 24-week core stability exercises. Thus, core stability exercises can lead to increased BMD and serve as a preventive measure against osteoporosis in women after menopause. Moreover, Liu et al. [31] revealed that an 8-month program combining consistent sling-based core strengthening exercises with calcium and vitamin D supplements can effectively modulate bone metabolism and potentially increase BMD. This dual approach resulted in consistent BMD improvements among the patients studied. Furthermore, Elnaggar et al. [32] indicate that a three-month program consisting of three sessions week yielded increased lumbar and femoral neck bone strength. These region-specific effects may be due to the dual focus of core stability exercises, i.e. strengthening (particularly in lumbar and hip areas) and balance training.

However, in contrast, Essa et al. [33] documented a substantial increase in femoral neck BMD among participants undergoing treadmill training compared to those engaging in core stability exercises. This contradicts our present findings indicating a significant increase in femoral neck BMD following four-month core stability exercises in postmenopausal women. Such inconsistency could potentially be attributed to differences in exercise protocol duration, with Essa et al. implementing a three-month protocol compared to the four-month duration used herein. Also, Kang et al. [34] showed that 24-week low-intensity spinal and pelvic stabilization exercises in postmenopausal women maintained, but did not significantly increase, bone density. This lack of significant improvement may be due to the variations in calcium intake, daily activities, and time since menopause onset among participants.

Regarding dynamic resistance exercise, our findings are confirmed by Mosti et al. [35], who observed significant lumbar spine improvements after 12 weeks of weight training performed three times a week. Similarly, Holubiac et al. [36] found that a six-month strength training protocol effectively increased BMD in osteopenic/osteoporotic women, providing an affordable bone loss prevention strategy. In addition, Salek Zamani et al. [37] demonstrated that women in the postmenopausal stage who engaged in regular exercise before reaching menopause displayed greater hip BMD, reinforcing the osteogenic benefits derived from mechanical loading. Moreover, Colletti et al. [38] found RE to be effective in enhancing BMD in body regions capable of supporting the entire body weight.

However, Lee et al. [39] report that a six-week resistance exercise program for 11 postmenopausal women, focusing on lumbar and femoral BMD, achieved only an
insignificant increase in lumbar bone density. This could be attributed to the fact that the study was quite short.

Regarding quality of life (QoL), our findings demonstrated a statistically-significant reduction in ODI favoring the study group. This improvement aligns with the general consensus from previous studies that physical activity positively influences QoL. For example, Kanwal et al. [40] found that performing core muscle stability exercises three days per week for 12 weeks reduced pain and disability in postmenopausal women while improving strength and QoL. Additionally, Berin et al. [41] demonstrated that resistance training performed three times per week for 15 weeks enhanced menopause-specific health-related QoL, further supporting the positive impact of resistance exercise on QoL. Among the recommended strategies, the value of regular exercise in promoting bone strength among elderly women cannot be overstated, having been identified as a primary non-pharmacological measure in preventing osteoporotic fractures in women after menopause [14,42].

Strengths and limitations
No negative outcomes were reported during the study period. While core stability and dynamic resistive exercises may be considered a promising treatment approach for women with osteoporosis, our research has limitations. One constraint is the absence of a patient follow-up, necessitating additional studies to assess the long-term impact of the training programme. Future research with longer durations and more diverse populations is necessary to build upon these initial results.

Clinical implications
The study provides robust evidence supporting the incorporation of this combined exercise regimen into routine physical therapy practice for postmenopausal women with osteoporosis. The significant improvements observed in BMD and QoL highlight the potential for this intervention to mitigate the detrimental effects of osteoporosis and enhance overall health outcomes in this population.

Conclusions
Integrating core stability exercises alongside dynamic resistive exercises yields advantageous effects among women with osteoporosis.

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Conflicts of interest
The authors declare no conflict of interest.

References


