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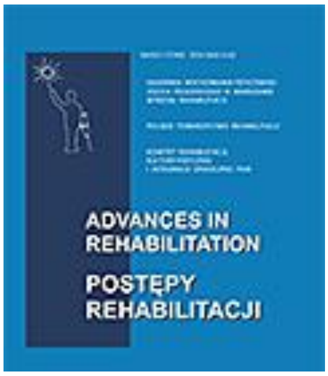

Original article

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DOI: https://doi.org/10.5114/areh.2024.141354

To appear in: Advances in Rehabilitation

Received date: 25 June 2024
Accepted date:

Please cite this article as: Abd El Azeem NS, Emara HM, Awad MA, Samir SH. Combined Effect of Core Stability and Dynamic Resistive Exercises on Bone Mineral Density in Postmenopausal Women. Adv Rehab. (2024), https://doi.org/10.5114/areh.2024.141354

Combined Effect of Core Stability and Dynamic Resistive Exercises on Bone Mineral Density in Postmenopausal Women

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Abstract

Introduction: Osteoporosis is prevalent in postmenopausal women, affecting their health and life quality. Therefore, physical activity offering benefits for managing osteoporosis. Thus, this 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. their ages 50 to 60 with a body mass index (BMI) of no more than 30 kg/m2, were randomly divided into two equal groups. The study group treated with core stability and dynamic resistance exercise in addition to medication (Alendronate) 70 mg 1 tab weekly and the Control group treated by medication only (Alendronate) 70 mg 1 tab weekly (n = 30 each). Treatment lasted for 4 months, 2 sessions per week. BMD was assessed by using Dual-energy x-ray absorptiometry (DEXA) and quality of life (QoL) was assessed by Oswestry Disability Index pre and post treatment.
Results: Bone mineral density of lumbar spine and left femoral neck in addition to quality of life showed a statistically significant increase when comparing before to after-treatment in both groups ($p < 0.001$). However, bone mineral density showed statistically significant increase of the T-score of lumbar spine (Z value= -5.588) and that of left femoral neck (Z value = -4.794) and significant decrease of ODI (F value= 243.686) in the study group only ($p < 0.001$) compared to the control group.
Conclusions: Accordingly, it can be concluded that core stability and dynamic resistance exercise are safe and effective methods in the treatment of osteoporosis in post-menopausal women.

Keywords: Bone density, Core stability, Post menopausal osteoporosis, Resistance training

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Introduction

Osteoporosis, marked by low bone density, bone tissue deterioration, and disrupted bone microarchitecture, leads to weakened bones and a higher fracture risk. As the most widespread skeletal disease among humans, osteoporosis poses a substantial public health issue. It is more prevalent in Caucasian populations, females, and individuals of advanced age [1].

Based on the World Health Organization (WHO) standards, osteoporosis corresponds to a bone mineral density (BMD) T-score of ≤ -2.5, whereas osteopenia corresponds to a T-score between -2.5 and -1.0, assessed at the lumbar spine or hip [2]. Osteoporosis is deemed a fracture risk factor akin to how hypertension predisposes individuals to strokes. It impacts a considerable portion of the population, irrespective of gender or race, and its prevalence is likely to rise with the increasing age of the population. It remains asymptomatic until fractures appear, causing serious secondary health issues and potentially fatal outcomes [3]. Therefore, osteoporosis's clinical significance stems from the fragility of the fractures associated with it. In the absence of such fractures, osteoporosis often remains asymptomatic. Western epidemiological studies indicate that one-third of postmenopausal women will suffer from an osteoporotic fracture during their lives [4-6].

Besides that, several studies report a relatively high prevalence of osteoporosis among the Egyptian population, connected to multiple risk factors and health conditions. According to estimates, 53.9% of postmenopausal women are osteopenic, and 28.4% are osteoporotic [7,8].

Estrogen deficiency at menopause impairs the normal cycle of bone turnover, possibly due to estrogen receptor presence 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 weakened inhibition of osteoclast genesis and function [9]. So, osteoporosis leads to a diminished quality of life (QoL) and 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].

Medications that target BMD are the primary treatment for osteoporosis, decreasing fracture risk by about 20-60% based on the specific medication, patient demographic, and medication adherence [10]. Despite treatment, approximately 80% of postmenopausal women with fragility fractures do not receive adequate follow-up care. Moreover, these treatments do not address other significant risk factors for fractures, including muscular strength, muscular power, dynamic balance, coordination, and functional capacity, factors linked to higher fall and fracture risks [11].

Strategies to prevent and ameliorate osteoporosis include regular physical exercise (especially weight-bearing activities), proper nutrition (with emphasis on calcium and vitamin D), avoiding detrimental lifestyle habits (like smoking and alcohol consumption), and hormone replacement therapy aimed at maintaining optimal bone mass [12,13]. Among these recommendations, regular exercising 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].

Core muscles include those attached to the vertebral column, pelvic girdle, and hips, providing spinal support and force transmission. 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]. So, core stability exercises play a crucial role in ensuring adequate muscle strength and postural control within the trunk-hip complex, which enables safe and efficient motion [16].

Moreover, the Mechanostat theory proposed by Frost indicates that exercises that high mechanical load exercises can enhance multiple 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 standalone 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 is because RE involves applying various levels of muscular loads to the bone, stimulating an osteogenic response [20]. To our knowledge, this study pioneers the exploration of the combined effect of core stability and dynamic resistance exercises on osteoporotic post-menopausal women. We hypothesized that the core stability and dynamic resistance exercises the most effective strategy to improve the BMD. Therefore, this study aimed to investigate the combined effect of the core stability and dynamic resistance exercises on BMD in postmenopausal women.

Materials and methods

Participants

Out of seventy osteoporotic women referred by a gynecologist, sixty qualified for the study. Ten were excluded: three by choice and seven due to ineligibility. The remaining sixty postmenopausal women were randomly assigned to two groups using closed envelop way. Inclusion criteria comprised: 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 prior. Women were excluded if they had taken bone metabolism-altering drugs (including calcium supplements, multivitamins with calcium and vitamin D), smoked, consumed alcohol, or had previously experienced fractures, surgeries, or severe injuries.

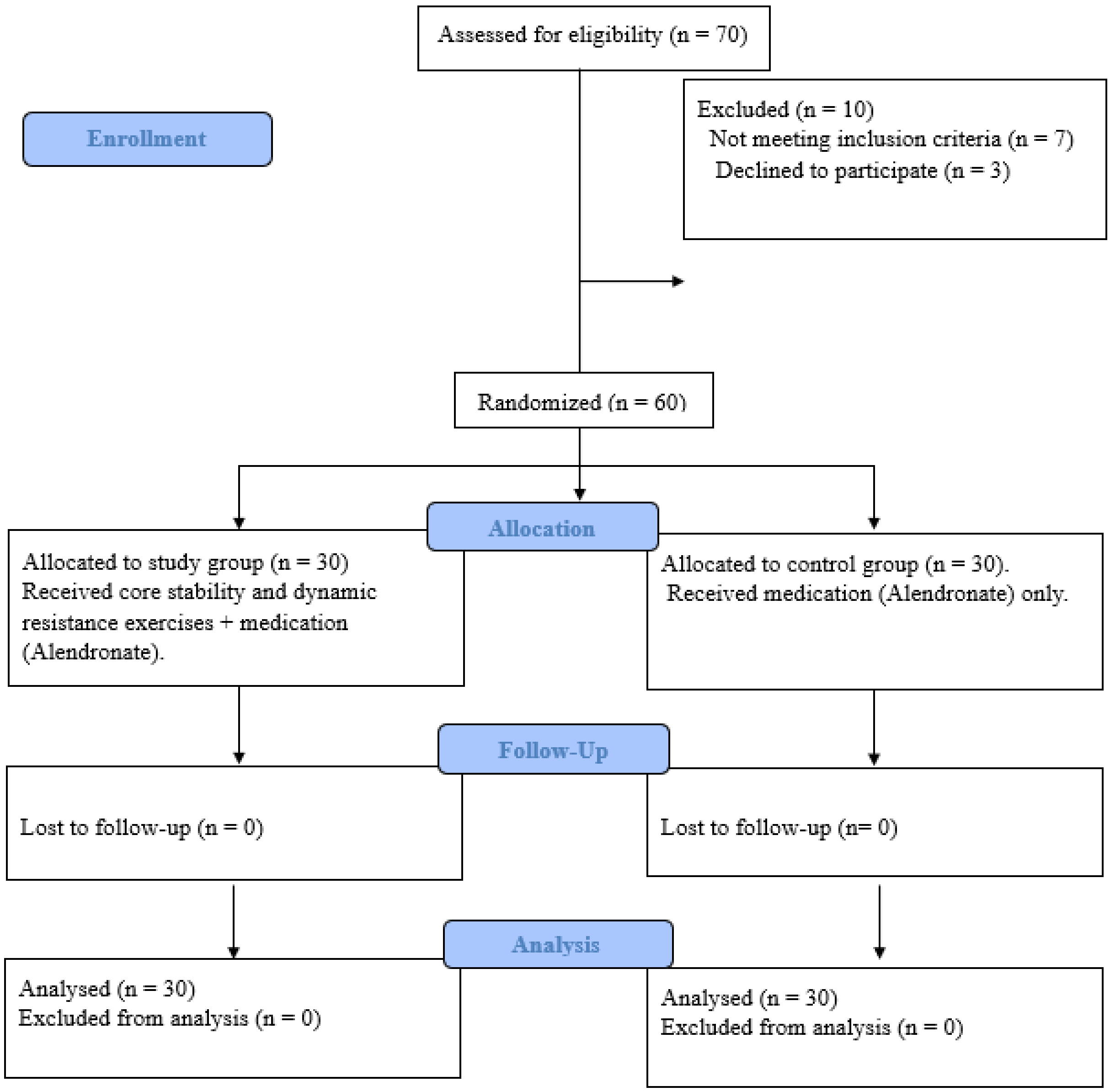

Fig. 1. Study flow chart

Procedures

Sample randomization was accomplished using a closed envelope method. The participants were evenly divided into two groups of thirty each through simple random allocation. Sixty sealed envelopes were prepared, with half labeled 'Group A' and 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 calculation was conducted based on a software (version 3.0.10). It was determined by assessing the significant difference in pilot study using G*Power the mean difference (pre-treatment minus post-treatment values) of ODI between the control (16.60 ± 2.22) and study (26.50 ± 4.09) groups through a two-tailed unpaired t-test. 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

a. Dual-energy x-ray absorptiometry (DEXA):

Dual-energy X-ray absorptiometry (DEXA) was utilized to assess BMD for each participant in both groups (A & B) before and after treatment. DEXA represents an imaging method that employs X-rays to analyze body composition by using the differences in mass attenuation coefficients among various body tissues. It has demonstrated reliability in assessing BMD in the neck of femur and distal thigh regions [22]. Vertebral fractures can be identified with good sensitivity and specificity by DEXA [23]. So, it considered gold standard for measuring BMD due to its thorough investigation and validation on a global scale [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 objects, such as keys or wallets that could potentially disrupt the scanning process. Before the examination, participants were required to remove certain garments and, if needed, wear a gown. They were advised to take off eyeglasses, removable dental appliances, jewelry, and any metal objects or attire that might disrupt the X-ray images. Subsequently, each woman 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 while the femoral neck each woman kept the femur straight on the table, with 15–25° of internal rotation. The detector was then moved gradually over the area, producing images displayed on a computer monitor. The woman was instructed to remain very still and might be asked to hold her breath momentarily while the technologist captured the X-ray to ensure clear X-ray images. 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.

b. Oswestry disability index (ODI):

The QoL was assessed using the ODI, which consists of 10 questions focusing on how low back pain impacts daily functioning for each woman in both groups (A & B) before and after treatment. The accuracy and validity of the OD index have been confirmed in the study carried out by Miyagi, which was also conducted 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]. The ODI assesses patients' functional limitations through 10 domains, such as 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. Disability severity is categorized as none, mild, moderate, severe, or complete, with scores ranging from 0 to 4, 5 to 14, 15 to 24, 25 to 34, and 35 to 50, respectively [27].

Interventions

Group A (control group) included 30 postmenopausal women who received medication only (Alendronate) 70 mg 1 tablet weekly for 4 months, while group B (study group) included 30 postmenopausal women who received both medication (Alendronate) 70 mg 1 tablet weekly plus core stability and dynamic resistive exercises twice weekly for 4 months. Each exercise intervention was performed under the supervision of the physical therapist twice weekly at the outpatient clinic of El Kasr El-Einy University Hospital, Cairo University.

a. Medication

All patients in both groups (A&B) followed the same medication (Alendronate) 70 mg 1 tablet weekly for 4 months.

b. Core stability and dynamic resistive exercises

All patients in group B were treated with core stability and dynamic resistive exercises for 60 minutes per session, which encompassed a 5-minute warm-up and a 5-minute cool-down in the form of stretching, twice weekly, for 4 months. All core stability exercises were executed for three sets of 15 seconds, with a 10-second rest between each set. Throughout these exercises, the intensity was systematically increased following the principle of gradual progression. Additionally, participants performed breathing exercises comprising three sets of 10 repetitions, with a 1-minute rest interval between sets. Throughout the study duration, women completed dynamic resistive exercises in 2 sets, gradually increasing repetitions to 8-12, with a 90-second rest interval between sets.

Core stability exercises included Forearm plank exercise (from kneeling position, elbows bent to 90 degrees, toes tucked under to press into the plank), side plank exercise (from side lying with bent knees, supporting the upper body on the elbow while lifting the hips upwards), weight transfer exercise (ask the woman to recline on her back with flexed knees, feet on the floor, hold a weight or pillow overhead with arms extended, in line with her ears, Keeping the head and shoulders on the floor, raise your arms and bring your knees up over your hips, place the weight between your knees, then lower your arms and legs to the floor without arching your back), squatting, prone opposite arm/leg raise exercise, supine bridge, single leg bridge, quadruped-arm/ leg raise, pelvic floor exercise, diaphragmatic breathing exercise.

Dynamic resistive exercises, including 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, 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. Performing biceps curls is 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 exercises enhance 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 in the two groups, an unpaired t-test was used for comparison. The use of analysis of covariance (ANCOVA) allowed for the comparison of baseline measures among the groups and the evaluation of post-treatment measures while controlling for initial differences. Within-group comparisons of initial and final assessments were analyzed using a paired t-test. Non-normally distributed data between the groups were compared through the Mann-Whitney U test, while within-group comparisons were conducted through the Wilcoxon Signed Ranks test. Data analysis was performed through the Statistical Package for Social Sciences (SPSS) software (version 19 for Windows). A significance level of $p \leq 0.05$ was considered statistically significant.

Results

Table 1 showed the General characteristics of the two studied groups as there was no statistically significant difference between the two groups with $p > 0.05$.

Tab. 1. Demographic data of participants in both groups

Demographic data	Group (A) $\bar{X} \pm SD$	Group (B) $\bar{X} \pm SD$	t-value	p-value
Age (years)	56.70 ± 3.00	55.70 ± 3.44	1.202	0.234
BMI (Kg/m2)	27.67 ± 1.31	27.35 ± 1.35	0.923	0.360

BMI- Body Mass Index, p- probability, SD- standard deviation, $\bar{X}$- mean.

Table 2, Figure 2 & 3 showed the T-score of lumbar spine and left femoral neck pre and post treatment of both groups, between groups, the mean difference is calculated by using Wilcoxon Signed Ranks test and Mann-Whitney U test to get the actual effect of different treatment modalities in the two studied groups. There was a statistically significant difference between the value of mean difference in T-score of lumbar spine and left femoral neck of both groups (A&B) with favor of group B (more increase in group B).

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

	Group (A) $\bar{X}$ ± SD	Group (B) $\bar{X}$ ± SD	Z# value	p-value
BMD (t-score of spine L1-4)				
Pre-treatment	-2.94 ± 0.57	-2.96 ± 0.55	-0.171	0.864
Post-treatment	-2.85 ± 0.56	-2.40 ± 0.69		
Mean difference	-0.09 ± 0.05	-0.56 ± 0.50	-5.588	0.001
% of improvement	3.06% ↑↑	18.92% ↑↑		
Z## value	-4.669	-4.639		
p-value	0.001*	0.001*		
BMD (t-score of left femoral neck)				
Pre-treatment	-2.20 ± 1.19	-2.56 ± 1.06	-0.845	0.398
Post-treatment	-2.10 ± 1.18	-2.12 ± 1.10		
Mean difference	-0.10 ± 0.07	-0.44 ± 0.50	-4.794	0.001
% of improvement	4.55% ↑↑	17.19% ↑↑		
Z## value	-4.520	-4.802		
P-value	0.001*	0.001*		

BMD- Bone mineral density, DEXA- Dual-energy x-ray absorptiometry, p- probability; SD- standard deviation, $\bar{X}$- mean, Z# value- Mann-Whitney U test, Z## value- Wilcoxon Signed Ranks test, *- significant with $p < 0.05$.

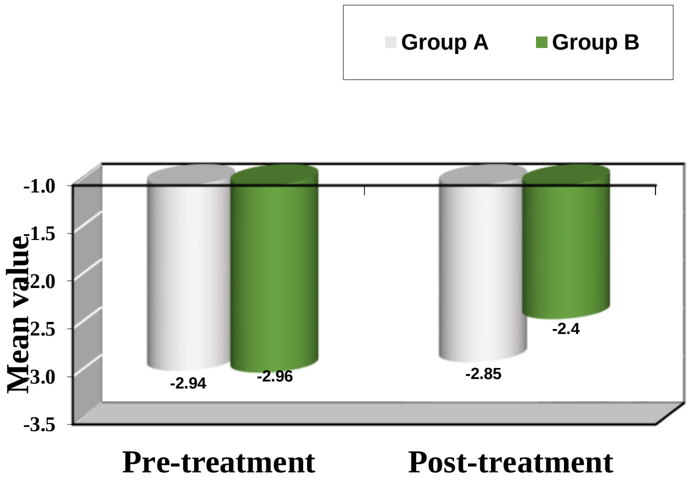

Fig. 2. Values of T-score of lumbar spine in the two studied groups measured pre- and post-treatment

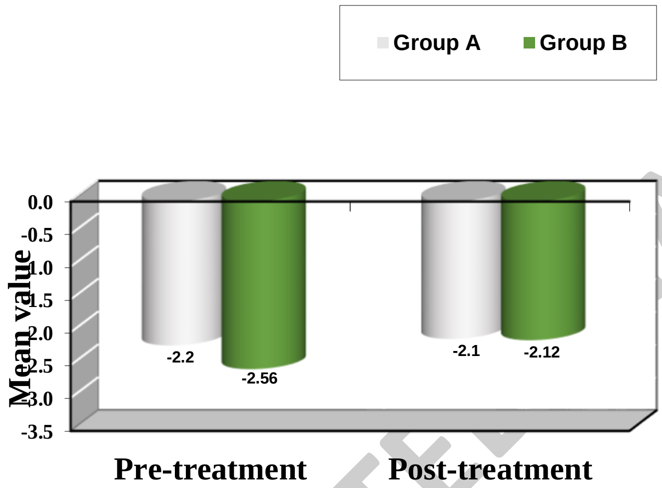

Fig. 3. Values of T-score of the left femoral neck in the two studied groups measured pre- and post-treatment

Table 3, and Figure 4 present the ODI value comparisons within and between the two study groups, assessed pre- and post-treatment. The post-treatment data indicate a statistically significant difference between groups A and B, with group B demonstrating a more significant ODI score decrease.

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

	Group (A) $\bar{X} \pm SD$	Group (B) $\bar{X} \pm SD$	F value	p-value
ODI score				

Pre-treatment	35.73 ± 2.96	36.27 ± 2.61	0.548	0.462
Post-treatment	18.40 ± 2.66	9.23 ± 3.24	243.686	0.001
Mean difference	17.33	27.04	-5.588	0.001
% of improvement	48.50% ↓↓	74.55% ↓↓		
t- value	43.733	52.467		
p-value	0.001*	0.001*		

F value- ANCOVA test, ODI score- Oswestry disability index, SD- standard deviation, t-value- paired t test, $\bar{X}$ = mean, *- significant with $p < 0.05$.

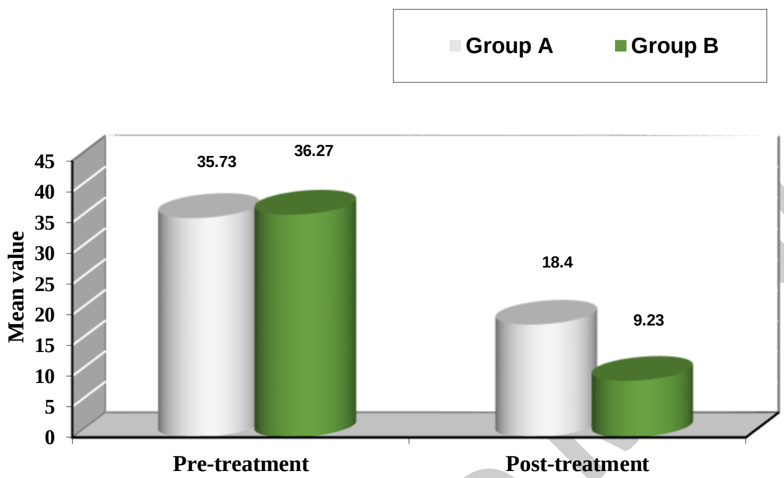

Fig. 4. Values of ODI in the two studied groups measured pre- and post-treatment

Discussion

This research aimed to examine how core stability exercises combined with dynamic resistance training impact BMD in women after menopause. The findings indicated significant improvements in BMD and reductions in ODI scores within both groups following the intervention. Group B demonstrated significantly greater increases in the 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 align with Riahi et al. [28], who demonstrated that a four-month core stability regimen significantly enhanced lower limb muscular strength (hip flexors and external rotators) in postmenopausal women ($p < 0.05$). Research indicates that well-designed exercise programs can maintain femoral neck BMD or promote annual bone mass increases of up to 1% in pre- and postmenopausal women [29]. Additionally, our findings align with Yung et al. [30] who observed a notable enhancement in proximal femur BMD among postmenopausal women aged 55 and older following 24-week core stability exercises, aligning with the results of the current study. 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. Additionally, our findings align with Elnaggar et al. [32], whose 3-month program, conducted thrice weekly, demonstrated increased lumbar and femoral neck bone strength. The dual focus of core stability exercises on strengthening (particularly in lumbar and hip areas) and balance training may contribute to these region-specific effects.

Nevertheless, as opposed to our discoveries, 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. In contrast, our research revealed a significant increase in femoral neck BMD following 4-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 in our study. 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. The 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 thrice-weekly weight training. Similarly, Holubiac et al. [36] found that a 6-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] noted the RE effectiveness in enhancing the BMD in body regions capable of supporting the entire body weight.

However, our results contraindicated with Lee et al. [39] who conducted a 6-week resistance exercise program for 11 postmenopausal women, focusing on lumbar and femoral

BMD. Although they observed an increase in lumbar bone density, the results were not statistically significant, which could be attributed to the study's short duration.

Regarding the QoL, our findings demonstrated a statistically significant ODI reduction favoring the study group. This improvement aligns with the general consensus from previous studies that physical activity positively influences QoL. Our findings align with Kanwal et al. [40], who studied core muscle stability exercises in postmenopausal women over 12 weeks (3 days/week). They found these exercises reduced pain and disability while improving strength and QoL. Additionally, Berin et al. [41] demonstrated that 15 weeks of thrice-weekly resistance training enhanced menopause-specific health-related QoL, further supporting the positive impact of resistance exercise on QoL. Within the realm of recommended strategies, the value of regular exercise in promoting bone strength among elderly women cannot be overstated, being identified as a primary non-pharmacological measure in preventing osteoporotic fractures in women after menopause [14,42].

Strengths and limitation

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. The absence of patient follow-up is a key constraint, necessitating additional studies to assess the exercises' long-term impacts. 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

This study demonstrates the advantageous effects of integrating core stability exercises alongside dynamic resistive exercises for osteoporotic women.

Acknowledgments

The research team acknowledges the crucial role played by all women who participated in this study. This work was completed without designated funding from governmental, commercial, or non-profit sources.

Funding

This research received no external funding.

Conflicts of interest

The authors declare no conflict of interest.

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