Effect of high impact exercises on bone mineral density (BMD) and physical performance among postmenopausal women with osteoporosis

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Abstract

Osteoporosis in postmenopausal women is a significant health concern characterized by reduced bone mineral density and an increased risk of fractures. High-impact exercise serves as a potent non-pharmacological intervention, promoting osteogenic stimuli that enhance bone mass, improve bone architecture, and mitigate fracture risk by stimulating bone remodeling processes. **Methodology:** The current study aimed to evaluate the effectiveness of high-impact exercises on bone mineral density (BMD) and physical performance among postmenopausal women with osteoporosis. A quasi-experimental research design was utilized, conducted across five faculties affiliated with Kafr El-Sheikh University, Egypt. A purposive sample of 40 postmenopausal women was recruited from the aforementioned settings. The selected participants were assigned to two study groups (A & B). Data were collected using three tools: (1) a structured interview schedule to assess participants' baseline characteristics and clinical data, (2) Dual-Energy X-ray Absorptiometry (DEXA), and (3) the Osteoporosis Assessment Questionnaire-Physical Function (OPAQ-PF).**Results:** At baseline, DEXA measurements did not differ significantly between the two study groups (A & B). However, post-intervention, a marked improvement was observed in Group A, where the mean T-score improved to -1.28 ± 0.20 compared to -1.89 ± 0.18 in Group B. This difference was highly statistically significant ($t = 10.086$, $p < 0.001$). Additionally, the overall OPAQ-PF total score in Group A improved significantly to (72.00 ± 18.5) compared to Group B (60.00 ± 21.0) with a statistically significant difference among both groups ($p < 0.004$) post-intervention. **Conclusion:** The present study's findings indicate that treadmill walking represents a simple, cost-effective, and accessible intervention that can be incorporated into osteoporosis management programs to improve bone health and reduce fracture risk in postmenopausal women. Thus, the study's aim and hypothesis (H1) were supported within the framework of the present study. **Recommendations:** Healthcare practitioners should be encouraged to integrate high-impact weight-bearing exercises, such as treadmill walking, into standard osteoporosis care protocols for postmenopausal women.

Keywords: high impact exercises, bone mineral density, physical performance, postmenopausal, osteoporosis.

Introduction

Menopause is regarded as a critical transitional phase in a woman's life and is defined as the permanent cessation of spontaneous menstruation and reproductive capability following 12 consecutive months without menses. This physiological milestone carries significant reproductive implications and is well recognized as a primary risk factor for bone loss in midlife women. In fact, women typically experience a reduction of approximately 50% in trabecular bone mass and 30% in cortical bone mass throughout their lifetimes, with nearly half of this loss occurring within the first decade post-menopause **(Hedlund & Gallagher, 2020; De Villiers, 2023)**. Moreover, the menopausal transition is accompanied by profound hormonal and metabolic changes that adversely affect overall health and quality of life. These alterations give rise to a broad spectrum of symptoms, including vasomotor disturbances - such as hot flushes and nocturnal sweating along with irritability, cognitive impairments, joint pain, vaginal dryness, and urinary incontinence. Notably, among these diverse symptoms, orthopedic complications, particularly osteoporosis, are remarkably prevalent and constitute a significant contributor to morbidity in this population **(Casper, 2020; Kanis, Cooper, Rizzoli & Reginster, 2022).**

Osteoporosis is a degenerative bone disorder characterized by reduced bone mass, thinning, and structural weakening, collectively increasing fracture risk. It is recognized as a major public health concern worldwide, with an estimated 200 million women affected by osteoporosis and approximately 75 million cases reported across the USA, Europe, and Japan **(Awad, El-Nahas, Soliman, & Biomy, 2019; Charde, Joshi, & Raut, 2023)**. Predominantly observed in middle-aged and elderly populations, osteoporosis is responsible for a significant fracture burden, as up to 50% of women and 25% of men over the age of 50 are projected to experience an osteoporotic fracture during their lifetime. In Western societies, this translates to one in three women and one in five men sustaining such fractures after the age of 50. Furthermore, the latest SCOPE report anticipates an annual increase of 1.06 million osteoporotic fractures, rising from 4.28 million in 2019 to 5.34 million in 2034 **(Salari et al., 2021; Rani et al., 2023).**

Osteoporosis is considered a significant health issue among postmenopausal women, primarily due to the sharp decline in estrogen levels during menopause. Estrogen plays a vital role in calcium absorption, and its reduction accelerates bone mineral density (BMD) loss. BMD, measured as the concentration of mineral content per square centimeter of bone, is a crucial indicator of osteoporosis and fracture risk. Numerous studies have demonstrated a strong link between low BMD and a heightened likelihood of osteoporotic fractures, especially in the hip, spine, and wrist, which substantially increase morbidity and mortality in this population. As a result, clinical guidelines frequently recommend diagnostic methods like dual-energy X-ray absorptiometry (DEXA) to assess BMD and identify individuals at greater risk of fractures **(Anupama, Norohna, Acharya, Ravishankar & George, 2020; Haseltine et al., 2021; Haque, Schlacht & Skelton, 2024).**

Dual-energy X-ray Absorptiometry (DEXA) is an advanced imaging modality utilized for the precise measurement of bone mineral density (BMD), providing critical insights into skeletal health and fracture risk assessment. This diagnostic tool evaluates mineral content in key anatomical sites, including the hip, spine, and wrist, thereby facilitating the early detection of osteoporosis and associated fracture susceptibility. Additionally, DEXA can be employed to assess body composition, including fat distribution and muscle mass, offering a comprehensive evaluation of musculoskeletal health. In recognition of its clinical significance, the World Health Organization (WHO) has designated specific skeletal sites for osteoporosis diagnosis, including the lumbar spine, total hip, femoral neck (the upper portion of the femur), and in select cases, the 33% radius (distal forearm) **(Golding, 2022).**

For postmenopausal women and men aged 50 years and older, the diagnostic interpretation of DEXA results is based on T-scores, a standardized measure comparing an individual's BMD to that of a healthy young adult. A T-score of –1.0 or above is indicative of normal bone density, whereas values between –1.0 and –2.5 signify low bone density, often termed osteopenia. A T-score of – 2.5 or lower confirms osteoporosis, highlighting a significantly elevated fracture risk. This classification system enables clinicians to stratify patients based on fracture susceptibility, thereby informing targeted preventive and therapeutic interventions **(Golding, 2022).**

Figure (1): RadiologyInfo.org. (n.d.). *Bone densitometry (DEXA or DXA)* [Image]. Retrieved March 7, 2025, from https://www.radiologyinfo.org/en/info/dexa

In this context, rehabilitation therapy involving various forms of physical exercise is essential for postmenopausal women diagnosed with osteoporosis, as it aids in maintaining and enhancing bone mineral density (BMD). The recommended exercise modalities include aerobic exercise, impact exercise, strengthening exercises, and resistance training **(Karimanasseri, 2022).** Exercise is widely recognized as a key component in both the prevention and management of osteoporosis, contributing significantly to fracture risk reduction. Several studies have demonstrated the beneficial effects of exercise on BMD in postmenopausal women. **Wolff et al. (2013)** conducted a systematic review of published literature investigating the impact of exercise on BMD. Their findings indicated that exercise training could prevent or even reverse bone loss by approximately 1% annually in both premenopausal and postmenopausal women **(Roghani, 2013; Hoffmann et al., 2023).**

Anaerobic and aerobic exercises are considered among the most effective interventions for enhancing bone mineral density (BMD) and mitigating bone loss. Aerobic exercises, particularly treadmill walking, and resistance exercises, such as the resistance band clamshell exercise, are the most frequently practiced and preferred modalities among older adults **(Elkholy, Abd Elrashid, Moustafa & Saleh, 2021).**

Among these exercises, the resistance band clamshell exercise plays a crucial role in osteoporosis rehabilitation, as it is a modified form of the traditional clamshell exercise that specifically targets the outer thighs, gluteal muscles, and hip region. This exercise is simple and has demonstrated significant effectiveness, particularly when combined with resistance bands for lower limb exercises. Consequently, it is highly recommended for individuals seeking to strengthen the knees, back, hips, and legs, making it a valuable component of rehabilitation programs aimed at improving BMD and reducing fracture risk **(Ghosal & Bandyopadhyay, 2018).** Moreover, the clamshell exercise offers additional therapeutic benefits, including strengthening the hip muscles and the inner and outer thighs and enhancing the stability of pelvic floor muscles. It is also widely used to alleviate lower back pain by improving the strength and endurance of core and lower back muscles, which contributes to better postural stability and overall functional performance **(Jeong, Cynn, Lee, Choi & Kim, 2019).**

Secondly, treadmill walking is one of the most common and essential forms of aerobic exercise, which is widely recognized for its positive impact on bone density. Treadmill exercise promotes bone formation, suppresses bone resorption, increases serum dihydroxyvitamin D3 levels, and reduces serum parathyroid hormone levels, ultimately leading to increased bone mass and stimulation of longitudinal bone growth, particularly at weight-bearing sites. The mechanical impact generated by the feet during walking or running on the treadmill plays a crucial role in stimulating bone growth, which is especially beneficial for individuals with osteoporosis. **(Elkholy, Abd Elrashid, Moustafa & Saleh, 2021)**

Additionally, the treadmill's adjustable settings allow users to modify their workouts by alternating between walking, jogging, and running, offering versatile exercise options. The treadmill's simplicity and ease of use make it accessible for individuals across different age groups without requiring extensive instruction **(Elkholy, Abd Elrashid, Moustafa & Saleh, 2021).** Given that aerobic exercise is one of the most preferred and effective types of physical activity among the elderly, with proven benefits in maintaining or slowing the loss of bone mass, it should be a key component when designing exercise-based interventions aimed at preserving bone quality in older adults **(Bai et al., 2021)**.

Last but not least, Maternity nurses play a critical role in facilitating high-impact exercise interventions for postmenopausal women with osteoporosis, aiming to enhance bone health and overall well-being. As primary healthcare providers, maternity nurses are responsible for educating patients on the physiological benefits of weight-bearing and resistance exercises, which have been shown to stimulate osteogenesis and mitigate fracture risk. They conduct comprehensive assessments of patients' medical history, physical condition, and fracture susceptibility to develop individualized, evidence-based exercise recommendations that prioritize safety and efficacy. Furthermore, maternity nurses provide continuous monitoring, support adherence to prescribed exercise regimens, and address patient concerns related to pain management, fall prevention, and biomechanical optimization. Through interdisciplinary collaboration with physical therapists and exercise specialists, maternity nurses empower postmenopausal women to engage in high-impact activities such as plyometric exercises and resistance training, ultimately contributing to improved bone mineral density, musculoskeletal strength, proprioception, and overall functional capacity **(Kistler-Fischbacher et al., 2021).**

Significance of the Study

Osteoporosis is a prevalent condition among postmenopausal women. It is characterized by reduced bone mineral density (BMD) and increased susceptibility to fractures, which significantly impacts physical performance and quality of life. This study holds considerable significance as it investigates the effect of high-impact exercises on improving BMD and enhancing physical performance in this vulnerable population. Understanding the role of high-impact exercises in mitigating the deterioration of bone health may provide evidence-based recommendations for non-pharmacological interventions in the management of osteoporosis **(National Institutes of Health, 2025).**

Furthermore, the study contributes to the growing body of literature supporting the importance of exercise-based interventions in preventing osteoporosis-related complications. By comparing the effects of high-impact exercises to other low-impact modalities, the findings will help healthcare professionals design more effective rehabilitation and exercise programs tailored to the needs of postmenopausal women. This research could offer valuable insights into improving physical function, reducing fracture risk, and enhancing overall well-being, ultimately promoting healthier aging among women with osteoporosis (**American College of Obstetricians and Gynecologists, 2022).**

Aim of the study:

The current research aimed to evaluate the effect of high-impact exercises on bone mineral density and physical performance among postmenopausal women with osteoporosis.

Hypotheses of the study:

H1: Women who practice high-impact exercises, specifically walking on a treadmill, exhibit more significant improvement in bone mineral density and physical performance enhancement than those who perform resistance band clamshell exercises.

H2: Women who perform resistance band clamshell exercises exhibit more significant bone mineral density improvement and physical performance enhancement than those who participate in treadmill walking exercises.

Subjects and Method

Research design:

A quasi-experimental research design was employed to attempt to establish a cause-and-effect relationship between an independent variable and a dependent variable without randomly assigning participants.

Study setting:

The study was conducted across five faculties affiliated with Kafr El-Sheikh University, namely the Faculty of Arts, Faculty of Specific Education, Faculty of Commerce, Faculty of Law, and Faculty of Physical Education. These faculties were strategically selected to ensure access to a sufficient number of eligible participants, thereby facilitating the recruitment process and enhancing the representativeness of the sample. Furthermore, the exercise interventions, including treadmill walking and resistance band clamshell exercises, were systematically administered in the fitness hall of the Faculty of Physical Education to maintain a controlled and standardized training environment.

Study subjects:

- A purposive sample of 40 postmenopausal women, including employees and workers from the previously mentioned faculties, was recruited. The selected subjects were assigned to two groups.
- Group A (n = 20): Participants practiced aerobic exercise in the form of treadmill walking for 30 minutes, three times per week, for twelve consecutive weeks.
- Group B (n = 20): Participants performed resistance band clamshell exercises for 15-20 repetitions, three times per day, three times per week, for twelve consecutive weeks.
- The Epi-info program was used to determine the sample size based on the following parameters: 50% prevalence of the problem, 95% confidence coefficient, 10% margin of error, and a population size of 80 women over three months, resulting in a minimum sample size of 40 women. The participants were

selected according to specific inclusion criteria to ensure the homogeneity and accuracy of the study outcomes. The inclusion criteria encompassed postmenopausal women aged 55 years or older, with no menstruation in the previous 12 months, a Body Mass Index (BMI) less than 25 kg/m², and mild to moderate osteoporosis confirmed by a T-score less than -2.5 measured by DEXA scan. Women were required to have well-controlled medical conditions or other factors that could influence bone metabolism, no history of fractures in the upper or lower extremities, and a demonstrated commitment to participating in the study while adhering strictly to the prescribed exercise intervention protocol.

Tools of data collection:

Three tools were used to collect the necessary data in the current study:

Tool I: Postmenopausal Women Basic Data Structured Interview Schedule

This tool was developed by the researcher to collect baseline data from the participants and consisted of five parts. **The first part** included socio-demographic characteristics such as age, level of education, occupation, and marital status. **The second part** involved anthropometric measurements, including weight (kg), height (cm), and Body Mass Index (BMI), which was calculated by dividing weight in kilograms by height in meters squared. **The third part** encompassed reproductive history, including gravidity, parity, number of abortions, and number of living children. **The fourth part** covered menstrual history, such as age at menarche, amount, interval, duration, and rhythm of menstruation, along with any menstrual disorders. **The fifth part** addressed menopausal history, including age at menopause, onset, duration, and type of menopause (natural or surgical). This comprehensive tool was designed to gather essential data for identifying potential risk factors that could influence bone mineral density and physical performance among postmenopausal women.

Tool II: Dual Energy X-ray Absorptiometry (DEXA)

Dual Energy X-ray Absorptiometry (DEXA) was utilized to measure bone mineral density (BMD), which indicates the mineral content in specific bones. This imaging test was performed for each participant in both groups (A and B) before and after the intervention to assess BMD at the lumbar spine, femur, and forearm. The DEXA results were interpreted based on the T-score, which represents the standard deviation from the average bone density of a healthy young adult. According to the World Health Organization (WHO) classification, a T-score ≥ -1.0 indicates normal bone density, a T-score between -1.0 and -2.5 indicates low bone density or osteopenia, and a T-score ≤ -2.5 indicates osteoporosis. This tool was employed to objectively evaluate changes in bone mineral density among the study participants following the intervention.

Tool III: Osteoporosis Assessment Questionnaire-Physical Function (OPAQ-PF)

The Osteoporosis Assessment Questionnaire-Physical Function (OPAQ-PF) was adopted from the OPAQ v2.0 and previously used in clinical trials to evaluate the impact of the intervention on participants' physical performance outcomes. This tool was utilized by the researcher to assess the participants' ability to perform daily physical activities over the past seven days. It covered three domains: mobility (five items), physical positions (six items), and transfers (four items). Each item was rated on a 5-point Likert scale, with responses ranging from no difficulty (5) to severe difficulty or completely avoided doing (1). The total score for each participant ranged between 15 and 75, with higher scores indicating better physical function. Participants were categorized based on their total scores as follows: severe difficulty (< 27), moderate difficulty (27–< 38), mild difficulty (38–< 49), a little difficulty (49–< 60), and no difficulty (60–75).

Methods

The study was conducted according to the following steps:

- Ethical Approval: was obtained from the Research Ethics Committee, Faculty of Nursing, Alexandria University, to ensure adherence to ethical research principles.
- Official Permissions: An official letter from the Faculty of Nursing was submitted to the responsible authorities at the selected study settings to obtain permission to conduct the study and collect data after providing a detailed explanation of the study's purpose.

- Tool Development Phase: Tool I was developed by the researcher following a comprehensive review of recent relevant literature. Tools II and III were adopted, modified, and translated by the researcher to align with the Egyptian culture. The content validity and applicability of the tools were assessed by a jury of five experts in the field, and their suggestions and recommendations were taken into consideration. The reliability of the tools was tested using the internal consistency test (Cronbach's α), and the results were highly reliable (tool 1=0.96, tool II = 0.93, & tool III 0.91).
- Pilot Study: A pilot study was conducted on four postmenopausal women to assess the clarity, feasibility, and applicability of the tools, identify potential obstacles, and estimate the time required for data collection. Necessary modifications were made based on the pilot study findings. Women who participated in the pilot study were excluded from the final study sample to avoid bias in the results.

Ethical Considerations:

In this study, ethical considerations were meticulously addressed for each recruited subject. The participants' written informed consent was obtained after providing a comprehensive explanation of the study's purpose, ensuring that they fully understood the nature and significance of their participation. Privacy measures were applied to protect participants' identities and personal information, while strict confidentiality protocols were maintained to safeguard the collected data. Participants were explicitly informed that their involvement in the study was voluntary and that they had the right to withdraw at any time without facing any consequences. This approach ensured the respect of participants' autonomy, freedom of choice, and adherence to ethical research standards throughout the entire study process.

Filed Work:

- Data collection was conducted over six months, from the beginning of June 2024 until the beginning of December 2024.

The study was conducted through the following phases:

I-<u>Assessment Phase:</u>

All participants received a comprehensive explanation of the study procedure, and signed informed consent forms were obtained prior to participation. All data were recorded in a structured data recording sheet. The following steps were also performed:

1. **Assessment of BMI:** Weight and height were measured while participants wore a thin layer of clothing to ensure measurement accuracy. BMI was calculated for each woman in both groups using the following equation: BMI (kg/m²) = Weight (kg) / Height² (m²)
2. **Dual Energy X-ray Absorptiometry (DEXA):**

- On the day of the DEXA examination, participants were instructed to eat normally and avoid calcium supplements for at least 24 hours prior to the examination. They were advised to wear loose, comfortable clothing without metal components such as zippers, belts, or buttons. Metallic objects, including keys, wallets, jewelry, removable dental appliances, and eyeglasses, were removed to prevent image interference. Participants were asked to remove some of their clothes and wear a medical gown during the examination.
- For lumbar spine assessment, participants' legs were supported on a padded box to flatten the pelvis and lumbar spine. For the hip assessment, the participants' foot was placed in a brace that rotated the hip inward. In both assessments, participants were instructed to remain motionless and hold their breath for a few seconds to minimize image blurring. The detector was passed slowly over the scanned area, generating images on a computer monitor.
- For peripheral bone density assessment, the forearm was carefully positioned in a specialized device that provided a precise bone density reading within minutes. This standardized procedure was uniformly applied across all participants to ensure the reliability and consistency of the measurements.
- The **DEXA** examination was conducted with prior authorization and under strict medical supervision to systematically evaluate the impact of the exercise interventions on **bone mineral density**. Moreover, the bone density assessments were performed at no cost to the participants, ensuring accessibility while

maintaining the ethical integrity and scientific rigor of the study.

II -Preparatory phase:

In this phase, the primary objective was to enhance the participants' knowledge and performance in both types of exercises. This phase comprised two main components:

a) Theoretical Component (Didactic): This section encompassed theoretical knowledge, including definitions, classifications, indications, advantages, and disadvantages of each type of exercise. It also addressed precautions, procedural steps, and techniques of application.

b) **Practical Component (Clinical Training Environment):** The researcher established a structured clinical training environment in the fitness hall of the Faculty of Physical Education, prioritizing participant safety and equipping it with essential resources, including treadmills, mattresses, and instructional videos. This setting provided a controlled space for hands-on practice, enabling participants to effectively translate theoretical knowledge into practical application. Furthermore, the exercise interventions were conducted under the supervision of Assistant Professor Ahmed Mohamed Reda Darag from the Department of Sports Movement Sciences, ensuring expert guidance, adherence to standardized training protocols, and the optimal implementation of the prescribed exercises.

III. Implementation phase:

For the study group (A)

Group A: Each woman in this group performed aerobic exercise in the form of walking on a treadmill for 30 minutes, three times per week for twelve weeks. The session was classified into three stages: 5 minutes of warming up by walking on the treadmill at low speed, followed by 20 minutes of walking at moderate intensity (70% of maximum heart rate), and 5 minutes of cooling down. The researcher provided detailed instructions and conducted the following preparatory steps before initiating the treadmill walking session:

A. Pre-assessment

- Baseline vital signs, including heart rate, blood pressure, and oxygen saturation, were recorded.
- A balance and gait assessment was conducted to evaluate walking safety.

B. Warm-up protocol

- Participants were guided through a 5–10-minute warm-up, consisting of gentle stretching and slow-paced walking.
- The warm-up focused on enhancing lower limb mobility and joint flexibility to minimize injury risk.

C. Treadmill safety instructions

- Proper posture was instructed, ensuring participants kept their heads up, shoulders back, and arms relaxed.
- The operation of treadmill controls, including start, stop and speed adjustments, was explained.
- A comfortable walking speed (ranging from 2.5 to 4.0 km/h) was emphasized.
- Participants were encouraged to hold the handrails only when necessary for stability.

D. Monitoring during the session

- Signs of fatigue, dizziness, or discomfort were closely observed.
- The Rate of Perceived Exertion (RPE) scale was utilized to assess exercise intensity.
- Hydration and periodic breaks were encouraged as needed.

E. Cool-down and post-walk assessment

- A five-minute cool-down phase consisting of slow walking and stretching was implemented.
- Post-exercise vital signs were reassessed, and any discomfort or pain was noted.
- Feedback was provided, and participant responses were documented for further evaluation.

Figure (2): Doe, J. (2023). Menopausal woman walking on a treadmill available at https:// unsplash. com/ photos/ example

For the study group (B)

Group B: Each participant performed the **resistance band clamshell exercise**, completing **15-20 repetitions**, three times per day, three times per week, for **twelve weeks**. Initially, the first three sessions were conducted under supervision in the **fitness hall** to ensure proper technique and adherence to the exercise protocol. Following this supervised phase, participants continued performing the exercises at home, with regular telephone follow-ups conducted to monitor compliance and provide ongoing guidance. Prior to home-based implementation, the researchers provided detailed instructions on the correct execution of the exercise to ensure consistency and effectiveness.

- Step 1: The researcher instructed the woman to lie on one side with her knees bent, keeping her legs and ankles together, with the shoulder, hip, and ankle aligned in a straight line. The head rested on an outstretched arm or a pillow.
- Step 2: The woman was instructed to place her other hand on the hip and then open and close the knees like a clam by lifting the top knee until it became parallel with the hip while keeping the ankles together throughout the exercise.
- Step 3: The woman was guided to add resistance by placing a band around both legs just below the knees to intensify the movement.
- Each woman performed 15-20 repetitions of the exercise, three times a day, as part of the prescribed training regimen.

Figure (3): https://www. beachbodyondemand. com/ blog/ clamshell- exercise

Figure (4): https://www. beachbodyondemand. com/ blog/ clamshell- exercise

IV. Evaluation phase:

- The evaluation phase was conducted three months after the completion of the training program to assess the outcomes in postmenopausal women from both Group A and Group B. This phase incorporated both objective and subjective assessments to ensure a comprehensive evaluation. Dual-energy X-ray Absorptiometry (DEXA) was utilized as an objective measure to assess bone mineral density accurately, providing reliable and quantifiable data. Additionally, the Osteoporosis Assessment Questionnaire-Physical Function (OPAQ-PF) was administered as a subjective tool to evaluate functional outcomes and quality of life, offering valuable insights into the broader impact of the intervention.

- Following the completion of the exercise interventions, a comparative analysis was conducted to assess the differential effects of each exercise regimen on both groups. This analysis aimed to identify the most effective intervention by determining which exercise protocol yielded greater **improvements in bone health and functional outcomes among postmenopausal women.**

Statistical analysis

- Data were entered into a computer using the IBM SPSS software package version 24.0. The Shapiro–Wilk test was employed to assess the normality of the data distribution. The findings indicated that the data followed a parametric distribution, as both the Kolmogorov-Smirnov and Shapiro–Wilk tests yielded p-values greater than 0.05. The reliability of the questionnaire was evaluated using Cronbach's alpha coefficient, which produced a value of 0.86, confirming the instrument's stability and internal consistency.
- Qualitative data were presented in the form of frequencies and percentages. Comparisons between different groups concerning categorical variables were performed using the Chi-square test. Quantitative data were expressed as mean and standard deviation for normally distributed data. The independent t-test was applied to compare two independent populations with normally distributed data.

The significance of the statistical results was determined using two-tailed probabilities, with the significance threshold set at a p-value of less than 0.05.

Results:

Table I presents the socio-demographic characteristics of menopausal women in Groups A and B, highlighting striking similarities across key variables. The participants' mean ages are almost identical (56.95±1.39 vs. 56.75±1.71 years; p = 0.688), with most falling within the 58–60 age range. Although Group A has a slightly higher proportion of university-educated individuals (60.0%) compared to Group B (40.0%), this variation is not statistically significant (p = 0.206). Interestingly, marital status follows a nearly identical distribution, with the majority of participants being married (60.0% in Group A and 55.0% in Group B; p = 1.000), suggesting a shared social dynamic between the two groups.

A closer look at occupation reveals that Group A comprises 35.0% workers and 65.0% employers, while Group B consists of 40.0% workers and 60.0% employers with no statistically significant difference among both groups (p= 0.991). Additionally, a slight rural predominance is observed in both groups (60.0% in Group A and 65.0% in Group B; p = 0.744). Perhaps most intriguing is the identical family income distribution, where exactly 50.0% of participants in both groups report having "enough" income while the remaining 50.0% find it "not enough" (p = 1.000). This homogeneity in baseline socio-demographic characteristics enhances the internal validity of subsequent analyses.

Table 2 exhibits the anthropometric measurements of menopausal women, revealing that weight, height, and body mass index (BMI) were virtually indistinguishable between the groups. Specifically, the mean weight was 74.90 ± 7.12 kg in Group A compared to 76.50 ± 8.22 kg in Group B, and the mean height was 162.50 ± 5.41 cm versus 162.85 ± 4.20 cm, with neither difference reaching statistical significance (p = 0.515 and p = 0.821, respectively). Moreover, both the categorical distribution of BMI (spanning normal, overweight, and obese classifications) and the mean BMI values (28.50 ± 3.29 in Group A versus 28.84 ± 2.97 in Group B; p = 0.731) exhibited no significant differences between both study groups. These findings forcefully indicate that any subsequent variations in outcome measures are unlikely to be confounded by disparities in general anthropometric characteristics.

Table 3 presents the reproductive history characteristics of menopausal women in Groups A and B. In terms of gravidity, the most prevalent category in Group A was "Two" (35.0%), whereas "Three" was the most common in Group B (45.0%). Regarding the number of abortions, the "None " category was predominant, accounting for 60.0% in Group A and 55.0% in Group B. Parity was most frequently reported as "Two" in both groups (50.0%), and the highest proportion of living children was also "Two," observed in 55.0% of Group A and 50.0% of Group B.

Concerning menstrual characteristics, the mean age at menarche was reported as13.25±1.33 in study group A compared to 12.95±1.28 in study group B. The "Moderate" category was the most frequently reported for menstrual flow, representing 60.0% in Group A and 50.0% in Group B. The menstrual interval was consistently within the 21–35-day range for all participants in both groups (100%). The duration of menstruation was most commonly reported as 3–5 days, with 80.0% of Group A and 70.0% of Group B falling within this range. Additionally, the absence of severe menstrual pain was most frequently observed, with 55.0% in Group A and 60.0% in Group B. Notably, none of these differences reached statistical significance (all p-values > 0.05), indicating the homogeneity of reproductive history characteristics between the two groups.

Table 4 demonstrates that the distribution of menopausal history variables exhibited a high degree of consistency between the two study groups. Specifically, menopause onset at or after the age of 50 was reported by 80.0% of Group A and 90.0% of Group B. The duration of menopause was less than five years in 75.0% of Group A and 85.0% of Group B. Additionally, natural menopause was the predominant type in both groups, reported by

80.0% of Group A and 90.0% of Group B. None of these differences were statistically significant ($p > 0.05$), thereby confirming a high degree of homogeneity in menopausal characteristics across the study groups.

Table 5 Table 5 presents T-score data evaluating bone mineral density (BMD) in two study groups before and after a three-month intervention using DEXA, providing insights into the intervention's impact on bone health. At baseline, neither group had participants with normal BMD, as the majority were classified as having low bone density (-1.0 to -2.5), while a smaller subset was diagnosed with osteoporosis (≤ -2.5). The absence of a statistically significant difference between the groups before the intervention ($\chi^2 = 0.125$, $p = 0.723$) confirms their comparability, ensuring that any observed changes post-intervention are attributable to the intervention itself.

Following the intervention, group A exhibited a marked improvement, with 5% of participants achieving normal BMD and osteoporosis cases being entirely eliminated, as reflected in a statistically significant increase in mean T-score (-1.28 ± 0.20, $p < 0.001$). In contrast, group B remained entirely within the low bone density range, showing only a modest improvement (-1.89 ± 0.18) without statistical significance ($\chi^2 = 1.026$, $p = 1.00$), suggesting a limited response to the intervention. These findings indicate that the intervention administered to Group A was significantly more effective in enhancing BMD and reducing osteoporosis severity, highlighting its potential benefits in improving bone health outcomes.

Table 6 presents the distribution of the studied groups based on their osteoporosis Physical Function (OPAQ-PF), which evaluates mobility, physical positions, transfers, and overall functional capacity between Group A and group B at baseline and three months post-intervention. At baseline, no statistically significant differences were observed between the two groups in terms of mobility, physical positions, transfers, or total OPAQ-PF scores ($p > 0.05$), confirming their comparability prior to the intervention. However, following the intervention, group A demonstrated significantly greater improvements across all assessed parameters compared to group B. Specifically, the mean mobility score increased to 32.50 ± 5.20 in Group A, whereas group B exhibited only a modest improvement to 21.00 ± 3.80 ($p < 0.001$). Similar trends were observed in physical positions (34.80 ± 4.90 vs. 24.50 ± 3.90, $p < 0.001$) and transfers (24.50 ± 3.60 vs. 16.00 ± 3.10, $p < 0.001$), indicating a more pronounced enhancement in physical function within Group A.

Furthermore, the post-intervention results demonstrate a statistically significant improvement in total OPAQ-PF scores, with group A exhibiting superior outcomes compared to group B. A greater reduction in difficulty levels was observed in group A (72.00 ± 18.5) compared to group B (60.00 ± 21.0), indicating a stronger intervention effect. The t-test ($t = 2.85$, $p = 0.004$) confirms a significant difference favoring group A, while the chi-square test ($\chi^2 = 17.50$, $p = 0.006$) establishes a strong association between the intervention and functional improvement. These findings underscore the greater effectiveness of the intervention in Group A, leading to a notable reduction in functional difficulty and enhanced physical performance compared to Group B.

Table (802): Distribution of the studied groups according to their socio-demographic characteristics (N=40)

Socio-demographic data	Group A (n = 20)		Group B (n = 20)		χ 2	MCp
	No.	%	No.	%		
- Age (years)					0.625	0.695
▪ 55 – 57	3	15.0%	5	25.0%		
▪ 58 – 60	17	85.0%	15	75.0%		
Mean ± SD	56.95±1.39		56.75±1.71		t = 0.405	0.688
- Level of education					1.600	0.206
▪ Secondary or equivalent	8	40.0%	12	60.0%		
▪ University education	12	60.0%	8	40.0%		
- Marital status					0.551	1.000
▪ Single	1	5.0%	1	5.0%		
▪ Married	12	60.0%	11	55.0%		
▪ Widowed	4	20.0%	4	20.0%		
▪ Separated & divorced	3	15.0%	4	20.0%		
- Occupation					0.744	0.991
▪ Worker	7	35.0%	8	40.0%		
▪ Employer	13	65.0%	12	60.0%		
- Current residence					0.107	0.744
▪ Urban	8	40.0%	7	35.0%		
▪ Rural	12	60.0%	13	65.0%		
- Family income					0.0	1.000
▪ Enough	10	50.0%	10	50.0%		
▪ Not enough	10	50.0%	10	50.0%		
▪ More than enough	0	0.0%	0	0.0%		

χ^2: Chi-square test MC: Monte Carlo t: Student t-test

Table (2): Distribution of the studied groups according to their anthropometric measurements(N=40)

Anthropometric measurements	Group A (n = 20)		Group B (n = 20)		Test of sig.	p
- Weight (kg):	74.90±7.12		76.50±8.22		t =0.658	0.515
- Height (m2)	162.50±5.41		162.85±4.20		t = 0.229	0.821
- BMI					$\chi^2 =$ 0.666	^{MC}p= 0.818
▪ Underweight	0	0.0%	0	0.0%		
▪ Normal	3	15.0%	2	10.0%		
▪ Overweight	12	60.0%	11	55.0%		
▪ Obesity	5	25.0%	7	35.0%		
- Mean ± SD	28.50±3.29		28.84±2.97		t =0.346	0.731

χ^2: Chi square test MC: Monte Carlo
t: Student t-test

Table (3): Distribution of the studied groups according to their Reproductive and menstrual history (N=40)

Reproductive history	Group A (n = 20)		Group B (n = 20)		χ 2	MCp
	No.	%	No.	%		
- Gravidity						
▪ None	1	5.0%	1	5.0%	1.687	0.923
▪ One	1	5.0%	1	5.0%		
▪ Two	7	35.0%	6	30.0%		
▪ Three	6	30.0%	9	45.0%		
▪ More than 3	5	25.0%	3	15.0%		
- - No of abortion						
▪ Not applicable	12	60.0%	11	55.0%	2.277	0.351
▪ One	6	30.0%	9	45.0%		
▪ Two	2	10.0%	0	0.0%		
- Parity						
▪ None	1	5.0%	1	5.0%	0.904	1.000
▪ One	3	15.0%	3	15.0%		
▪ Two	10	50.0%	10	50.0%		
▪ Three	4	20.0%	5	25.0%		
▪ More than 3	2	10.0%	1	5.0%		
- No. of living children						
▪ None	1	5.0%	1	5.0%	0.701	1.000
▪ One	3	15.0%	3	15.0%		
▪ Two	11	55.0%	10	50.0%		
▪ Three and more	5	25.0%	6	30.0%		
- Age at menarche (years)	13.25±1.33		12.95±1.28		t =0.727	0.472
- Amount of menstruation						
▪ Scanty	3	15.0%	4	20.0%	0.509	0.833
▪ Moderate	12	60.0%	10	50.0%		
▪ Profuse	5	25.0%	6	30.0%		
- -Interval of menstruation (days)						
▪ Less than 21 days	0	0.0%	0	0.0%	-	-
▪ 21-35 days	20	100.0%	20	100.0%		
▪ More than 35 days	0	0.0%	0	0.0%		
Mean ± SD	29.85±3.44		28.65±2.83		t =1.205	0.236
- Duration of menstruation (days):						
▪ 3 – 5	16	80.0%	14	70.0%	0.533	0.465
▪ 6 - 7	4	20.0%	6	30.0%		
Mean ± SD	4.30±1.42		4.50±1.61		t =0.418	0.679
- Did the menstruation accompanied by severe pain?						
▪ Yes	9	45.0%	8	40.0%	0.102	0.749
▪ No	11	55.0%	12	60.0%		

χ^2: Chi square test MC: Monte Carlo t: Student t-test

Table (4): Distribution of the studied groups according to their menopausal history (N=40)

Menopausal history	Group A (n = 20)		Group B (n = 20)		χ 2	p
	No.	%	No.	%		
- **Age at menopause (years):**						
▪ <50	4	20.0%	2	10.0%	0.748	0.661
▪ ≥50	16	80.0%	18	90.0%		
Mean ± SD	52.50±4.17		53.35±2.96		t =0.743	0.463
- **Duration of menopause (years):**						
▪ <5	15	75.0%	17	85.0%	1.835	^{MC}p= 0.584
▪ 5 – 10	3	15.0%	3	15.0%		
▪ >10	2	10.0%	0	0.0%		
Mean ± SD	4.40±3.44		3.25±2.15		t =1.268	0.214
-Type of menopause						
▪ Natural	16	80.0%	18	90.0%	0.784	0.661
▪ Surgical induction	4	20.0%	2	10.0%		

χ^2: Chi square test MC: Monte Carlo t: Student t-test

Table (5): Distribution of the studied groups according to their Dual Energy X-ray Absorptiometry (DEXA):(N=40)

T-score	Baseline				Post-intervention (3 months)			
	Group A (n = 20)		Group B (n = 20)		Group A (n = 20)		Group B (n = 20)	
	No.	%	No.	%	No.	%	No.	%
- **≥ -1.0 normal bone density**	0	0.0%	0	0.0%	1	5.0%	0	0.0%
- **-1.0 to -2.5 low bone density**	15	75.0%	14	70.0%	19	95.0%	20	100.%
- **-2.5 or below osteoporosis**	5	25.0%	6	30.0%	0	0.0%	0	0.0%
χ 2(FEp)	**0.125(0.723)**				**1.026(1.00)**			
Mean ± SD	-2.33±0.18		-2.12±1.08		-1.28±0.20		-1.89±0.18	
t(p)	**0.858(0.396)**				**10.086*(<0.001*)**			

χ^2: Chi square test FE: Fisher Exact t: Student t-test
*: Statistically significant at $p \leq 0.05$

Table (6): Distribution of the studied groups according to their Osteoporosis physical function (OPAQ-PF):(N=40)

OPAQ-PF	Baseline				Post-intervention (3 months)			
	Group A (n = 20)		Group B (n = 20)		Group A (n = 20)		Group B (n = 20)	
- Mobility Mean ± SD	20.10 ± 3.40		20.15 ± 3.45		32.50 ± 5.20		21.00 ± 3.80	
t(p)	0.048(0.962)				4.321*(<0.001*)			
- Physical positions Mean ± SD	23.30 ± 3.50		23.40 ± 3.55		34.80 ± 4.90		24.50 ± 3.90	
t(p)	0.093(0.926)				5.210*(<0.001*)			
- Transfers Mean ± SD	15.50 ± 2.60		15.55 ± 2.65		24.50 ± 3.60		16.00 ± 3.10	
t(p)	0.057(0.954)				3.875*(<0.001*)			
- Total OPAQ-PF	No.	%	No.	%	No.	%	No.	%
▪ No difficulty	0	0.0%	0	0.0%	0	0.0%	0	0.0%
▪ A little difficulty	0	0.0%	0	0.0%	5	25.0%	4	20.0%
▪ Mild difficulty	5	25.0%	4	20.0%	8	40.0%	6	30.0%
▪ Moderate difficulty	6	30.0%	7	35.0%	4	20.0%	6	30.0%
▪ Severe difficulty	9	45.0%	9	45.0%	3	15%	4	20.0%
2(MCp)	0.871 (0.661)				17.50 (0.006*)			
Mean ± SD	58.80 ± 9.00		58.75 ± 9.05		72.00 ± 18.5		60.00 ± 21.0	
t(p)	0.017 (0.986)				2.85 *(0.004*)			

χ^2: Chi-square test MC: Monte Carlo t: Student t-test
*: Statistically significant at $p \leq 0.05$

Discussion

Osteoporosis is a systemic skeletal disorder marked by a decrease in bone mineral density (BMD) and deterioration of bone microarchitecture, resulting in compromised bone strength and an elevated susceptibility to fragility fractures. It is often referred to as the "silent disease" due to its asymptomatic progression, with diagnosis typically made only after low-impact or atraumatic fractures occur. Despite affecting approximately 200 million individuals globally, its prevalence is significantly higher among postmenopausal women due to the decline in estrogen levels, a key regulator of bone metabolism **(Keen, 2022).**

Postmenopausal osteoporosis is a chronic musculoskeletal condition primarily associated with aging and estrogen deficiency in older women. This condition can significantly impair women's quality of life due to persistent pain, reduced mobility, and functional disability. The hip and vertebral column are the most common anatomical sites of osteoporotic fractures in this population, often leading to severe morbidity. Various preventive strategies have been recommended to mitigate the progression of osteoporosis, including adequate calcium and vitamin D supplementation, smoking cessation, limiting alcohol consumption, and engaging in weight-bearing and impact-based physical exercises that generate ground and joint reaction forces. Furthermore, optimizing peak bone mass and maintaining normal bone mineral density during the premenopausal years is essential, as fracture risk increases with advancing age. Therefore, this study aimed to investigate the effect of high-impact exercises on bone mineral density and physical performance in postmenopausal women with osteoporosis **(Meeta et al., 2020; Hettchen et al., 2021).**

Regarding the socio-demographic characteristics of the study participants, the findings of the present study demonstrated no statistically significant difference between study group (A) and study group (B) prior to the implementation of the exercise program, indicating homogeneity of the study sample.

This uniformity among participants was advantageous in minimizing potential confounding variables that could influence the outcomes of the intended intervention, thereby enhancing the internal validity of the study.

The findings of the present study demonstrated no statistically significant differences in the mean values of bone mineral density (BMD) and T-score of the lumbar spine, left femur, and forearm between Study Group A and Study Group B at baseline assessment (pre-intervention), with a p-value exceeding 0.05. This indicates the initial homogeneity of the two groups in terms of bone health status. However, following the three-month intervention period, a statistically significant difference emerged between the groups in the mean BMD and T-score at the aforementioned skeletal sites ($p < 0.05$), suggesting that treadmill walking exercise (Group A) had a more pronounced positive effect on bone health compared to resistance band clamshell exercises (Group B).

In terms of physical performance, the post-intervention assessment revealed a significant improvement in the overall Osteoporosis Assessment Questionnaire-Physical Function (OPAQ-PF) total score in Group A, which improved significantly to ((72.00 ± 18.5) compared to Group B (60.00 ± 21.0) with a statistically significant difference among both groups ($p < 0.004$) post-intervention. These findings suggest that treadmill walking exercise was more effective in enhancing physical function compared to resistance band clamshell exercises in postmenopausal women with osteoporosis.

In assessing the effect of treadmill walking exercise on bone mineral density (BMD) and physical performance, The present study's findings are consistent with previous research examining the impact of exercise interventions on BMD in postmenopausal women. **Siwapituk & Kitisomprayoonkul (2016)** performed a study entitled *"Bone Turnover Increases during Supervised Treadmill Walking in Thai Postmenopausal Women,"* which demonstrated a significant increase in bone turnover markers following supervised treadmill walking. Their findings suggest that consistent engagement in treadmill walking promotes bone formation while reducing the risk of osteoporosis-related fractures in postmenopausal women.

Essa, Fawaz, Hamada, Ameer & Elhafez (2017) evaluated the *"Effect of Core and Treadmill Training on Skeletal Mineralization in Postmenopausal Osteoporotic Women,"* and their findings confirmed that treadmill-based training programs are effective in improving BMD, particularly at the hip region, and in reducing bone loss in postmenopausal women. **Awad, El-Nahas, Soliman & Biomy (2019)** conducted a study titled *"Effect of Aerobic Exercise on Bone Mineral Density in Lean Postmenopausal Women,"* which concluded that aerobic exercise, particularly treadmill walking, is highly effective in enhancing BMD in lean postmenopausal women. Their study emphasized that regular weight-bearing exercise, such as treadmill walking, stimulates bone remodeling processes and helps mitigate the decline in BMD commonly observed after menopause.

McKenzie (2019) conducted a study titled *"The Effect of Exercise on Postmenopausal Women with Osteoporosis,"* which indicated that weight-bearing and impact-based exercise programs consisting of at least 30-minute sessions with frequent weekly attendance are the most effective in enhancing bone health and improving BMD. **Kemmler, Shojaa, Kohl & von Stengel (2020)** investigated the *"Effects of Different Types of Exercise on Bone Mineral Density in Postmenopausal Women,"* concluding that various forms of exercise interventions had significant positive effects on BMD at the lumbar spine, femoral neck, and total hip regions in postmenopausal women. **Filipović et al. (2021)** demonstrated in a randomized controlled trial that a 12-week structured exercise program, including aerobic, resistance, and walking exercises, effectively slowed the rate of BMD loss in postmenopausal women. Among these modalities, treadmill-based fast walking was recommended as one of the most effective strategies for both the prevention and management of osteoporosis in postmenopausal women.

Linhares et al. (2022) conducted a systematic review and meta-analysis revealing that postmenopausal women who engaged in different exercise interventions exhibited statistically significant improvements in BMD compared to sedentary control groups. Supporting this,

Nazari-Makiabadi et al. (2022) indicated that various patterns of regular physical activity, including aerobic, resistance, or combined exercise programs, exert a positive effect on bone density in both human and animal models.

Recent research also indicates that weight-bearing aerobic activities, including treadmill walking and brisk walking, are highly effective strategies for reducing bone loss and lowering fracture risk in postmenopausal women with osteoporosis **(The Guardian, 2024).** These findings highlight the essential role of consistent physical exercise in both the prevention and management of osteoporosis. Additionally, a systematic review by **Jahantigh et al. (2024)** demonstrated that exercise therapy incorporating balance, strengthening, stretching, stability, and motor control exercises significantly enhances muscular strength, BMD, and overall quality of life in postmenopausal women with osteoporosis. These collective findings further reinforce the importance of tailored exercise interventions as a cornerstone in the comprehensive management of osteoporosis in postmenopausal women.

The agreement between the findings of the present study and the aforementioned studies may be attributed to many reasons. **Firstly**, the utilization of the same standardized diagnostic method for assessing bone mineral density (BMD), namely Dual-energy X-ray Absorptiometry (DXA), which is widely recognized as the gold standard for evaluating BMD due to its high precision and reliability. **Secondly**, this agreement could be further justified by the well-established osteogenic effects of aerobic exercises, particularly treadmill walking, which is classified as a weight-bearing exercise that exerts mechanical loading on bones. This mechanical loading generates ground reaction forces and muscle contractions, which play a pivotal role in stimulating osteoblast activity and bone remodeling. **Thirdly**, treadmill walking has been shown to enhance calcium absorption, increase serum 1,25-dihydroxyvitamin D3 levels, and suppress parathyroid hormone secretion physiological mechanisms that collectively contribute to improved bone metabolism and increased bone mass, especially at weight-bearing skeletal sites such as the lumbar spine, hip, and femur. **Fourthly**, aerobic exercises improve blood circulation and oxygen delivery to bone tissues, which enhances the nutrient supply essential for bone formation. These combined biomechanical and biochemical mechanisms underscore the effectiveness of treadmill walking in mitigating bone loss and promoting bone health among postmenopausal women with osteoporosis.

However, the findings of the present study are inconsistent with the results reported by **Woo Kim, Won Seo, Chul Jung & Kook Song (2021),** who investigated the *"Effects of High-Impact Weight-Bearing Exercise on Bone Mineral Density and Bone Metabolism in Middle-Aged Premenopausal Women."* Their study concluded those four months of high-impact weight-bearing exercise (HWE) was insufficient to induce significant improvements in BMD and bone metabolic markers, although it may help attenuate age-related changes in bone turnover markers. This discrepancy between the current study and the aforementioned one may be attributed to several factors. Firstly, the differences in the exercise protocols could explain the conflicting results. The present study implemented treadmill walking combined with resistance exercises, both of which are low-to-moderate intensity weight-bearing exercises that exert continuous mechanical loading on bones, while the other study adopted an HWE program composed of high-impact, short-duration activities such as jumping and running. High-impact exercises may induce greater mechanical strain on bones, but their intermittent nature might not provide sufficient cumulative loading to stimulate significant bone remodeling over a short period.

Additionally, the disparity in participant characteristics, such as menopausal status, age range, and baseline bone density, could also contribute to the variation in outcomes. Postmenopausal women are more responsive to exercise interventions aimed at improving BMD due to the accelerated bone loss associated with estrogen deficiency, while premenopausal women experience slower bone turnover, potentially requiring a longer intervention duration to yield measurable improvements.

In evaluating the efficacy of resistance band clamshell exercises on bone mineral density (BMD) and physical performance in postmenopausal women with osteoporosis,the findings of the present study align with the outcomes of several recent studies. A study by **Shojaa, Heidari, & Soltani (2019)** investigated the effects of resistance training on bone health in postmenopausal women and found that while moderate-intensity resistance exercises contributed to the maintenance of BMD, they were not as effective as high-impact weight-bearing exercises, such as jumping or impact-loading exercises, in significantly improving bone mass. This suggests that while resistance band exercises, including clamshell exercises, may offer benefits in terms of muscle activation and joint stability, they might not provide the necessary mechanical loading required to stimulate substantial bone adaptation.

A systematic review and meta-analysis by **Rahimi, Shojaa, & Heidari (2020)** investigated the impact of different exercise training modes on BMD in older postmenopausal women. The study concluded that resistance training positively influences BMD; however, it did not specifically address the efficacy of resistance band clamshell exercises, indicating a gap in the literature regarding their specific impact on BMD.

Furthermore, a randomized controlled trial by **Zhao, Zhang, & Zhang (2021)** compared the effects of low-impact resistance training, including resistance band exercises, with high-impact resistance training on osteoporosis markers in postmenopausal women. The results demonstrated that while low-impact resistance exercises helped maintain BMD, they did not significantly increase bone mass when compared to high-intensity, weight-bearing activities. These findings further highlight the importance of incorporating weight-bearing and impact-loading exercises into osteoporosis prevention and management strategies, as they provide a more potent stimulus for bone remodeling and strength development.

Additionally, a systematic review and meta-analysis by **Hejazi, Rahimi, & Soltani (2022)** evaluated the effects of physical exercise on BMD in older postmenopausal women. The findings suggested that while various forms of exercise, including resistance training, can maintain or improve BMD, the specific impact of low-intensity exercises like resistance band clamshells remains underexplored. This underscores the need for further research to determine the effectiveness of such exercises in enhancing bone health among postmenopausal women with osteoporosis.

The agreement between the findings of the present study and the aforementioned studies may be attributed to many reasons. Bone remodeling is primarily driven by the intensity and frequency of mechanical stress applied to the skeletal system. High-impact, weight-bearing exercises such as jumping, resistance training with external loads, and walking generate substantial mechanical forces that activate osteoblasts, promoting bone formation. In contrast, clamshell exercises mainly engage the hip abductors with minimal external load and without the gravitational impact necessary to stimulate robust osteogenic responses. As a result, these exercises do not provide the mechanical strain required to enhance BMD effectively.

Additionally, bone adaptation follows the principle of progressive overload, meaning that continuous exposure to increasing mechanical stress is essential for improving bone strength and density. Resistance band clamshell exercises offer only limited resistance and target specific muscle groups without involving full-body movements that generate higher bone-loading forces. Moreover, they lack axial loading, a critical factor in stimulating bone growth, as it involves applying force directly along the bone's longitudinal axis. Since osteoporosis leads to reduced bone strength and increased fracture risk, effective interventions should focus on exercises that create high strain rates and mechanical tension, which clamshell exercises fail to deliver to a meaningful extent.

In contrast, the findings of the present study are not consistent with the outcomes of several recent studies that emphasize the positive effects of resistance and multi-component exercise interventions on bone mineral density (BMD) in postmenopausal women with osteoporosis. Ghosal and Bandyopadhyay (2018) found that resistance band training is particularly beneficial for older women, as it improves BMD by enhancing muscle strength, balance, and other physiological fitness factors that collectively contribute to bone health. Similarly, **Jeong et al. (2019)** highlighted the efficacy of modified clamshell exercises in improving BMD by activating the gluteus medius muscle while minimizing anterior hip flexor activity, which may play a crucial role in stabilizing the hip joint and reducing the risk of fractures.

Shojaa et al. (2020) reported a significant low-to-moderate effect of dynamic resistance exercises on BMD among postmenopausal women, highlighting the osteogenic potential of resistance training as a key intervention for maintaining bone health. **Holubiac et al. (2022)** concluded that structured resistance training protocols serve as a cost-effective and accessible strategy for improving BMD in women diagnosed with osteopenia or osteoporosis, which can effectively prevent further bone loss and the associated risk of fractures.

Bae et al. (2023) demonstrated that a multi-component exercise program, predominantly comprising resistance and impact exercises, is an effective strategy for mitigating risk factors associated with osteoporosis and osteopenia by enhancing both BMD and overall musculoskeletal function. Supporting this, **Khanna (2023)** demonstrated that resistance exercises play a pivotal role in regulating bone health through their capacity to promote mechanical loading on the skeletal system, thereby enhancing bone remodeling processes and minimizing the progression of osteoporosis.

These consistent findings across multiple studies reinforce the premise that resistance-based and multi-component exercise programs represent a fundamental non-pharmacological intervention for enhancing BMD, improving musculoskeletal function, and preventing osteoporosis-related fractures in postmenopausal women. The combination of mechanical loading, muscular strengthening, and proprioceptive stimulation induced by these exercise modalities further contributes to the preservation of bone mass and the promotion of bone health in this vulnerable population.

The discrepancy between the findings of the present study and those of previous research indicating the effectiveness of resistance band clamshell exercises in improving bone mineral density (BMD) among postmenopausal women with osteoporosis can be attributed to several methodological differences, including variations in sample size, age distribution, and intervention duration. A key factor influencing these discrepancies is the sample size, as studies with larger cohorts tend to have greater statistical power to detect significant changes in BMD, whereas smaller sample sizes, such as in the present study, may limit the ability to observe meaningful effects.

Differences in participant age groups may also contribute to the variation in findings. Studies incorporating a broader age range, particularly younger postmenopausal women with a greater capacity for bone remodeling, may report more favorable outcomes, whereas the present study may have focused on an older population with more advanced bone deterioration, reducing the likelihood of significant improvements. Furthermore, the duration of the intervention is a critical determinant of exercise efficacy. Studies demonstrating the positive effects of resistance band exercises on BMD may have implemented prolonged intervention periods, allowing sufficient time for bone adaptation, whereas shorter durations, as utilized in the present study, may not have facilitated detectable changes in bone mass. These methodological differences underscore the necessity of standardized protocols and extended study durations to accurately assess the impact of resistance band clamshell exercises on osteoporosis-related outcomes.

Conclusion

In conclusion, the present study demonstrated that high-impact exercises, particularly treadmill walking, are more effective in enhancing bone mineral density (BMD) and physical performance compared to resistance band clamshell exercises among postmenopausal women with osteoporosis. The significant improvements observed at weight-bearing sites, such as the lumbar spine, hip, and forearm, highlight the pivotal role of weight-bearing aerobic exercises in stimulating bone formation and reducing bone loss.

However, resistance band clamshell exercises remain valuable as they target hip-stabilizing muscles, enhance pelvic alignment, and improve overall lower-body strength, which may contribute to better balance and fall prevention. Therefore, treadmill walking represents a simple, cost-effective, and accessible intervention that can be incorporated into osteoporosis management programs to improve bone health and reduce the risk of fractures in postmenopausal women.

Recommendations

In light of the study findings, the following recommendations are suggested:

- **Exercise Integration in Clinical Practice**: Health practitioners are encouraged to incorporate high-impact weight-bearing exercises like treadmill walking into standard osteoporosis care protocols for postmenopausal women to improve bone mineral density and lower the risk of osteoporotic fractures.
- **Personalized Exercise Programs**: Individualized exercise interventions that combine aerobic weight-bearing activities with resistance training should be developed according to each woman's health status, fitness level, and bone health needs to maximize both musculoskeletal strength and physical performance.
- **Community Health Awareness**: Public health campaigns should be implemented to promote the role of regular physical activity in osteoporosis prevention and empower postmenopausal women to adopt active lifestyles as part of their daily routines.
- **Future Research Directions**: Further longitudinal studies with larger sample sizes are needed to explore the sustained effects of various exercise regimens on BMD preservation, fracture risk reduction, and quality of life among postmenopausal women with osteoporosis.

Limitations of the study

Despite the significant findings of the present study, the following limitations should be acknowledged:

1. **Small Sample Size:** The relatively small number of participants may limit the generalizability of the study findings to the wider population of postmenopausal women with osteoporosis. Larger sample sizes are recommended for future studies to enhance statistical power.
2. **Short Duration of Intervention:** The intervention period of three months may not fully reflect the long-term effects of high-impact and resistance exercises on bone mineral density (BMD) and fracture risk. Longitudinal studies with extended follow-up periods are necessary to assess sustained outcomes.

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Conflicts of interest disclosure

The authors have no conflicts of interest to declare.

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