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ORIGINAL RESEARCH

Prevention of Postmenopausal Osteoporosis — A Comparative Study of Exercise, Calcium Supplementation, and Hormone-Replacement Therapy

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ABSTRACT

Background: Postmenopausal osteoporosis is a significant health concern, leading to increased risk of fractures and decreased quality of life among affected women. Various preventive strategies, including exercise, calcium supplementation, and hormone-replacement therapy (HRT), have been proposed. This study aims to compare the effectiveness of these interventions in preventing bone density loss among postmenopausal women. **Materials and Methods:** A total of 150 postmenopausal women aged 50-65 years were enrolled in this study. Participants were randomly assigned to one of three groups: Group A (n=50) received a structured exercise program, Group B (n=50) was given daily calcium supplementation (1000 mg), and Group C (n=50) underwent hormone-replacement therapy. Bone Mineral Density (BMD) was measured at baseline and after 12 months using dual-energy X-ray absorptiometry (DEXA). The primary outcome was the percentage change in BMD at the lumbar spine and hip regions. **Results:** After 12 months, Group A (exercise) showed a mean increase in BMD of 1.5% at the lumbar spine and 1.2% at the hip. Group B (calcium supplementation) demonstrated a mean increase of 1.0% at the lumbar spine and 0.8% at the hip. Group C (HRT) exhibited the most significant improvement, with a mean increase in BMD of 3.2% at the lumbar spine and 2.9% at the hip. Statistical analysis revealed that the improvements in BMD in Group C were significantly greater than those in Groups A and B ($p < 0.05$). **Conclusion:** Hormone-replacement therapy is more effective in preventing bone density loss in postmenopausal women compared to exercise and calcium supplementation. However, all three interventions positively impact bone health, suggesting that a combined approach may offer the best protection against postmenopausal osteoporosis.

Keywords: Postmenopausal osteoporosis, bone mineral density, exercise, calcium supplementation, hormone-replacement therapy, prevention.

INTRODUCTION

Osteoporosis is a prevalent condition characterized by reduced bone mass and deterioration of bone tissue, leading to an increased risk of fractures. It is particularly common among postmenopausal women due to the decrease in estrogen levels, which accelerates bone loss (1,2). The lifetime risk of fracture due to osteoporosis in women over the age of 50 is estimated to be as high as 40%, underscoring the importance of effective prevention strategies (3).

Several approaches have been explored to mitigate the risk of osteoporosis in postmenopausal women. Regular physical exercise, particularly weight-bearing and resistance exercises, has been shown to improve bone density and reduce the risk of fractures (4,5). Calcium supplementation is another widely recommended strategy, as adequate calcium intake is essential for maintaining bone health (6). However, the effectiveness of calcium supplementation alone in preventing osteoporosis has been debated, with some

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studies suggesting that it may not be sufficient without concurrent vitamin D supplementation or other interventions (7).

Hormone-replacement therapy (HRT) has long been considered one of the most effective means of preventing bone loss in postmenopausal women (8). By replacing the estrogen that is lost during menopause, HRT can significantly reduce the rate of bone resorption and increase bone mineral density (BMD) (9). However, concerns about the potential risks of HRT, including an increased risk of breast cancer and cardiovascular events, have led to a decline in its use (10).

Given the various preventive strategies available, it is crucial to determine which approach or combination of approaches is most effective in reducing the risk of osteoporosis in postmenopausal women. This study aims to compare the effects of exercise, calcium supplementation, and hormone-replacement therapy on bone mineral density in a cohort of postmenopausal women.

MATERIALS AND METHODS

Study Design

This was a randomized, controlled trial conducted over a 12-month period at a tertiary care center. The study was approved by the Institutional Review Board, and written informed consent was obtained from all participants.

Participants

A total of 150 postmenopausal women aged 50-65 years were enrolled in the study. Inclusion criteria included being at least 5 years postmenopausal, having no history of osteoporosis or bone fractures, and not currently undergoing treatment for osteoporosis. Exclusion criteria included any contraindications to exercise, calcium supplementation, or hormone-replacement therapy (HRT), as well as existing chronic conditions that could affect bone metabolism, such as thyroid disorders, renal insufficiency, or malabsorption syndromes.

Randomization and Interventions

Participants were randomly assigned to one of three intervention groups using a computer-generated randomization sequence:

- **Group A (Exercise)**: Participants in this group followed a structured exercise program, which included weight-bearing and resistance exercises. The program was supervised by a certified physiotherapist and consisted of 3 sessions per week, each lasting 60 minutes.
- **Group B (Calcium Supplementation)**: Participants in this group were prescribed daily calcium supplements (1000 mg of elemental calcium). Compliance was monitored through monthly follow-up visits and pill counts.
- **Group C (Hormone-Replacement Therapy)**: Participants in this group received HRT, consisting of a combination of estrogen and progestin. The specific formulation and dosage were determined based on individual needs and risk factors, following the guidelines of the North American Menopause Society.

Outcome Measures

The primary outcome measure was the change in Bone Mineral Density (BMD) at the lumbar spine (L1-L4) and hip (femoral neck) regions. BMD was assessed at baseline and after 12 months using dual-energy X-ray absorptiometry (DEXA) scans, performed by a trained technician who was blinded to the group assignments.

Secondary outcome measures included markers of bone turnover (serum calcium, serum phosphorus, alkaline phosphatase, and urinary deoxypyridinoline) and self-reported adherence to the interventions.

Statistical Analysis

Data were analyzed using SPSS version 25.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD), and categorical variables as frequencies and percentages. Changes in BMD were compared between the three groups using one-way ANOVA, followed by post-hoc analysis with Bonferroni correction. A p-value of <0.05 was considered statistically significant.

RESULTS

Participant Characteristics

A total of 150 postmenopausal women were enrolled and completed the study. The mean age of the participants was 57.3 ± 4.2 years, with no significant differences in age, BMI, or baseline BMD between the three groups ($p > 0.05$).

Changes in Bone Mineral Density (BMD)

The primary outcome, BMD, was measured at the lumbar spine and hip at baseline and after 12 months. The results are summarized in Table 1.

Table 1: Changes in Bone Mineral Density (BMD) at Lumbar Spine and Hip Regions

Group	Baseline Lumbar Spine BMD (g/cm²)	12-Month Lumbar Spine BMD (g/cm²)	% Change in Lumbar Spine BMD	Baseline Hip BMD (g/cm²)	12-Month Hip BMD (g/cm²)	% Change in Hip BMD
Exercise (Group A, n=50)	0.890 ± 0.120	0.904 ± 0.115	+1.5%	0.850 ± 0.105	0.860 ± 0.102	+1.2%

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Calcium (Group B, n=50)	0.885 ± 0.110	0.894 ± 0.108	+1.0%	0.845 ± 0.100	0.852 ± 0.098	+0.8%
HRT (Group C, n=50)	0.880 ± 0.115	0.908 ± 0.110	+3.2%	0.840 ± 0.107	0.864 ± 0.104	+2.9%

Bone Turnover Markers

Serum calcium, serum phosphorus, alkaline phosphatase, and urinary deoxypyridinoline levels were measured at baseline and after 12 months. The results are summarized in Table 2.

Table 2: Changes in Bone Turnover Markers

Marker	Group A (Exercise)	Group B (Calcium)	Group C (HRT)
Serum Calcium (mg/dL)	Baseline: 9.4 ± 0.3	Baseline: 9.5 ± 0.4	Baseline: 9.3 ± 0.4
	12-Month: 9.5 ± 0.3	12-Month: 9.6 ± 0.4	12-Month: 9.4 ± 0.3
Serum Phosphorus (mg/dL)	Baseline: 3.5 ± 0.2	Baseline: 3.6 ± 0.2	Baseline: 3.4 ± 0.2
	12-Month: 3.6 ± 0.3	12-Month: 3.7 ± 0.2	12-Month: 3.5 ± 0.2
Alkaline Phosphatase (U/L)	Baseline: 85.2 ± 10.5	Baseline: 84.7 ± 11.2	Baseline: 86.1 ± 9.8
	12-Month: 83.1 ± 9.8	12-Month: 82.4 ± 10.5	12-Month: 80.7 ± 10.1
Urinary Deoxypyridinoline	Baseline: 12.5 ± 3.2	Baseline: 12.8 ± 3.0	Baseline: 12.3 ± 3.5
(nmol/mmol creatinine)	12-Month: 11.8 ± 3.0	12-Month: 12.5 ± 3.1	12-Month: 10.5 ± 3.2

Statistical Analysis

Statistical analysis using one-way ANOVA revealed significant differences in the percentage change in BMD at both the lumbar spine and hip regions among the three groups ($p < 0.05$). Post-hoc analysis with Bonferroni correction indicated that the increase in BMD in Group C (HRT) was significantly greater than in Group A (Exercise) and Group B (Calcium) ($p < 0.01$). No significant differences were observed between Groups A and B in terms of BMD changes.

In terms of bone turnover markers, Group C (HRT) showed a more pronounced reduction in urinary deoxypyridinoline levels, indicating a decrease in bone resorption, compared to Groups A and B ($p < 0.05$).

Adherence and Adverse Effects

Adherence to the interventions was high, with over 90% of participants in each group completing the study. Mild adverse effects, such as gastrointestinal discomfort in the calcium group and transient hot flashes in the HRT group, were reported but did not lead to discontinuation.

These results suggest that HRT is the most effective intervention for increasing BMD in postmenopausal women, followed by exercise and calcium supplementation.

DISCUSSION

The findings of this study demonstrate that hormone-replacement therapy (HRT) is significantly more effective in increasing bone mineral density (BMD) in postmenopausal women compared to exercise and calcium supplementation. This result aligns with previous studies that have shown HRT to be a potent intervention for preventing postmenopausal osteoporosis due to its ability to mitigate estrogen deficiency, which is a primary contributor to accelerated bone loss during menopause (1,2).

Exercise, particularly weight-bearing and resistance exercises, has long been recommended as a non-pharmacological intervention for maintaining bone health in postmenopausal women. Our study found that the exercise group experienced a modest but statistically significant increase in BMD at both the lumbar spine and hip regions. These findings are consistent with other studies that have reported similar benefits of exercise in reducing bone loss and improving bone strength (3,4). However, the magnitude of BMD improvement in the exercise group was lower compared to the HRT group, suggesting that while exercise is beneficial, it may be more effective when combined with other interventions such as HRT or calcium supplementation (5).

Calcium supplementation has been widely advocated as a preventive measure for osteoporosis, based on the critical role of calcium in bone mineralization (6). In our study, participants in the calcium supplementation group showed a slight increase in BMD, although the gains were smaller than those observed in the exercise and HRT groups. This finding is in line with the literature, where calcium supplementation alone has been found to have limited efficacy in significantly improving BMD, particularly in the absence of adequate vitamin D levels or concurrent physical activity (7,8). Moreover, the small BMD gains observed with calcium supplementation underscore the importance of adopting a multifaceted approach to osteoporosis prevention in postmenopausal women.

The significant reduction in urinary deoxypyridinoline levels in the HRT group, indicative of decreased bone resorption, further supports the efficacy of HRT in mitigating postmenopausal bone loss (9). However, it is essential to balance the benefits of HRT with its

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potential risks. Although HRT is effective in improving BMD, concerns about the long-term risks associated with HRT, including an increased risk of breast cancer and cardiovascular disease, must be carefully considered when prescribing this therapy (10,11). Therefore, HRT may be most appropriate for women at high risk of fracture, where the benefits outweigh the risks, or in those who are unable to achieve adequate bone health through lifestyle interventions alone.

This study's findings should be interpreted in light of certain limitations. The sample size, although sufficient to detect significant differences in BMD between groups, may limit the generalizability of the results. Additionally, the study duration of 12 months may not fully capture the long-term effects of these interventions on bone health. Future studies with larger sample sizes and longer follow-up periods are warranted to confirm these findings and to explore the potential benefits of combining these interventions.

CONCLUSION

In conclusion, our study supports the superiority of HRT over exercise and calcium supplementation in increasing BMD in postmenopausal women. However, given the potential risks associated with HRT, a personalized approach that considers the individual patient's risk factors and preferences is essential. Combining lifestyle modifications, such as exercise and adequate calcium intake, with pharmacological interventions may offer the best strategy for preventing postmenopausal osteoporosis.

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