


The effect of magnetic therapy and moderate aerobic exercise on osteoporotic patients

A randomized clinical study

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Abstract

Background: Osteoporosis is a frequent musculoskeletal condition with significant complications that would be a global health problem and one of the major causes of mortality and morbidity.

Objectives: The current study aimed to ascertain the impact of pulsed magnetic therapy, aerobic exercise, and a combination of both modalities on osteoporotic female patients postthyroidectomy.

Methods: Between May 2018 and September 2019, 45 female patients with osteoporosis were included in the randomized clinical study, their age ranged from 40 to 50 years, had thyroidectomy for at least 6 months ago, and had an inactive lifestyle for at least the previous 6 months. Patients were assigned randomly into 3 equal groups. Group A (magnetic therapy group): received routine medical treatment (bisphosphonates, calcium, and vitamin D) in addition to pulsed magnetic therapy on the hip region for 12 weeks (3 sessions/week). Group B (exercise group): received routine medical treatment plus moderate-intensity aerobic exercise for 12 weeks (3 sessions/week). Group C (combined magnetic therapy and exercise therapy group): received routine medical treatment plus pulsed magnetic therapy and moderate-intensity aerobic exercise for 12 weeks (3 sessions/week). The 3 groups were assessed for bone mineral density (BMD) at baseline by dual-energy x-ray absorptiometry and after 12 weeks of treatment.

Results: The results showed that within-group analysis a statistically significant increase was revealed ($P < .05$) for BMD in the 3 studied groups. Comparing the results among the 3 tested groups revealed a significant increase ($P < .05$) in posttesting mean values of BMD in group (C) compared to group (A) and group (B). No significant statistical difference in BMD means values between the 2 groups (A) and (B) after testing was detected.

Conclusion: Combination of both pulsed magnetic therapy and moderate-intensity aerobic exercise showed significant improvement in BMD at the hip region than using any of the 2 modalities alone.

Abbreviations: ANOVA = analysis of variance, BMD = bone mineral density, DEXA = dual-energy x-ray absorptiometry, PEMF = pulsed electromagnetic field.

Keywords: aerobic exercise, bone mineral density, dual-energy x-ray absorptiometry, magnetic therapy, osteoporosis, thyroidectomy

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The data involved in this study are available from the corresponding author upon request, and privacy-related parts of the patient will not be provided.

All data generated or analyzed during this study are included in this published article [and its supplementary information files].

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1. Introduction

Osteoporosis increases the risk of fractures and consequent morbidity due to decreased bone mineral density (BMD) and disturbed microarchitecture and geometry of bone tissue.^[1] Urban people have high hip fractures rates, which are associated with about 20% mortality rate within 12 months.^[2] Thyroid disorders significantly aggravate osteoporosis, bone loss, and fracture risk; hyperthyroidism causes a reduction in bone mass, and in several cases, calcitonin secretion decreased after complete or subtotal thyroidectomy, has been proven to cause osteopenia.^[3] According to the World Health Organization, a dual-energy x-ray absorptiometry (DEXA) estimate is based on BMD. Osteoporosis is diagnosed if the BMD of young adult women is lower than the average of -2.5 .^[4]

The increased rate of related morbidity and mortality fractures which result from osteoporosis represents major health, social, and economic burden.^[5] Recently, increased awareness of side effects of the main osteoporosis drug, bisphosphonates, led to decreased adherence to pharmacotherapy regimes, which has been highlighted as “a crisis in the treatment of osteoporosis”.^[6] Improving physician and patient’s awareness by non-pharmacological methods for osteoporosis prevention and treatment is essential. Regular exercise is a cornerstone of various chronic diseases’ prevention and management because of its benefits in a range of disorders, especially age-associated diseases.^[7]

Exercise is a good measure for bone density; this process through which the exercise causes changes in the metabolism of bone is not completely clarified. Very little is recognized about the changes in bone metabolism due to various forms of regular exercise.^[8] The exact mechanism of exercise-induced osteogenesis is yet to be fully clarified because of the difficulties facing bone-cell responses studying *in vivo*. It may be attributable to the mechano-transduction; exercise-induced anabolic, or homeostatic effect on bone.^[9,10] Resistive exercise training and weight-bearing activities might be the most beneficial forms of physical activity to maintain and increase BMD especially in older people.^[11]

It is supposed that electro physical modalities, such as pulsed electromagnetic fields (PEMF) might help to decelerate or prevent bone loss because of its piezo-electrical effect, which influences the deposition of calcium in bone and plays a significant role in mineral metabolism.^[12] PEMFs stimulate osteoblastic activities.^[13] PEMF with a specific intensity and frequency have been shown to reduce bone loss and relieve pain, therefore, it may be an effective therapeutic modality for patients with osteoporosis.^[14,15]

Rehabilitation modalities (as exercises, PEMF) are commonly advocated as a non-pharmacological option in the non-pharmacological management of osteoporosis due to their crucial roles in reducing risk factors related to fractures, restoring function, and increasing quality of life.^[16,17]

To the best of our knowledge, there is not enough data comparing the effects of PEMF, aerobic exercise, and a combination of the two on BMD in postthyroidectomy osteoporosis. As a result, the purpose of this study was to assess the impact of these strategies and determine whether a combination of both techniques is better than either technique alone.

2. Methods

Between May 2018 and September 2019, a randomized clinical study was conducted at outpatient clinic of faculty of physical

therapy, Cairo University, Egypt. According to declaration of Helsinki 1964, a signed informed consent was obtained from all patients including their agreement to participate in this study. The study protocol was approved by ethical committee, Faculty of Physical Therapy, Cairo University, Egypt (P.T. REC/012/002533) and clinical trial registry number is (NCT04488328).

2.1. Participants

Forty-five female patients, with age ranging from 40 to 50 years were included in this study, with osteoporotic changes in the hip region, diagnosed and referred by expert physician. All participants had thyroidectomy for at least 6 months ago and had an inactive lifestyle for at least the previous 6 months. Patients excluded from the study were those with malignancies or undergoing radiotherapy or chemotherapy, cardiovascular disorders, sensory impairment, renal failure, or alcoholic drinkers in addition to patient receiving immunosuppressive and anti-convulsant medications, were excluded from this study.

2.2. Procedures and randomization

Sixty-seven patients were checked for eligibility. Initial medical screening was performed for each participant by the physician; clinical history was documented for all participants. To avoid bias, participants’ random assignments were performed by independent colleague physical therapists who were working in the outpatient clinic reported all persons who fulfilled the inclusion criteria of the study and had no exclusion criteria. Only forty-five patients met the requirements for inclusion criteria and were randomly assigned using sealed envelopes prepared with random number generation (Fig. 1) into 3 equal groups; Magnetic Therapy Group (Group A), Aerobic Exercise Group (Group B), and Combined Magnetic and Exercise Group (Group C).

Group A: included 15 patients who received pulsed magnetic field therapy on the hip region (magnetic field intensity, 50 Gauss; frequency, 33 Hz) for 50 minutes (3 sessions/week) for 12 weeks, in addition to the routine medical treatment (bisphosphonates, calcium and vitamin D).

Group B: included 15 patients who received moderate-intensity aerobic exercise for 12 weeks (3 sessions/week), plus the routine medical treatment. Group C: included 15 patients who received moderate-intensity aerobic exercise, 3 sessions/week combined with 50-minute magnetic field intensity, 50 Gauss; frequency, 33 Hz, (3 sessions/week) for 12 weeks.

To avoid bias, participants’ random assignments were performed through 2 stages: first, colleague physical therapists who were working in the outpatient clinics of the Faculty of Physical Therapy, Cairo University, reported all persons who fulfilled the inclusion criteria of the study and had no exclusion criteria; second, after medical counseling, participants were randomly assigned to either magnetic field or aerobic exercise group by opening an opaque envelope prepared by an independent subject with random number generation. Participants were randomly assigned to 3 equal groups: group A (n=15) received electromagnetic field and group B (n=15) received moderate intensity aerobic exercises and group C (n=15) received combined program of both electromagnetic field and aerobic exercise. They participated in the study for 12 weeks (3 sessions/week).

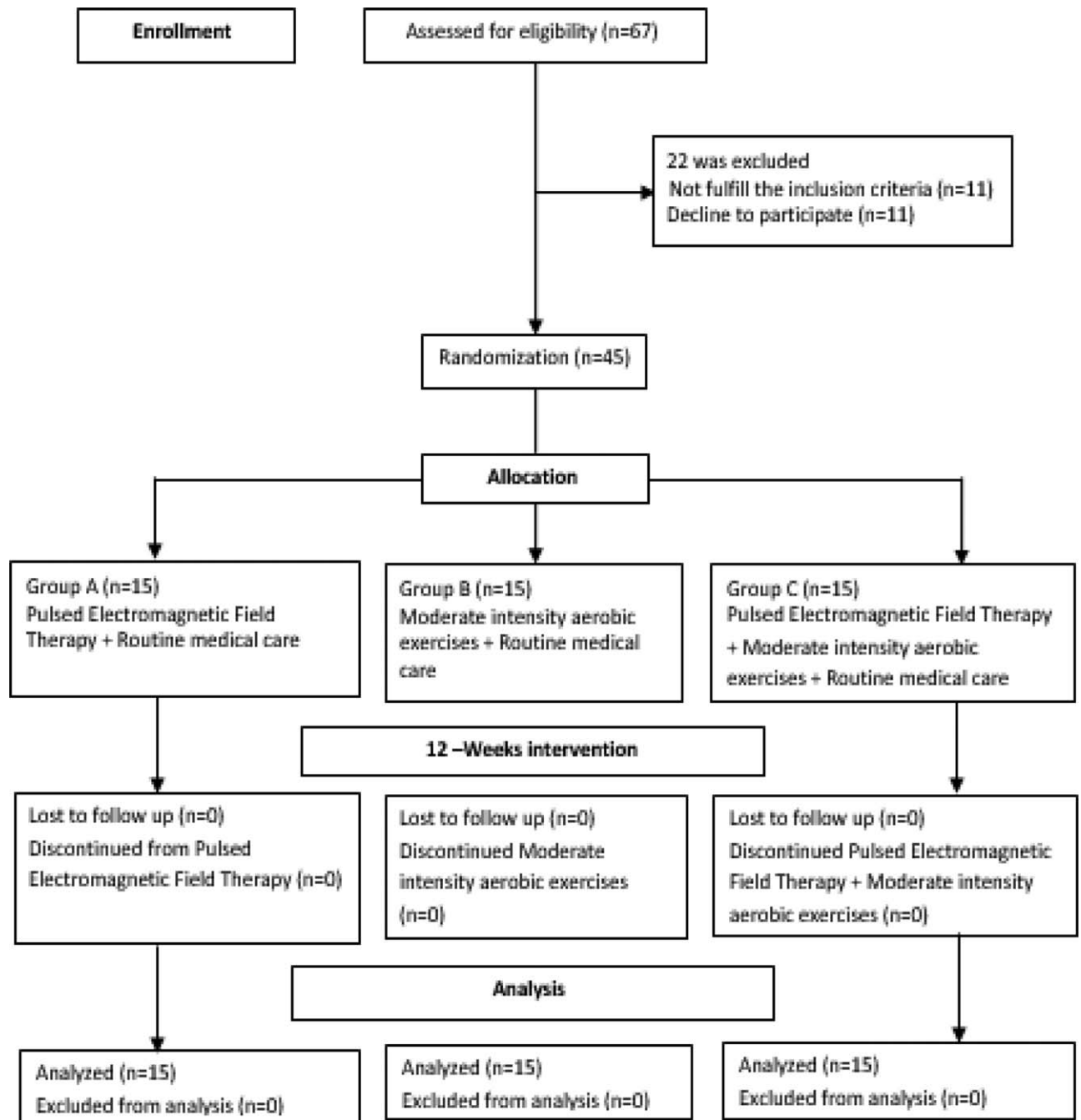


Figure 1. The flowchart of the study.

2.3. Outcome measures

2.3.1. Evaluation of bone mineral density. The 3 groups' evaluation was performed at baseline and 12 weeks after the intervention. Measurements were carried out by a professional examiner who was blinded to the group assignment on the pre- and post-intervention, including BMD assessment at the hip region by DEXA. DEXA is a method of measuring BMD. Two X-ray beams are targeted to the patient's bones, with varying energy levels. Once soft tissue absorption is subtracted, the BMD can be calculated by each beam being absorbed by bone. The bone density is the double-energy X-ray absorptiometry measurement

technique most commonly used and researched in depth. DEXA measurements were expressed as T score. Participants were diagnosed with osteoporosis using the T-score DEXA method; Normal (0 to -0.99); Osteopenia (low bone density) (-1 to -2.49); Osteoporosis (≤ -2.5); Severe or defined osteoporosis (≤ -2.5).^[18]

Test-retest reliability of the DXA measures based on test-retest using 10 subjects resulted in high intra-class correlation coefficient for BMD. The intra-class correlation coefficient for BMD of neck of femur was 0.97, for greater trochanter 0.98, for Ward triangle 0.95, for L2 0.97, for L3 0.96, and for L4 0.97.^[19]

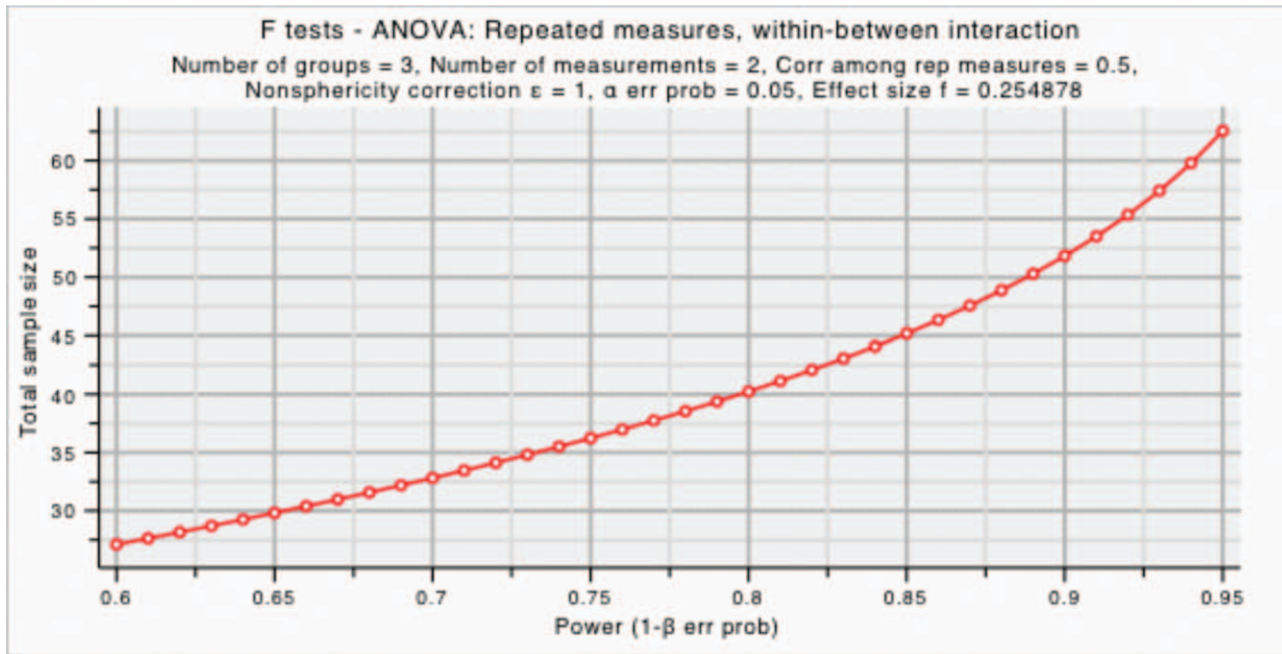


Figure 2. Plot of sample size calculation.

2.4. Intervention

Pulsed electromagnetic therapy: the pulsed electromagnetic unit was Quattro Pro, ASA, Italy with a serial number (00001543). The device consisted of a controlled generator mounted on a movable frame for easy movement, field power of up to 85 Gauss in emission, it produced pulsed magnetic fields of up to 100Hz and varied in intensity depending on the type of solenoid used.

The subjects were placed in supine position on a motorized bed and the solenoids were connected to an electrical power supply 230V with an earth contact frequency of 50 or 60Hz. The magnetic therapy was applied on the hip region with intensity 50 Gauss and frequency 33Hz for 50 minutes (3 sessions/week) for 12 weeks, in addition to the routine medical treatment (bisphosphonates, calcium and vitamin D).^[19]

Moderate intensity aerobic exercise program: each session started with 5 minutes of warm-up in the form of slow-paced walking on the treadmill, then participants were asked to walk briskly on the treadmill at a rate that generated exercise heart rates between 60% and 75% of the age of the person modified, as prescribed by the guidelines of the American College of Sports Medicine. The lower and upper limit for the aerobic heart rate range of each participant was computed according to the formula of Karvonen: $(220 - \text{age}) \times (0.60 \text{ [lower-limit] or } 0.75 \text{ [upper-limit]})$. Treadmill speed was set as necessary to ensure that participants stayed within the lower and upper limits of aerobic exercise for the length of each exercise session throughout the medium-intensity exercise. Finally, a cooling down stage for 5 to 10 minutes as walking without resistance^[20]

The average exercise time was 50 minutes; Treatments were repeated 3 times a week for 12 weeks in addition to the routine medical treatment (bisphosphonates, calcium and vitamin D).

2.5. Sample size and statistical analysis

G*POWER statistical programming (version 3.1.9.2; Franz Faul, Universität Kiel, Germany) was used to test size estimation (F-

tests, analysis of variance [ANOVA]: repeated measures, within-between interaction, $\alpha = 0.05$, $\beta = 0.20$, number of predictors = 2, number of dependent = 1, and effect size = 0.254) and reported that the sample size acceptable for this study was (N=42). This effect size was calculated from the pilot study on 15 participants, 5 in each group (Fig. 2). Descriptive statistics including the mean, standard deviation of posttreatment data (BMD) as compared to pre-one. 3×2 mixed-design ANOVA had been used to compare the effect of magnetic field therapy and moderate-intensity aerobic exercises and a combination of both techniques on BMD in participants with postthyroidectomy osteoporosis. The study included 2 independent variables. The first independent variable (between-subject factor) was the tested group with 3 levels: group (A), group (B), and group (C). The second independent variable (within-subject factor) was the testing time with 2 levels: pre-testing and posttesting. The 1 dependent variable was the BMD. SPSS version 23 (IBM Corp., Armonk, NY, USA) for Windows was used for statistical measures. The level of significance for each statistical test was set at $P < .05$.

3. Results

Statistical tests revealed no violations of the assumptions of normality and homogeneity of variance for any of the BMD. Results revealed non-significant differences ($P > .05$) between the 3 groups regarding demographic characteristics, as shown in Table 1.

3.1. 3×2 mixed-design ANOVA

Univariate test for outcome measure indicated a statistically significant effect for group ($F = 4.249$, $P = .021$, Partial $\eta^2 = 0.168$) and a statistically significant effect for time ($F = 301.789$, $P = .001$, Partial $\eta^2 = 0.878$), and group-by-time interaction ($F = 3.676$, $P = .034$, Partial $\eta^2 = 0.149$). The within-group analysis revealed a statistically significant increase ($P < .05$) for BMD in

Table 1**Demographic characteristics of participants in all groups.**

Variables	Group A (n=15)	Group B (n=15)	Group C (n=15)	F-value	P value
Age (year)	47.26±2.6	47.33±2.84	47.66±2.22	0.104	.901
Height (cm)	161.13±4.27	163±4	163±3.94	1.054	.358
Weight (kg)	85.46±5.65	87.26±4.77	83±6.17	2.219	.121
BMI (kg/m ²)	32.9±1.7	32.8±1.8	31.9±1.7	1.513	.232

Data are represented as mean±SD; a=the value is calculated using the Kruskal-Wallis test; Level of significance at $P \leq .05$.

BMI=body mass index.

the 3 studied groups. After comparing the results among the 3 tested groups, it was revealed that there was a significant improvement ($P < .05$) in the posttesting mean values of BMD in the group (C) compared to group (A) and group (B). No statistically significant difference in the posttesting mean values of BMD between the 2 groups (A) and (B), as shown in Table 2.

4. Discussion

The current research goal was to study the impact of PEMF, aerobic exercise and the combination of both techniques on BMD in female patients postthyroidectomy. The results showed significant improvements after treatment with either modality, however, combination of both treatment modalities resulted in further improvement than the effect of each modality alone.

PEMF were discovered to promote bone formation by boosting the development and differentiation of osteoblasts while inhibiting the function of osteoclasts in bone resorption. PEMFs may influence Ca^{2+} -related receptors on the bone cell membrane, which play a regulatory function in bone remodeling maintenance. Furthermore, PEMF exposure may alter the physiopathology of osteoporosis by reducing inflammation and possibly decreasing pain through these regulatory processes and improvements in bone remodeling.^[21-23]

The mechanism of improvement of BMD after PEMF exposure, could be due to the piezoelectric effect on bone cells, which promotes calcium deposition in the bone. This is confirmed by the findings of Vincenzi et al^[24] who concluded that the application of electromagnetic field results in the flow of ionic electrical current in bone tubules to produce blood and accumulate calcium as an action potential of the bone marrow.

The improvement in BMD in the treated areas can also be due to the influence of PEMF on cell surface binding receptor, which can in turn affect cell metabolism and stimulate growth leading to improved trabecular and cartilage alignment. This agrees with the conclusion of Carpenter et al,^[25] which stated that PEMFs may also influence the gating mechanism that regulates the lymphocyte membrane concentration and might increase the net

calcium flux. They additionally concluded that human calcium osteoblast cells can be increased by PEMFs.^[25,26]

Also, the positive clinical efficiency of PEMF on BMD was supported by Ongaro et al^[27] who evaluated PEMF on bone marrow mesenchymal cells and reported its stimulatory effect on bone growth. This osteogenic differentiation could be explained by different mechanisms such as increased osteocalcin level, alkaline phosphatase activity, and bone matrix mineralization rate. Besides, Jing et al^[28] demonstrated that PEMF improves the impaired bone formation and could partially prevent diabetes mellitus effect on bone strength and architecture deterioration and concluded that PEMF might become a potential additive method for inhibiting diabetic osteoporosis. Also, Fu et al^[29] proved that PEMF has been shown to accelerate osteogenic differentiation and improve the repair of bones, neo-vascularization, and necrotic bone cell growth in mice.

This also comes in accordance with Jing et al^[28] who stated that, increased morphogenetic bone proteins, transforming growth factor-beta, insulin-like growth factor II, and increased extracellular matrix of the bone and the cartilage could be the underlying mechanisms of the electromagnetic field that result in marked improvement of BMD.

On the other hand, Van der Jagt et al^[30] stated that PEMF treatment is very sensitive to the specific set-up, and no available evidence was found on the influence of PEMF stimulation on bone mass and management of osteoporotic patients.

In this study, the increment in BMD with exercising may be attributed to extracellular fluid movement in the bone, resulting in force exertion on osteocytes triggering nitric oxide and prostaglandin release. Those materials lead to the division and differentiation of osteoprogenitor cells. The maturation of pre-osteoblasts to osteoblasts and its attachment to the matrix's surface begins the new bone production. The extracellular fluid within the bone matrix may be affected by a shear stress induced by muscle contraction during exercise leading to bone deformations. During exercise, the gravitational forces cause shear stresses of the extracellular fluid and subsequent mechano-transduction.^[7]

Table 2**The 3 × 2 mixed design multivariate ANOVA for BMD.**

BMD	Group A (n=15)	Group B (n=15)	Group C (n=15)	Group A vs B P value* (MCID)	Group A vs C P value* (MCID)	Group B vs C P value* (MCID)
Pre-treatment	-2.16±0.18	-2.10±0.18	-2.06±0.26	.98 ^{NS} (0.12)	.592 ^{NS} (0.106)	.99 ^{NS} (0.106)
Posttreatment	-1.65±0.18	-1.66±0.17	-1.42±0.19	.99 ^{NS} (0.124)	.004 ^S (0.130)	.002 ^S (0.127)
P value** (MCID)	.001 ^S (0.034)	.001 ^S (0.037)	.001 ^S (0.06)			

* Inter-group comparison.

** Intra-group comparison of the results pre- and posttreatment. Data expressed by mean±SD, ^{NS} $P > .05$ =non-significant, ^S $P < .05$ =significant.

ANOVA = analysis of variance, BMD=bone mineral density, MCID=minimal clinically important difference, P =probability.

Also, moderate aerobic activity substantially improved serum calcium, which was consistent with other research.^[31,32] Stressful exercise appears to send calcium from the blood reserves to meet the needs of the athlete in strenuous and tiresome sports. Parathyroid hormone is responsible for managing and maintaining blood calcium concentration. Intensive stimulation from exercise and physical activity helps to activate the gland and increase serum calcium.^[32]

Moderate intensity aerobic exercise exerts substantial beneficial effects on bone formation marker and bone density accompanied by a significant decrease in the amount of bone resorption that could help in preventing or slowing down osteoporosis.^[22]

Rossouw et al^[33] stated that following exercises, the BMD change could be due to the mechanical loads applied to bones that produce strain. This strain is transmitted to the bone cells (osteoblasts, lining cells of the bone, and osteocytes) which, due to their physical associations, are well adapted to sensing load changes. An increase in cell metabolism and collagen synthesis occurs in response to mechanical pressure.

This is in consistent with the report of Neil and Ronald,^[34] who reported that resistance training has recently been recognized as a valuable therapeutic method for the treatment of a variety of chronic diseases. Resistance training has been reported to improve insulin sensitivity, daily energy expenditure, and quality of life, similar to aerobic exercise.

The results of the current study were compatible with other reviews that showing a major effect of exercise on femoral neck BMD.^[35–38] Our findings also align with those of Martyn-St James and Carroll's earlier meta-analysis^[36] who found that standardized exercise protocols of low-impact integrated loading and exercise programs could preserve BMD at the lumbar spine and femoral neck in postmenopausal women.

These results also are supported by the findings of Chodzko-Zajko et al^[39] who concluded that aerobic exercise training can be successful in counteracting age-related declines in BMD. The results of a meta-analysis of RCTs by Marques et al^[40] similarly support the effectiveness of exercise in increasing lumbar spine and femoral neck BMD in older adults.

Furthermore, higher statistical results were noticed in the combined group; the prominent effects of both modalities may augment the bone density that could be explained as a result of boosting effect on osteoblastic growth and bone remodeling. To the best of our knowledge, this is one of the earliest studies to examine the impact of pulsed magnetic therapy combined with moderate-intensity aerobic exercise on BMD in women post-thyroidectomy. Physiotherapists may consider using this approach to improve BMD in women postthyroidectomy. Further studies are needed to examine the most appropriate parameters (intensity, frequency, and duration) of PEMF and aerobic exercises on osteoporotic patients.

The limitations of this study were the absence of secondary outcome measures as a functional scale for measuring functional changes after each intervention, which in turn may affect patients' quality of life.

5. Conclusions

According to this study results, it was concluded that the use of pulsed magnetic therapy combined with moderate-intensity aerobic exercise resulted in an improvement in BMD at the hip region than using any of the 2 modalities alone. These results

recommend physiotherapists and rehabilitation providers include both magnetic therapy and moderate-intensity aerobic exercise in the treatment of postthyroidectomy osteoporosis.

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