Effect of pulsed electromagnetic therapy versus low-level laser therapy on bone mineral density in the elderly with primary osteoporosis: a randomized, controlled trial

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Background
Osteoporosis is a major health problem in the elderly worldwide.
Aim
The aim of the present study was to evaluate and compare the effect of low-frequency pulsed electromagnetic field therapy (LFPEMFT) versus low-level laser therapy (LLLT) on bone mineral density (BMD) in osteoporotic elderly.
Patients and methods
A total of 60 participants with primary osteoporosis, aged 55–65 years, were randomly allocated into three groups: the LFPEMFT group (group I; $n=20$), the LLLT group (group II; $n=20$), and the control group (group III; $n=20$). Each treatment regimen was applied for 30 min, three times weekly for 3 months on the lumbar region. BMD was evaluated using dual-energy X-ray absorptiometry.
Results
There were significant increases in BMD in groups I and II, whereas there was a nonsignificant increase in group III ($P<0.001$, 0.001, and 0.14 for groups I, II, and III, respectively). Between groups, there were significant differences in BMD but in favor of group I ($P<0.001$). The mean values and percentages of change in BMD were –1.94±0.76 and 39.48%, –2.63±0.49 and 16.79%, and –3.19±0.54 and 0.79% in groups I, II, and III, respectively.
Conclusion
LFPEMFT and LLLT are useful therapeutic procedures to increase BMD in osteoporotic elderly. Furthermore, LFPEMFT is more effective than LLLT in increasing BMD in the elderly with primary osteoporosis.

Keywords:
elderly, electromagnetic field, laser, osteoporosis

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Introduction

Osteoporosis is a systemic disease due to an imbalance between bone resorption and formation, resulting in accelerated bone fragility [1]. Osteoporosis can be classified into two broad categories: the primary type, for which no specific etiology is known, and the secondary type, which is mainly due to chronic medical conditions, medications, and nutritional deficiencies [2].

Osteoporosis is a recognized major public health problem in both developed and developing countries. It is one of the major contributors to disability, morbidity, and mortality in older people [3]. Osteoporosis is a multifactorial progressive skeletal disorder, associated with pain, decreased mobility, disability, and disturbed quality of life [4]. As the age span and the size of the world's elderly population have increased, osteoporosis has become an important global health problem [5], and has become the fourth most common disease in aged adults.

Osteoporosis is a silent 'epidemic' that has become a major health hazard in recent years; loss of bone strength magnifies the risk of fractures that are often associated with increased morbidity, mortality, loss of function, and high economic costs [6].

Various pharmacological and nonpharmacological therapies have been developed to enhance bone mineral density (BMD) and reduce the risk of fractures in patients with osteoporosis [7]. Traditional medical treatment can partially prevent and reverse osteoporosis through enhancing bone formation and inhibiting bone resorption, but the possible side-effects and increased cost could become real limitations [8]. Nonpharmacological treatment is usually based on specifically designed physical exercise

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and physical agents that preserve and enhance BMD [9].

Pulsed electromagnetic fields (PEMFs) are subsets of electromagnetic fields that display frequencies at the lower end of the electromagnetic spectrum [10]. PEMF therapy has growing beneficial effects on many pathological conditions such as osteoporosis and osteoarthritis. PEMF application enhances BMD and reduces the incidence of osteoporotic fractures [11]. Furthermore, PEMF has been proved to improve bone biomechanical properties, prevent bone mass loss, and prevent bone microarchitecture decay [12]. Laser is light amplification by stimulated emission of radiation; it accelerates bone matrix deposition and improves vascularization, alters osteoblast and osteoclast cell activities [13], enhances fracture healing [14], and improves bone regeneration [15].

Although low-frequency pulsed electromagnetic field therapy (LFPEMFT) and low-level laser therapy (LLLT) are therapeutic modalities that have a promising anabolic effect on bone regeneration, comparison between the effects of LFPEMFT and those of LLLT on BMD in humans has not been explored so far. The aim of this study was to compare the effects of PEMF and LLLT on BMD in the elderly with primary osteoporosis.

Patients and methods

Patients

Sixty sedentary, volunteer participants of both sexes [26 (43%) men, 34 (57%) women] with established osteoporosis were recruited from Kaser El-Aini Hospital, Cairo, Egypt. Their ages ranged from 55 to 65 years, with BMI less than 30 kg/m^2. Participants were nonsmokers and led a sedentary lifestyle without participation in any exercise training for 3 months before the study. All women participants had natural menopause, parity of 1–3, and no history of ovariectomy. All participants adhered to the calcium and vitamin D medications prescribed by their physicians.Exclusion criteria included the following: participants under steroids or estrogen treatments, patients with a history of cancer, renal disease, gastrectomy, metabolic bone disease, thyroid/parathyroid disorder, and neurogenic, myopathic, or connective tissue disorders that could cause secondary osteoporosis. Patients with significant or unstable cardiac, musculoskeletal, or psychological problems were also excluded.

Sample size was calculated on the basis of an estimated large Cohen effect size (F=0.53) using 95% power and 5% significance level that determined a realistic sample size of 60 participants for this study. Patient randomization was performed through two stages: first, patients who fulfilled inclusion criteria were reported by physical therapists who did not share any other task in the study. Second, reported patients were randomly assigned into either the LFPEMFT group (group I; n=20), the LLLT group (group II; n=20), or the control group (group III; n=20) by randomly choosing an opaque envelope prepared by another independent therapist using random number generation (I, II, or III) (Fig. 1). All patients were given full explanation of the treatment protocol, and signed informed consents were obtained for participation and publication of results. This study was approved by the Ethics Committee for Scientific Research of the Faculty of Physical Therapy, Cairo University.

Evaluation

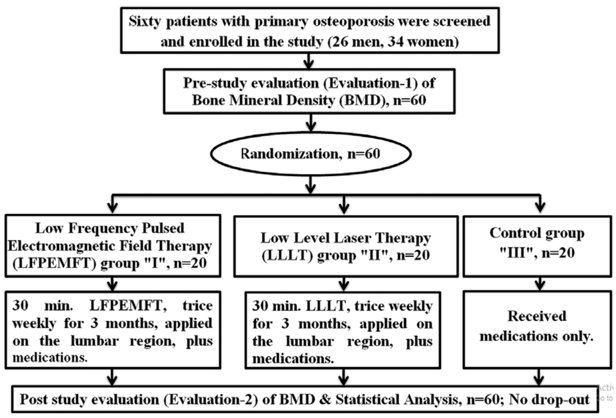
All participants underwent the same evaluation procedure. The main evaluated parameter was BMD of the lumbar spine (L1–L5) in mg/cm^2 (evaluated using DXA, Model QDR-1000W, NORLAND; Hologic Inc., Waltham, Massachusetts, USA). Evaluations of BMD using DXA were performed at baseline and after completion of the study by a specialized physician who was blinded to allocations and treatments throughout the study. All patients' data were collected using standard laboratory procedures. Demographic data including weight (kg), height (m), and BMI (weight kg/m^2) were all recorded at baseline.

Treatment

Low-frequency pulsed electromagnetic field therapy program (for group I; n=20)

Participants in group I received low-intensity LFPEMFT using Fisiofield Maxi (Fisioline s.r.l., Verduno, Italy)

Figure 1



Participant flowchart. BMD, bone mineral density; LFPEMFT, low-frequency pulsed electromagnetic field therapy; LLLT, low-level laser therapy exposure system comprised of one 60-cm solenoid for 30 min/session, 3 sessions/week for 3 months. The patient was placed in a comfortable supine position. After properly cleaning the skin with alcohol, the solenoids were adjusted and positioned under the lumbar region with a very low frequency of 33 Hz and a very low intensity of 40 Gauss, with the rectangular waveform.

Low-level laser therapy program (for group II; n=20)

Participants in group II received the LLLT 'GaAl-type diode laser' program for 30 min/session, 3 sessions/week for 3 months. The BTL-BTL-5110 (Ga–Al–Ar) infrared LLLT Laser Apparatus (BTL Industries, Inc. United States) was used to deliver LLLT. The patient was placed in a comfortable prone position on a plinth. The lumbar area was completely exposed and cleaned using alcohol. The patients' and the operator's eyes were protected by goggles at all times. Laser was irradiated to the lumbar vertebrae (L1–L5) using the following laser parameters: He–Ne and IR laser with wavelength of 904 nm, frequency of 3000 Hz, power output of 25 mW, and beam diameter of 1.5 mm. The delivery technique for this group was automatic scanning with an energy density of 4 J/cm^2. Laser scan over the lumbar region was performed by adjusting the laser-scanned area with amplitude–frequency adjustments of horizontal and vertical scanning.

Control group (group III; n=20)

Participants of the control group received only medications.

Statistical analysis

Statistical analyses were performed using SPSS software (version 16.0; SPSS Inc., Chicago, Illinois, USA). The mean changes in BMD within and between groups at the two evaluation points were analyzed using 2×3 repeated-measures analysis of variance with two within-subjects factors – treatment (LFPEMFT, LLLT, control) and time (before and after) – to test the hypothesis within and between groups. Repeated-measures analysis of variance with a Greenhouse–Geisser correction was used to determine whether there was a statistically significant difference in mean values of the measured variable between the two evaluation points. Post-hoc tests using the Bonferroni correction were carried out after that. The χ^2-test of independence was used to test for equality of proportions between populations. The level of significance was set at *P*-value less than 0.05.

Results

Sixty participants with primary osteoporosis participated in this study. The general characteristics of the three groups at baseline (age, body weight, height, and BMI) are shown in Table 1. There were no significant differences between the three groups with respect to demographic characteristics. Prestudy results showed that the BMD mean values were −3.11±0.61, −3.22±0.53, and −3.22±0.57 mg/cm^2 for the LFPEMFT, LLLT, and control groups, respectively. Prestudy results also showed that there was a nonsignificant difference between the three groups with regard to BMD mean values (P=0.76). Collected data from the three groups were compared within and between groups.

Within-group comparison showed that there was a significant increase in the mean BMD value by 39.48% within the LFPEMFT group (P<0.001), a significant increase in the mean BMD value by 16.79% within the LLLT group (P=0.001), and there was a nonsignificant decrease in the mean BMD value by −0.79% within the control group (P=0.14). Between-group comparisons clarified that there were significant differences in poststudy mean values (P<0.001) and mean percent changes (P<0.001) of BMD (Table 2 and Fig. 2). Bonferroni's post-hoc multiple comparisons revealed that there were significant differences between groups in mean BMD values, but in favor of the LFPEMFT group. Bonferroni's post-hoc multiple comparisons of post-study mean values of BMD revealed that there were significant differences between LFPEMFT and LLLT groups (P=0.03), significant differences between LFPEMFT and control groups (P<0.001), and significant differences between LLLT and control groups (P=0.04). Results of the χ^2-test of independence in this study revealed no significant association between BMD and participants' sex (P=0.12).

Table 1 Demographic characteristics of all groups (before study)

Characters	LFPEMFT group I (mean±SD)	LLLT group II (mean±SD)	Control group III (mean±SD)	*P*-value
Age (years)	59.85±2.35	60.2±2.17	60±2.62	0.9**
Weight (kg)	70.55±5.44	69.7±4.34	70.1±3.77	0.84**
Height (m)	1.59±0.05	1.58±0.04	1.57±0.04	0.68**
BMI (kg/m^2)	28.05±1.09	27.84±1.21	28.3±0.64	0.76**

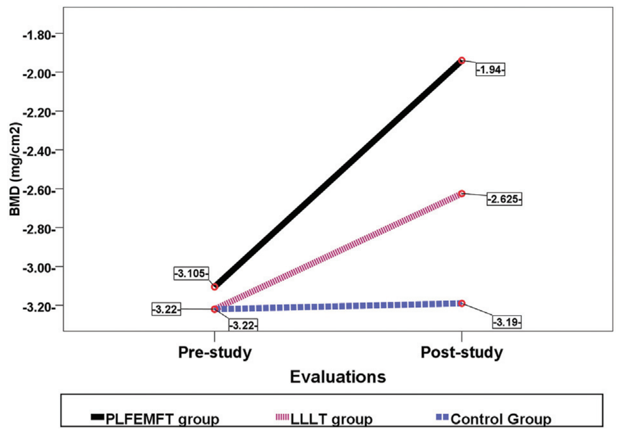
LFPEMFT, low-frequency pulsed electromagnetic field therapy; LLLT, low-level laser therapy. Level of significance at P<0.05.
**Nonsignificant.

Table 2 Repeated-measures analysis of variance, within-group and between-group comparisons of mean values of bone mineral density (mg/cm²) for all groups

	LFPEMFT group I (*n*=20)		LLLT group (II (*n*=20)		Control group III (*n*=20)	
	Prestudy	Poststudy	Prestudy	Poststudy	Prestudy	Poststudy
Mean±SD	−3.11±0.61	−1.94±0.76	−3.22±0.53	−2.63±0.49	−3.22±0.57	−3.19±0.54
P-values	$P<0.001$*		0.001*		0.14**	
Treatment group			0.02*			
Time			<0.001*			
Treatment×time			<0.001*			

LFPEMFT, low-frequency pulsed electromagnetic field therapy; LLLT, low-level laser therapy. Level of significance at $P<0.05$. *Significant. **Nonsignificant.

Figure 2



Between-group comparison of bone mineral density (BMD) mean values. LFPEMFT, low-frequency pulsed electromagnetic field therapy; LLLT, low-level laser therapy

Discussion

This study was designed to determine and compare the effectiveness of LFPEMFT versus LLLT on BMD in the elderly with primary osteoporosis. At the end of the study, the results showed that, although both LFPEMFT and LLLT were effective in improving BMD in the elderly with osteoporosis, LFPEMFT was more effective than LLLT. In the present study, the effect of LFPEMFT was investigated and compared with LLLT on BMD in the elderly with osteoporosis. Although many studies have been performed on the effects of PEMFs or LLLT on BMD, both *in vivo* and *in vitro*, the results are still controversial, and no definite conclusion exists about which among them is better in increasing BMD in the elderly with osteoporosis.

LFPEMFT is a safe therapeutic modality for elderly patients with osteoporosis [4]. Although many of the following supporting results were not tested in the present study, they serve well to explain the beneficial effect of either LFPEMFT or LLLT on the evaluated outcomes in the present study. Regarding LFPEMFT, results of the present study are in accordance with the study by Glazer *et al.* [16], who investigated the effects of LFPEMFT on bone synthesis, and concluded that the use of LFPEMFT enhances osteogenesis and bone union even in nonunion bone fractures through the effects of its physical forces [17]. The results of the present study regarding effects of LFPEMFT on bone formation were further supported by the results of previous studies, which proved that LFPEMFT can effectively stimulate bone marker gene expression [18] and transforming growth factor β1 [19]. The effect of LFPEMFT was not only limited to stimulate localized bone remodeling but also extended to enhance the supporting vital elements; LFPEMFT can positively affect bone matrix synthesis and vascularization [20]. LFPEMFT stimulates bone formation by altering DNA synthesis in osteoblasts, leading to increasing cell proliferation and differentiation [21], and by increasing alkaline phosphatase (ALP) expression at the early stages of osteogenesis [22].

Many practical clues were settled to explain the ‘previous and present’ positively established effects of LFPEMFT on BMD and bone repair. Electromagnetic field influences bone tissue by enhancing calcification of the fibrocartilage, expanding the blood supply that emerges because of the impact of the electromagnetic field on ionic calcium channels, and finally expanding the rate of bone arrangement by osteoblasts [23]. Another important explanation for the favorable effects of the LFPEMFT on BMD is through its piezoelectric potentials brought about by mechanical deformation that creates fluid and ion motion through the bone as well as electric streams generated in the bone or muscle tissue [24]. Application of LFPEMFT on the osteoporotic area in elderly patients can favorably affect BMD. This can be attributed in part to the fact that LFPEMFT can positively affect enzyme-based processes at the cellular level and stimulate growth factors involved in cellular repair and bone formation [25]. Every cell membrane carries an electromagnetic charge, and LFPEMFT alters this charge by causing movement of ions across the cell membrane. In addition, LFPEMFT has been shown to exert an anti-inflammatory effect through the restoration of plasma membrane calcium

ATPase activity [26]. The results of this study are in agreement with those obtained from a study conducted by NASA, and showed that very low-level PEMFs upregulate genes involved in normal cell growth [27] – a process that can provide a countermeasure for the muscle atrophy and bone loss encountered during space trips [28].

Quiet recently, the biostimulation of bone repair by using laser has increased. Numerous studies have demonstrated the positive effect of laser on healing of bone tissue [29]. LLLT proved to be effective in improving ALP enzyme activity, enhancing cell proliferation, and increasing bone matrix production in rat marrow cells [30]. LLLT application favorably affects BMD in the elderly with osteoporosis. This is in accordance with Diniz *et al.* [31], who reported that LLLT can significantly increase bisphosphonate and trabecular bone volume in the vertebrae of osteopenic rats. Application of GaAlAs infrared diode laser proved to enhance bone synthesis in osteoporotic as well as in normal rats [32]. LLLT is effective in increasing bone components and parameters even in the presence of comorbidities other than osteoporosis. Application of LLLT on diabetic rats increased cortical area representation, bone mineral content, and BMD [33]. LLLT is also effective in improving human osteoblast-like cells attachments, proliferative activities, and differentiation of surrounding an implant material [34].

LLLT can effectively alter cellular functions by increasing the activity of cytochrome oxidase and ATP in the mitochondrial respiratory chain [35] and can accelerate bone formation by increasing local vascularization [36] and organization of collagen fibers [37]. The interaction between tissue and laser radiation alters the mechanics of the cell microenvironment, thus acting on the cells as mechanical stress [38].

The results of this study are in agreement with a previously published study that reported laser therapy improves the bone repair process by accelerating bone formation, increasing angiogenesis, and collagen deposition rates in osteoporotic rats [39]. The significant increase in BMD in response to laser radiation can be attributed to improved bone repair secondary to stimulation of the newly formed bone, fibrovascularization, and angiogenesis in osteoporotic bones [40].

Application of laser therapy has the ability to accelerate the process of fracture repair by increasing callus volume and BMD, especially in the early stages of bone remodeling. LLLT also has a positive effect on osteogenesis in osteopenic rats, increasing bone strength, calcium content, and BMD of the irradiated area [41]. LLLT has stimulatory effects on osteoblast-like cells, increasing its viability [42], DNA and RNA synthesis, bone nodule formation [43], ALP activity, and expressions of osteopontin and collagen type-I mRNA [44]. Moreover, Diniz *et al.* [31] demonstrated that the association between bisphosphonate and LLLT increases trabecular bone volume in the vertebrae of osteopenic rats in an additive manner.

In contrast to results of this study, Coombe *et al.* [45], reported that application of diode laser of 830 nm has no cellular activity-modulating effects. The conflict can be simply resolved by taking into account that cellular activity biomodulation in response to laser irradiation depends on a group of parameters including wavelength, energy density, and power density [44,46]. The negative results obtained in some studies on the use of laser irradiation for bone regeneration may be attributed to very low levels and inadequate wavelength [47]. Limitations of this study that should be considered include lack of double blinding and follow-up studies; it was impossible to blind the patients or the therapist to the treatment. The results of the present study confirmed the effectiveness of LFPEMFT and LLLT as therapeutic modalities in alleviating the negative impact of osteoporosis in the elderly. Furthermore, when we are treating osteoporosis in the elderly, LFPEMFT should be more preferable than LLLT, as LFPEMFT proved to be more effective than LLLT in increasing BMD and in gaining more favorable outcomes.

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Nil.

Conflicts of interest
There are no conflicts of interest.

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