The Effect of Different Frequencies of Interferential Current on Bone Mineral Density on Osteoporotic Postmenopausal Women

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ABSTRACT

The aim of this current study was to investigate the physiological effect of different frequencies interferential therapy (IFT) directly upon BMD and indirectly on gait in osteoporotic postmenopausal women. Forty-five postmenopausal osteoporotic women their age ranged from 55-67 years were divided randomly into three equal groups, receiving IFT with different frequencies for 6 months. IFT_I group received frequency (10-100Hz), IFT_{II} group (80-100Hz) and IFT_{III} group (10-20Hz). Dual energy absorptiometry (DEXA) was used for assessment of BMD and Qualysis Gait Analysis System was used for assessment of gait parameters (Kinematics analysis) before and after 3 and 6 months of treatment. The results of the study demonstrated the superiority of low frequency IFT (10-20 Hz) to increase BMD and improve the gait parameters in postmenopausal osteoporotic women. Further research is recommended in this area to examine long term effectiveness with the same treatment parameters.
Key words: *Postmenopausal, Bone Mineral Density, Interferential therapy, osteoporosis, gait.*

INTRODUCTION

Osteoporosis is become the most common disorder of our aging population. The incidence of osteoporosis is critical if successfully minimize the impact of this disorder on morbidity, mortality and the cost of health cares[28]. However, osteoporosis is characterized as a condition resulting in low bone mass and micro-architectural deterioration of bone tissue leading to bone fragility and an increase in fracture risk[23]. The racial, ethnic and geographic differences in bone mineral density (BMD) which is the result of balance between bone resorption and bone formation, but the differences are often relatively small, suggesting that other architectural or metabolic differences in the skeleton is an important contribution[25].

Osteoporosis can result pathogenically from inadequate peak bone mass, excessive bone resorption, or impaired bone formation. These can be affected by genetics, nutrition, lifestyle, systemic hormones and local factors[13]. Loss of sex hormones is critical in the pathogenesis of both postmenopausal and age related bone loss, also physical activity has been implicated as one of the major contributing factors. Estrogen deficiency plays the major role and the loss of estrogen at menopause, which is the main reason, that cause osteoporosis to be more common in women than men. It is more rapid in the trabecular bone which is found mainly in lower thoracic and lumbar spine, than in cortical bone in the axial skeleton[17]. Also, after menopause the muscle strength decreased specially the extensors that affecting the gait parameters, in which reduced muscle strength had been highly associated with altering the stride characteristics[30].

Gait is a functional task requiring complex interactions and coordination between neuromuscular and structural elements of the locomotor system[22]. Abnormal gait may result from disorder in any part of these systems, including the brain, spinal cord, nerves, muscles, joints and skeleton[29].

A full gait cycle is defined by the occurrence of sequential stance and swing phase. Stance phase occupies 60% and the swing phase occupies 40%of the walking gait cycle[3].

Gait analysis has evolved into a recognizing medical evaluation that is necessary for appropriate planning of surgery or other therapeutic interventions in the management of musculoskeletal conditions[1]. It was reported in the literature that gait speed alone is an excellent and sensitive measure of walking performance and closely related to clinical outcome or to functional health. While gait analysis providing profile across strides would yield the desired descriptive information for deficiencies in muscle work and potential for comparison[24].

Stride analysis is used to calculate basic-time distance variables. These variables are derived from temporal and spatial occurrence of the stance and swing phase. A spatial parameters are a spatial measure of foot contact during gait cycle and include stride length, stride width and angle of progression. The temporal parameters reflect the timing of events in the gait cycle that include stance time, swing time, single support, double support and the entire gait cycle time[29].

Prevention and treatment of osteoporosis focus on three main areas, nutrition (calcium intake), hormone therapy and/or other drugs and therapeutic modalities (exercise, electrical [28]. Therapeutic modalities have the potential to play an important role in the management of osteoporosis both in maintenance of and increase bone density[14].

Interferential therapy (IFT) is a popular non pharmacological modality for the management of pain[9]. A variation of IFS, with superimposed duty cycle, is used to reeducate muscle and to augment muscular strength[7]. Also, it is used for reducing edema[2], promoting of tissue and bone healing[6,11,12,16] and treatment of incontinence[15]. It involves the application of two slightly different medium frequency currents that interfere with each other within the tissues to produce a resultant low beat frequency[21]. Few studies have examined the neurophysiologic effects of IFT, or indeed, its efficacy.

Despite the popularity of IFT, no controlled studies have been completed to date that investigate the relative effect of different frequencies in the management of osteoporosis. Therefore, the present study was designed as a prerequisite to such clinical research as an attempt to establish the putative relevance of parameter manipulation. In the present study, three individual stimulation frequencies (10-100, 80-100 and 10-20Hz) commonly used in clinical practice were investigated to determine the physiological effect of IFT directly upon BMD and indirectly on gait in osteoporotic postmenopausal women and to monitor any frequency specific effects of IFS.

SUBJECTS, MATERIALS AND METHODS

Subjects

Forty-five consecutive women with established postmenopausal osteoporosis type I were enrolled in this study from Al Galaa Educational Hospital.

The criteria for diagnosis of osteoporosis was a BMD at the lumbar spine, neck of femur and greater trochanter below the standard deviations by -2.5 of the normal adult women at the same age. While the criteria for inclusion were as follows: (a) no evidence of compression fractures in the lumbar vertebrae and/or neck of femur, (b) age between 55 to 67 years, (c) body mass index not exceeding 30 Kg/m^2, (c) did not receive any medications associated with accelerated bone loss (corticosteroids) or affected bone metabolism (calcium, vitamin D and estrogen supplementation) and (e) no history of renal diseases, metabolic bone diseases or any condition that could cause type II osteoporosis.

Detailed medical histories were obtained that included parity (not more than three times), age at menopause and any previous illness. Patients were divided randomly into three equal groups.

Instrumentation

1- The muscle stimulator used throughout this study was an Endomed 433 medium frequency IFS with a medium frequency output of either 2 or 4KHz. According to the manufacturer, the amplitude modulated frequency spectrum (interference frequency) was adjustable between 0-100Hz according to the study group and four suction electrodes connected with it. The force of maximum muscle contraction was adjusted according to the tolerance of each patient.

2- Dual energy absorptiometry (DEXA) was used for detection of lumbar spines (L_{1-5}), neck of femur and greater trochanter BMD.

3- Qualysis Gait Analysis System, is a Q Trac software consists of the following parts: 6 cameras, a wand- kit used for calibration of the system, an ACB-530 serial interface adapter and APC computer with Q Trac software installed. This system allows Qualysis Gait Manager (QGM) which is a 3D gait analysis software that has been customized for use with Qualysis motion capture system to calculate the global gait parameters (Kinematics analysis).

Procedures

A- Procedures for evaluation

1- BMD of lumbar spines (L_{1-5}), neck of femur and greater trochanter of both lower limbs were measured by DEXA, then mean for both limb BMD at neck of femur and greater trochanter were calculated.

2- Global gait parameters (Kinematics analysis), it was performed in the laboratory gait evaluation at Faculty of Physical Therapy. In which three-dimensional kinematics were collected at a sampling rate of 100 Hz. Reflecting markers of size 8mm were placed bilaterally on each woman as in the model figure (1).

The patient was instructed to walk at their natural speed toward a target located at the end of the walking. A few practice trials were carried out before data acquisition in order to get the natural speed. At least three successful trials were recorded for subsequent analysis. After that analysis was done automatically to find the gait speed, cadence, stride length, stance phase and swing phase.

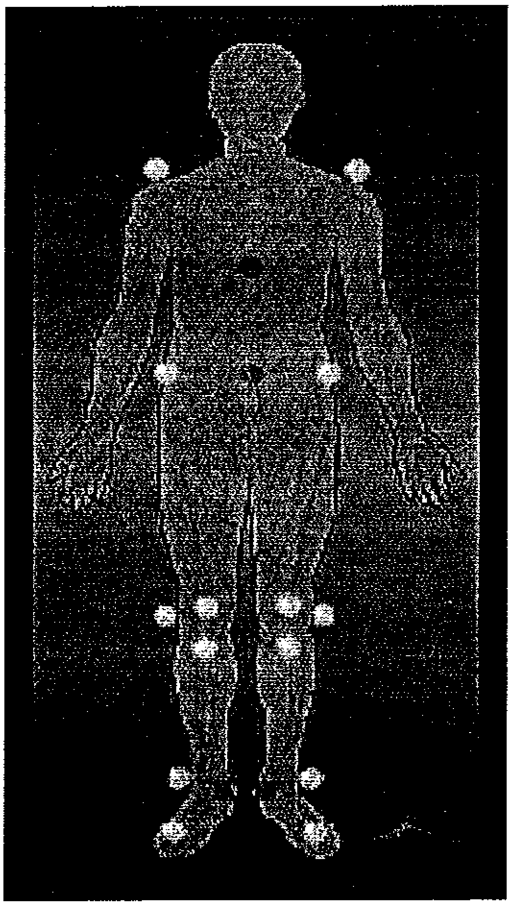

Fig. (1): Diagrammatic representation for the placing sites of the reflecting markers used during gait analysis. Adapted from Medical AB Sweden.

Evaluations of BMD and gait parameters were measured pre treatment, after three months and at the end of six months of treatment.

B- Procedures for treatment

Each patient attended three treatment sessions per week on alternative days during six consecutive months. Each treatment session consisted of 20 minutes periods of IFS on the lumbar region. For the treatment, the patient was assumed to be in the prone lying position on a padded wooden treatment table with a thin cushion under the pelvic region to flatten the lumbar spine and another small one under the ankle joints for maintenance of relaxation. To obtain IFS, two medium frequency currents were introduced into the underlying tissue separately so that they cross in the treatment field perpendicular to each other. For that purpose four leads with four suction electrodes ($10cm^2$) were applied, two each circuit. The suction electrodes were placed diagonally at the level of lumbar (L_{1-5}), each electrode was placed bilaterally 5cm away from the lumbar spinous process. At the

completely distinct currents of medium frequency within the tissues was produced a new biological active low frequency current.

Suction pressure was pulsed at the highest level of pulses per minute (60PPm) at intensity high enough to securely attach the electrode to the skin of the patient.

The current study included three experimental groups that span a wide frequency spectrum to examine the relevance of frequency modulation to observe any physiological effects. IFS was applied for 20 minutes via four suction electrodes and the carrier frequency was set at 4KHz. The pulse duration was fixed at 125s . Treatment parameters for each of the experimental groups are summarized in table (1). The average intensity dose of IFS between 4-50 mA was applied and was increased to each patient until she reported a strong but comfortable sensation, and this was maintained throughout the treatment time according to the protocol of Noble and Associates, (2000)[21].

Table (1): Summary of the treatment parameters for all experimental groups.

Treatment groups	Beat frequency	Sweep	Rotating vector system	Suction
IFT_I	10-100Hz	6/6	Active	Yes
IFT_{II}	80-100Hz	6/6	Active	Yes
IFT_{III}	10-20Hz	6/6	Off	Yes

C- Data analysis

The results were analyzed using repeated measures and one factor analysis of variance (ANOVA) and T test to determine whether observed changes between conditions were statistically significant ($P<0.05$).

RESULTS

Subject characteristics are summarized in table (2). In which there were no significant differences in age, height, weight and BMI between three groups (IFT_I, IFT_{II} and IFT_{III}).

Table (2): Subject characteristics of the three groups.

Treatment groups	Age (yrs)	Height (cm)	Weight (Kg)	BMI (Kg/m^2)
IFT_I	64.5 5.3	159.8 5.9	73.6 8.9	29.7 2.7
IFT_{II}	63.9 5.8	160.2 6.3	76.5 9.5	28.6 1.9
IFT_{III}	65.1 5.5	158.6 7.1	75.2 7.7	29.9 2.2

In the present study, the response of BMD to IFS was investigated. The data collected from the three groups after three and six months of IFS were compared with the pre treatment. As revealed from table (3) and figure (2), the baseline raw data of all patients showed non significant differences between the three groups ($P<0.75$), therefore confirming that baseline values of the BMD at Lumbar (L_{1-5}), neck of femur and greater trochanter were comparable. Results showed a slight increase in BMD in IFT_I group and $IFTI_{II}$ group while, in the IFT_{III} (10-20 Hz) group, there was a dramatic increase in BMD at all examined areas between before and after 3 and 6 months of IFS. When comparing between the three groups, there was a significant difference in BMD ($P<0.03$) after 3 months of IFS and after 6 months ($P<0.001$). Additionally, BMD at all examined areas showed significant increase in the IFT_{III} group at 3 and 6 months of treatment when compared to all other experimental groups (IFT_I and $IFTI_{II}$).

Table (3): BMD at lumbar spine, neck of femur and greater trochanter of the three groups.

Variables		IFT_I group			IFT_{II} group			IFT_{III} group		
		Pre treatment	Post three months of treatment	Post six months of treatment	Pre treatment	Post three months of treatment	Post six months of treatment	Pre treatment	Post three months of treatment	Post six months of treatment
Lumbar BMD of L_{1-5} (mg/cm^2)	Mean	0.658	0.728	0.881	0.642	0.73	0.865	0.653	0.783	0.953
	S.D.	0.043	0.041	0.055	0.024	0.056	0.042	0.064	0.067	0.030
	T value	1.560		1.941	1.78		1.965	2.327		2.170
	Level of significance	0.2		0.09	0.32		0.09	0.05*		0.05*
BMD of the neck of femur (mg/cm^2)	Mean	0.583	0.651	0.733	0.579	0.621	0.712	0.592	0.682	0.788
	S.D.	0.031	0.025	0.034	0.023	0.028	0.035	0.033	0.036	0.037
	T value	1.397		1.958	1.255		1.872	2.255		2.744
	Level of significance	0.22		0.09	0.2		0.12	0.05		0.02*
BMD of the greater trochanter (mg/cm^2)	Mean	0.517	0.560	0.613	0.502	0.559	0.609	0.520	0.591	0.632
	S.D.	0.044	0.025	0.015	0.030	0.029	0.018	0.030	0.029	0.018
	T value	1.055		1.241	1.220		1.910	1.220		2.450
	Level of significance	0.2		0.24	0.2		0.09	0.2		0.05*

The spatiotemporal parameters reported in the present study were considered as measures of gait analysis. As indicated in table (4), patients in the three groups showed non significant difference at baseline values. While after the end of 3 and 6 months of treatment there was a very slight increase in the walking speed, cadence, stride length and duration of the swing phase with decrease in the duration of the stance phase in IFT_I group and $IFTI_{II}$ group, while in IFT_{III} group after 6 months of treatment a remarkable increase was found. The previous changes were showed non significant differences between pre and post 3 and 6 months of treatment in the three groups.

Table (4): Gait parameters of the three groups.

Variables		IFT_I group			IFT_{II} group			IFT_{III} group		
		Pre treatment	Post three months of treatment	Post six months of treatment	Pre treatment	Post three months of treatment	Post six months of treatment	Pre treatment	Post three months of treatment	Post six months of treatment
Gait speed (m/s)	Mean	1.05	1.11	1.19	1.07	1.10	1.22	1.03	1.09	1.25
	S.D.	0.24	0.23	0.11	0.12	0.24	0.18	0.16	0.12	0.21
Cadence (steps/min.)	Mean	106.3	111.9	113.4	106.1	112.1	116.6	108.1	110.8	112.6
	S.D.	8.5	6.3	5.7	7.4	6.6	5.9	8.7	7.5	6.7
Stride length (m)	Mean	0.93	1.0	1.1	0.91	0.99	1.2	0.94	1.2	1.3
	S.D.	0.15	0.32	0.17	0.21	0.16	0.18	0.17	0.19	0.22
Stance phase (%)	Mean	67.8	65.9	65.8	66.9	66.1	65.6	66.8	65.3	64.6
	S.D.	3.4	2.7	1.3	1.9	2.5	1.8	2.8	3.1	2.7
Swing phase (%)	Mean	32.2	34.1	34.2	33.1	33.9	34.4	33.2	34.7	35.4
	S.D.	2.8	1.9	1.8	5	2.0	2.5	2.2	2.1	2.3

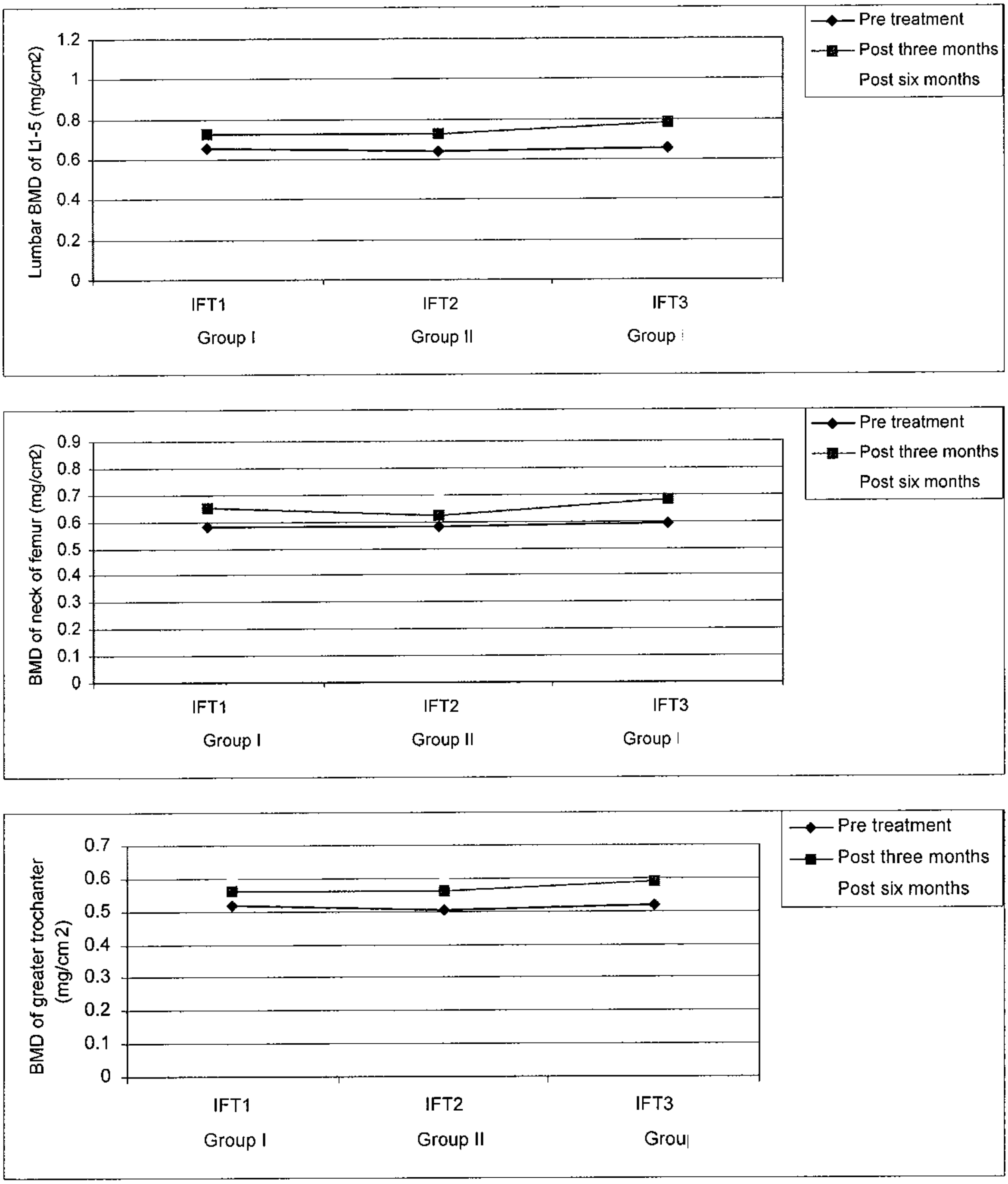

Fig. (2): BMD at (a) lumbar, (b) neck of femur and (c) greater trochanter plotted against time of treatment in months for all groups.

DISCUSSION

All through the history of the humanity, attempts to combat pain have not stopped and will never stop, as long as, there is life on earth. The primary problem in postmenopausal with osteoporosis is thought to be enhancement of bone resorption, with consequent net loss of bone mass as osteoblasts fail to repair the defect completely which increase the risk to fracture[17]. The basic problem in the remodeling of bone is directly related to the stimulation, multiplication and proliferation of the extraperiosteal, periosteal and medullar connective tissue that forms reparative blastemas leading to the consolidation of the bone[28].

In our field, this is the first study to investigate a direct effect of different frequencies of IFS on BMD in postmenopausal osteoporotic women.

The results of this study demonstrated no statistically significant difference in IFT_I group (10-100Hz) and $IFTI_{II}$ group (80-100Hz) on BMD at Lumbar (L_{1-5}), neck of femur and greater trochanter, while in IFT_{III} (10-20Hz) group there was a significant increase after 6 months of treatment when compared to the pre stimulation values.

The problem of the effect of different frequencies of IFT has not yet been fully elucidated. Despite the obvious lack of puplished experimentally based research to provide evidence for its proposed effects, which make difficulties for comparison. Various authors have postulated that the process of bone healing and/or remodeling might be stimulated by IFT which is reported in our results.

IFT has been found to modulate various process in various biological system[7]. Most of the electrical stimulation is a frequency dependent which is the reason for failure of physiotherapy management. It was reported that the whole frequency range (as in IFT_I group) has predominately stimulating effect, combined with analgesic one. This frequency often results in active hyperemia, acceleration of lymph flow and activation of cell functions and it enables the restoration of normal tissue reactions. It addition to activation of electrolyte metabolism (Ca, K and Na)[27]. While the high frequency range (as in IFT_{II} group) has a suppressing effect on the sympathatic segment of the autonomic nervous system[7], the low frequency range (as in IFT_{III} group) are motor stimulating and cause muscle contraction[4], thus favorable effect on trophism has been observed by activating tissue functions. Nikolova et al., (1987)[20] reported that IFS retain the collagenisation of the reticulum due to intense oxidation, improved trophism and normalization of the mucopolysaccharide and collagen protein metabolism. Also, it has been found that the usage of suction electrodes stimulates circulation and allows better transport of tissue fluids which enhancing their therapeutic effects. Theses previous effects were supported the results of the present study.

Osteoporosis manifested by low bone mass (porous bone) and microarchitectural deterioration of bone tissue leading to bone fragility and an increase in fracture risk, in addition to non-equilibrium of the Haversian basic multicellular units that is responsible for normal bone remodeling[25]. Laabs et al., (1982_b)[12] investigated the effect of dynamic interferential current on bone healing and concluded that there was altering of the temperature in the treated tissue and increase the occurrence of hydroxyproline and amino acid specific collagen which also, reflected increased calcified activity at the site of fracture (radius bone) . At the same year, acceleration of callus formation with strong mineralization and stimulation of both endosteal and periosteal callus formation by IFS was confirmed experimentally by Laabs, (1982_a)[11].

Also, Schubert et al., (1986)[26] reported that IFT leads to shortening of fracture healing periods by skipping the physiologically occurring delay of the Haversian remodeling in fracture. In addition, May et al., (1985)[16] confirmed by histological, chemical, radiological and electron microscopic evaluations the higher mineralization of the new bone, the extracellular alkaline phosphatase and the earlier the weight bearing in animal experiments with standardized artificial fractures after IFS.

Regarding to the time of treatment, Fourie and Bowerbank, (1997)[5] found no significant reduction of the healing time of the tibial fracture. These authors applied IFS via suction electrode for 30 minutes/day for only 10 days with beat frequency 10-25Hz and swing mode of 6/6. In 1998, Fouria and Thompson[6] replicated the previous study with different long period of treatment and stated that IFS for six months has most suitable time for healing of tibial fracture. These authors used the same parameters in our study except for only short period (10 days) while the present study used 6 months for treatment which coincide with the replicated study of Fourie with Thompson, (1998)[6] which recommended 6 months as best time for management of healing.

Also, Nikolova, (1992)[19] found a positive recovery in patients with forearm fractures with sudeck atrophy and attributed his results to recovery of normal blood flow and microcirculation in the region of bone atrophy. Accelerated recovery of the limb functions after the use of IFT in the rehabilitated treatment of patient with fracture of the leg bones was reported by Chukina et al., (1995)[2] and attributed their results to the stimulating effect of involuntary muscular activity, reduce tissue edema and increase mobility of ankle joint.

Many authors had reported a relationship between increase muscle strength and increasing BMD[17,18] which attributed it to the mechanical effect of muscle contraction on the bone that stimulate osteoblastic deposition of bone. The deposition of bone at the stressed area has been suggested to be caused by pizoelectric force[8]. So, the results of our study could be attributed to the role of IFS that make repeated passage of excitation over the same neural pathways makes it progressively easier for subsequent transmission through decreasing the synaptic impedance along the neural pathway. All this activates the muscle and enables the process of stronger muscular contraction and inturn improve muscle performance as observed during muscle contraction[10]. Moreover, IFS could augment the muscle strength via increasing the recruitment order of type II fibers and become resembles to type I which is necessary for muscle strength[7,15].

Regarding to the gait analysis, the present study revealed a statistically non significant differences in all gait parameters between before and after 6 months of treatment in all groups in spite of slight improvement of all parameters in IFT_{III} group. At that point there is a deficiency in the published research concerning the effect of IFS on gait parameters in postmenopausal osteoporotic women. But, it was believed that IFS could augment the strength of the muscles[7,15] and reduced pain[9] that might be necessary for postmenopausal osteoporotic women to improve their gait as occur in the present study.

CONCLUSION

Although osteoporosis is a primary metabolic disease of bone and a major public health problem that mostly occurs in postmenopausal period, there is no cure of it. Therapy should be directed primarily toward increasing physical activity, reducing the risk of falling and secondarily toward stabilizing bone mass. The results of this study demonstrated the superiority of low frequency IFT (10-20Hz) to increase BMD and improve gait in postmenopausal osteoporotic women.

Although the findings of this study are significant increase in BMD, but treatment of low bone mass might not be effective enough to guarantee that any gains in mass will be of sufficient magnitude to reduce fracture risk significantly, so further research is required to examine long term effectiveness of the treatment and combine it with physical activity that reported its effectiveness on bone repair in literatures.

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الملخص العربي

تأثير الترددات المختلفة للتيار الكهربائي المتداخل على كثافة العظام لدى السيدات بعد انقطاع الطمث مع وجود هشاشة في العظام

الهدف من هذا البحث هو دراسة التأثير المباشر للترددات المختلفة للعلاج بالتيار الكهربائي المتداخل على كثافة العظام و الغير مباشر على بعض مقومات المشي لدى السيدات بعد انقطاع الطمث مع وجود هشاشة فى العظام. وقد اقتصرت الدراسة على ٤٥ مريضة بهشاشة العظام و تم تقسيمهن عشوائيا إلى ثلاث مجموعات متساوية العدد. و تم علاج المجموعة الأولى و الثانية و الثالثة بالتيار الكهربائى المتداخل بتردد قدرة ١٠-١٠٠, ٨٠-١٠٠ , ١٠-٢٠ هرتز على التوالى لمدة ستة أشهر على المنطقة القطنية. تم تقييم الحالات قبل و بعد ثلاثة و ستة أشهر من العلاج باستخدام جهاز الديكسا و جهاز ثلاثى الأبعاد للتحليل الحركى للمشى. و قد أظهرت نتائج البحث أن التردد المنخفض من ١٠-٢٠ هرتز أدى إلى زيادة كثافة العظام وتحسن فى مقومات المشى فى العينة المستخدمة أكثر من الترددات الأخرى المستخدمة فى الدراسة.

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الملخص العربي

تأثير الترددات المختلفة للتيار الكهربائى المتداخل على كثافة العظام لدى السيدات بعد انقطاع الطمث مع وجود هشاشة في العظام

الهدف من هذا البحث هو دراسة التأثير المباشر للترددات المختلفة للعلاج بالتيار الكهربائي المتداخل على كثافة العظـــام و الغـــير مباشر على بعض مقومات المشي لدى السيدات بعد انقطاع الطمث مع وجود هشاشة فى العظام. وقد اقتصرت الدراسة على ٤٥ مريضـــة بهشاشة العظام و تم تقسيمهن عشوائيا إلى ثلاث مجموعات متساوية العدد. و تم علاج المجموعة الأولـــــى و الثانيـــة و الثالثـــة بالتيـــار الكهربائى المتداخل بتردد قدرة ١٠-١٠٠, ٨٠-١٠٠ , ١٠-٢٠ هرتز على التوالى لمدة ستة أشهر على المنطقة القطنية. تم تقييم الحالات قبل و بعد ثلاثة و ستة أشهر من العلاج باستخدام جهاز الديكسا و جهاز ثلاثى الأبعاد للتحليل الحركى للمشى. و قد أظهرت نتائج البحـــث أن التردد المنخفض من ١٠-٢٠ هرتز أدى إلى زيادة كثافة العظام وتحسن فى مقومات المشى فى العينة المستخدمة أكثر من الـــــترددات الأخرى المستخدمة فى الدراسة.