The Effect of Exercise Training on Bone Mineral Density Modulation and Regional Fat Distribution in Obese Women Underwent Diet Control

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ABSTRACT

Background: *There are many beneficial effects of physical training for maximizing bone mineral density (BMD) during premenopausal and preventing bone loss during last years. The purpose of this study was to investigate the effect of exercise program (aerobic and resistive training) on bone mineral density, body weight, body mass index (BMI), and waist to hip ration (WHR) in premenopausal women underwent negative balanced diet.* ***Methods and Results:*** *Forty premenopausal women had been participated and randomly divided into two equal groups. Group I (Diet) consisted of 20 patients and instructed to have negative balanced diet under medical supervision. Group II (Diet + Exercise training) consisted of 20 patients who have been instructed to do exercise training, in addition to negative balanced diet. Aerobic training was performed for 40 minutes in the form of treadmill walking at an intensity of 65% of the increment between the resting and maximum heart rate, the resisted training was performed using free weights for major muscle groups of lower limbs. Such resisted training was performed for each muscle for twelve repetitions, with total duration of sixty minutes. Exercise training was conducted three sessions per week for twelve weeks. Anthropometric variables (weight, body mass index, and waist to hip ratio) and bone mineral density (BMD) of the femur were taken at the beginning of the study and after twelve weeks. The results showed a significant reduction of anthropometric variables for both groups, with a greater reduction for group II. Concomitant with this improvement, group II showed an increase in BMD with a percentage of 3.2% improvement. On the other hand, group I showed a significant reduction equal to 2.15% over the three months period.* ***Conclusion:*** *Addition of exercise training to negative balanced diet resulted in reduction of body weight, BMI, waist to hip ratio associated with maintenance effect on BMD in premenopausal obese women.*
Keywords: *bone mineral density, exercise training, diet, premenopausal obesity.*

INTRODUCTION

Obesity is a global health problem affecting an estimated 300 million people worldwide. Its prevalence is increasing in both developed and developing countries[29]. Obesity is characterized by excess adipose tissue, and contributes to numerous chronic diseases and early mortality. The adverse health consequences include cardiovascular disease, stroke, type 2 diabetes mellitus, hypertension, breast cancer, osteoarthritis, respiratory problems and depression[17]. Several environmental factors have been associated with obesity among adult television watching, low physical activity, lower socioeconomic status and consumption of sugar-containing beverages, skipping breakfast, and unstructured meals. Society has sometimes been described as a "toxic environment for the development of obesity"[21].The relationship between the type of food rather than total energy intake and obesity has also been explored. It was found that the contribution of soft drinks and sugar-sweetened beverages to energy intake was

higher among overweight[16]. At least three body composition components are associated with obesity-related adverse health outcomes: (1) the total amount of body fat (expressed as a percentage of body weight), (2) the amount of subcutaneous abdominal or truncal fat, and (3) the amount of visceral fat located in the abdominal cavity[13]. Excess body mass has one advantage of increasing bone mass which is a protection against osteoporosis. Probably because of this, researchers have been able to show that people who successfully lose weight, have greater loss of bone compared with those who don't lose weight and should pay more attention for preventing of osteoporosis[14].

Negative balanced diet is defined as one that is perfect blended of all essential nutrients that human body extracts from foods[12]. Negative balanced diet will help in lowering energy intake below that of energy expenditure and so it is a typical therapy for management of obesity[17].

Physical activity has been suggested as a non pharmacological intervention for maximizing BMD and bone mineral content (BMC) during premenopausal period and preventing bone loss during later years. Beside the positive effect on BMD, resisted exercises increase lean body mass, decrease body fat, and increase muscle strength[26]. It is difficult to create sufficient negative energy balance for weight loss with exercise alone. These does not mean that exercise is not important. Exercises can help to achieve a greater negative energy balance[1]. People who have successfully maintained weight loss for over two years, report continuing high levels of physical activity[27].The present study was undertaken to investigate the effect of exercise programs (aerobic and resisted training) on BMD in premenopausal obese women.

Methods

Patient population: This study involved forty premenopausal obese women selected from the different out patients clinics of Faculty of Physical Therapy. Their mean age was 36.3±3.62 and 37.15±3.46 years for group I and group II respectively.

Table (1): Baseline anthropometric characteristics of patients in group I (diet), and group II (diet plus exercise).

Variables	$\overline{X}$ ±SD	
	Group I	Group II
Age (years)	36.3±3.62	37.15±3.46
Weight (kg)	83.9±5.63	83.35±6.25
Height (cm)	159.0±4.01	159.55±4.14
BMI (Kg/m^2)	32.9±1.5	32.45±1.58
Waist to hip ratio	1.21±0.8	1.29±0.14
BMD (g/cm^2)	0.93±0.18	0.92±0.15

$\overline{X}$ =mean SD=standard deviations

Their body mass index (BMI) ranged from 30-35 kg/m^2 with average 32.9±1.5 and 32.45±1.58 kg/m^2 for groups I and group II respectively. Their mean weight was 83.9 5.63 kg for group I and 83.35±6.25 for group II. Their BMD was 0.93±0.18 g/cm^2 for group I and 0.92±0.15 for group II. The selected women were randomly assigned into two equal groups; group (I): received negative balanced diet only for three months, group (II), received negative balanced diet in addition to exercise in the form of treadmill walking and resisted

exercise program for three months. Women were excluded if they had history of bone disease, renal and liver disease, endocrinal disorders, low back pain, previous surgery at back and lower limbs, cardiac disorders, or women who participate in physical activity program on regular base.

Evaluation procedures: The evaluation procedures were conducted at the beginning and the end of the study period (three months) in the form of:

1- Weight and height measurement: The measurement was taken during fasting and wearing light clothes and barefoot. The BMI was then calculated according to the formula: BMI = weight (kg)/ height (m^2).
2- Waist and hip circumference measurement: It was evaluated over single layer of clothing with the participant standing in an erect position with feet together. For waist circumference, it was obtained at the bending point while the subject attempting to touch the ground and measurement was taken when she was returned to the upright position. For the hip circumference, it was obtained at the level of the greater trochanter over the widest part of the hip region. Waist hip ratio (WHR) was calculated as; WHR=waist circumference /hip circumference[30].
3- Bone mineral density measurement: Measurement was done by using ultrasonometer (5000 KHz) device. Before application of it, the patient was informed about the use and aim of the procedure to be familiarized with the test. The participant was instructed to put her foot on the specified place of silicon sheet for about one minute, she was in a sitting position with back supported.

Training program:

1- Diet therapy protocol:

The diet therapy principles in both groups assured that energy intake was 500 kilocalories (Kcal) below daily requirements on average of three meals. The caloric proportions of protein, fat and carbohydrates were 15%, 30% and 55% respectively. Addition of 28 grams of fibers and three liters of fluid was included daily. Each female's basal metabolic rate (BMR) was measured using body fat analyzer to determine her energy requirement during the twelve weeks of diet. The subjects were instructed not to consume large amount of water just prior to testing. The sensor pads of body fat analyzer were placed on 3rd metacarpophalangeal and 3rd metatarsophalangeal joints after cleaning these areas with soap and water. After that, each subject chose her kind of food intake from a list given to her at the beginning of the study.

2- Exercise training programs:

(a) Aerobic training:

Patients assigned in group II had a preparatory session to get familiarized with treadmill walking and exercise limiting symptoms (fatigue, breathlessness, chest pain, leg cramp) before going through the training program. Each exercise session consisted of warming up and cooling down phase on treadmill with walking speed equal to two miles per hour (mph) for five minutes at the beginning and the end of the session. The stimulus phase was designed at an intensity of 60%-80% of heart rate reserve according to karvonen formula[24]. Training heart rate = resting heart rate + 60%-80% (maximum heart rate [MHR] - resting heart rate). For each subject, MHR was estimated from age- fitness adjusted predicted maximum heart rate table. After warming up, the speed was increased to 3mph, the increased by one mph each minute

until reaching the required training heart rate. The duration of the stimulus phase was twenty minutes. During exercise, heart rate was monitored on treadmill screen and after coding down, the subjects were seated and monitored for heart rate using pulse meter until reaching the resting level.

(b) Resisted exercise training:

Resistive training was performed using free weights for lower limbs. It was consisted of strengthening exercises for major muscle groups of the hip, knee, and ankle joints with an intensity equal to 40-60% of one repetition maximum for each women. Each women performed two sets of twelve repetitions / session for each specific exercise. The one repetition maximum was re-evaluated periodically at the end of each month to readjust exercise intensity[10].

Data analysis

The percentage of change was calculated as; % of change = (post - pre)/ pre x100. Unpaired t-test was used to compare between treatment-variables between both groups. Data were expressed as mean ± SD. Statistical significance was assumed for P-values < 0.05.

RESULTS

The results of this study showed that in group I, the body weight was decreased from 83.9±5.63 to 77.55±5.47 kg by 7.56%, BMI decreased from 32.9± 1.5 to 30.23±1.33 $Kg/m^2$by ratio 8.32%, waist to hip ratio decreased from 1.21±0.18 to 1.13± 0.16 by ratio 6.63% (table 2, Fig. 1). While in group II, it showed a significant reduction, ($P<0.05$) for all anthropometric measurements with a percentage of reduction about 11.39%, 9.83% and 20.15% for weight, BMI, and waist to hip ratio, respectively (table 3, Fig. 2). As shown in table (4) and fig. (3), the bone mineral density was reduced from 0.93± 0.18 to 0.91± 0.14with percentage of 2.15% in group I and this reduction was significant ($P=0.05$) and table (5), fig (4) showed a significant increase of bone mineral density in group II from 0.92±0.15 to 0.95±0.19 after training with a percentage of increase about 3.2% ($P<0.05$).

Table (2): Mean values of anthropometric measurements pre and post values in group I and improvement ratio (IR %).

Variables		$\overline{X}$ ± SD	MD	t-value	P-value	IR%
Weight(Kg)	Pre	83.9±5.63	6.35	24.98	0.01	7.56%
	Post	77.55±5.47				
BMI(Kg/m^2)	Pre	32.9±1.5	2.74	14.33	0.01	8.32%
	Post	30.23±1.33				
Waist/hip ratio	Pre	1.21±0.18	0.08	5.5	0.01	6.63%
	Post	1.13±0.16				

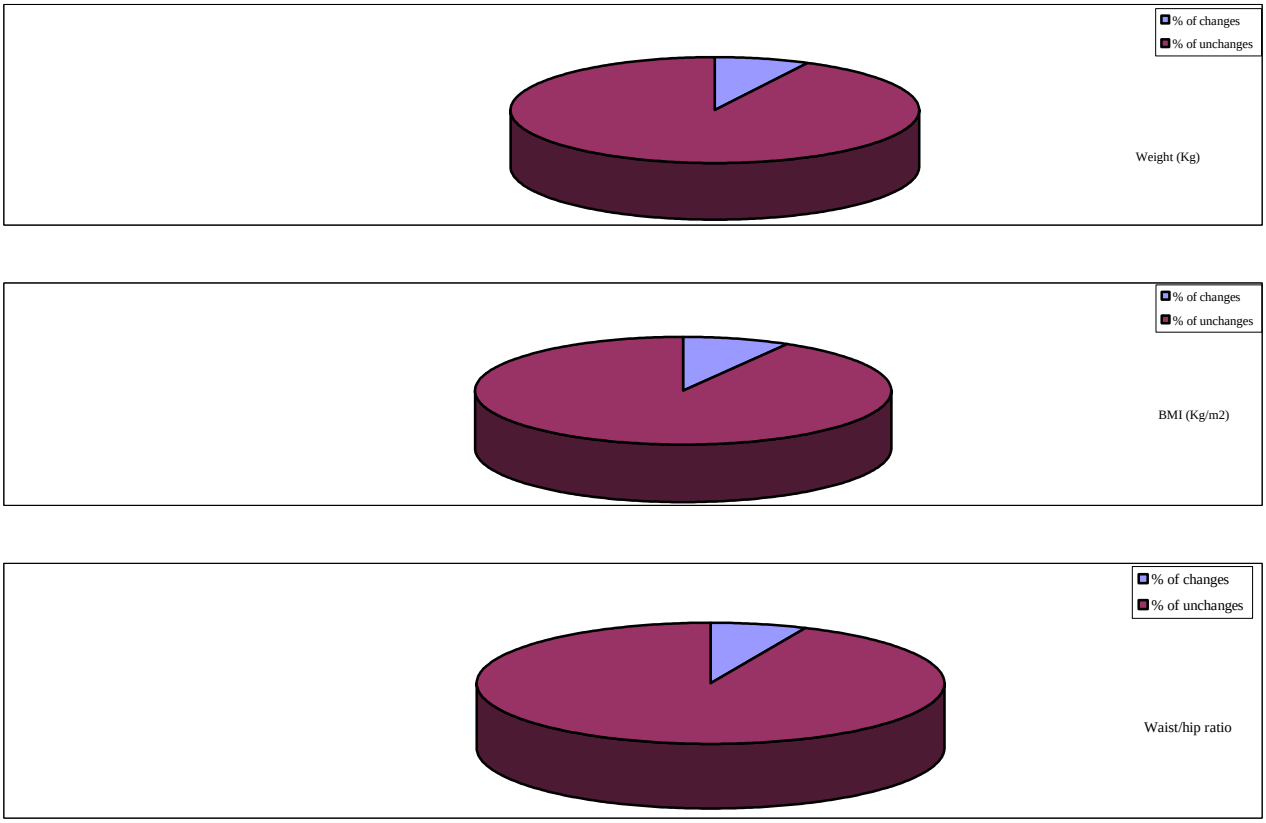

Fig. (1): Percentage of changes among group I including anthropometric parameters.

Table (3): Mean values of anthropometric measurement changes among in group II and improvement ratio (IR %).

variables		$\overline{X}$ ± SD	MD	t-value	P-value	IR%
Weight(Kg)	Pre	83.35±6.25	9.5	23.33	0.01	11.39%
	Post	73.85±5.35				
BMI(Kg/m^2)	Pre	32.45±1.58	3.19	15.98	0.01	9.83%
	Post	29.26±1.42				
Waist/hip ratio	Pre	1.29±0.14	0.26	13.25	0.01	20.15%
	Post	1.03±0.09				

MD: mean difference.

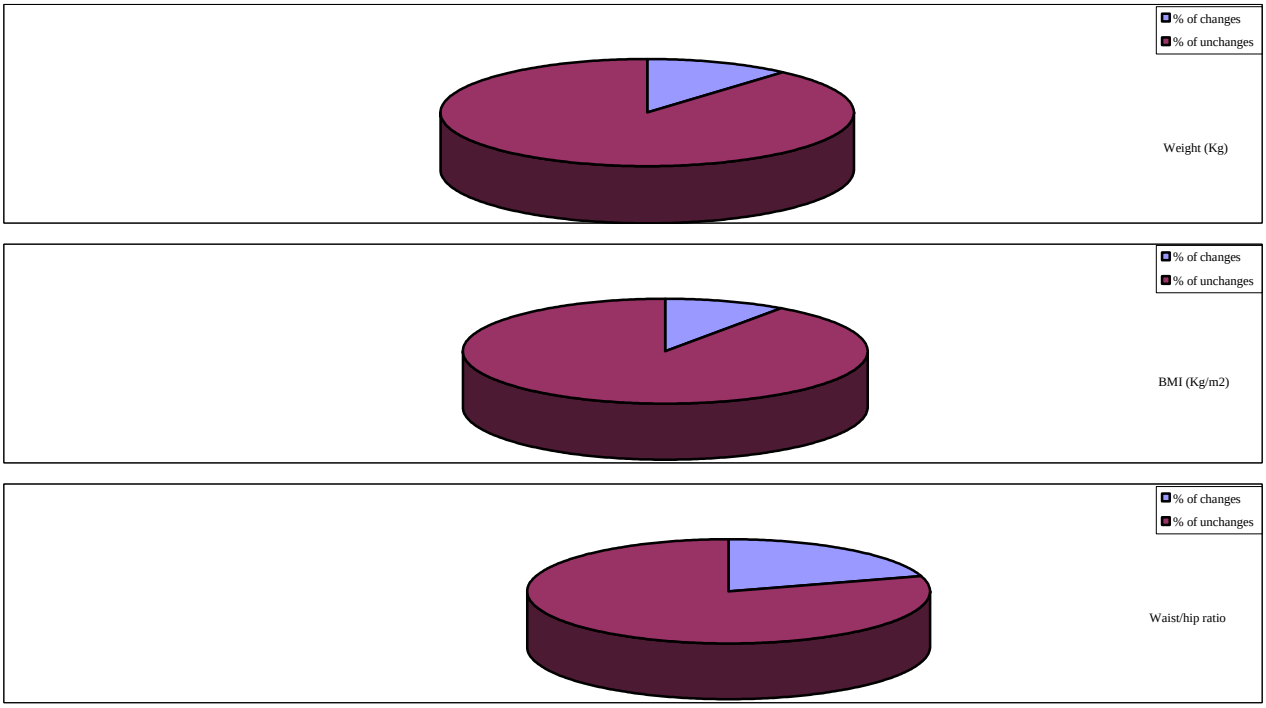

Fig. (2): Percentage of changes among group II including anthropometric parameters.

Table (4): Mean values of bone mineral density changes among group I and II.

BMD (g/cm^2)		$\overline{X}$ ±SD	MD	t-value	P-value	IR%
Group I	Pre	0.93±0.18	0.02	2.13	0.05	2.15%
	Post	0.91±0.14				
Group II	Pre	0.92±0.15	0.03	2.54	0.03	3.2%
	Post	0.95±0.19				

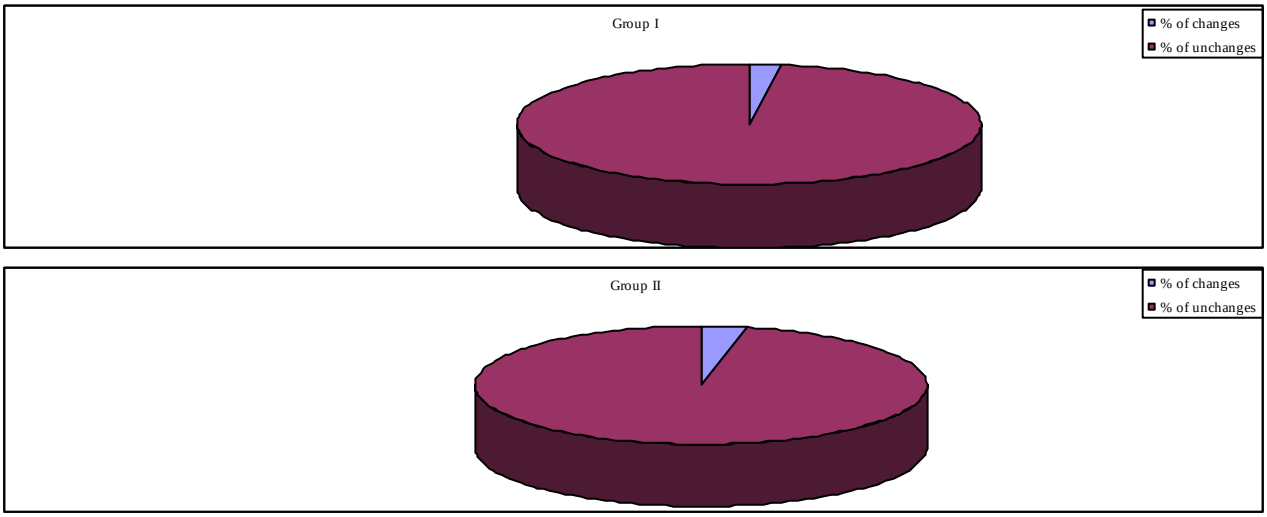

Fig. (3): Percentage of changes of bone mineral density among both groups.

In comparison of the changes between both groups as shown in table (5), there was non-statistical significant difference between both groups in the mean value of body weight after exercise while after 12 weeks, there was a statistical significant difference in the mean value of body weight that decreased significantly in group II (73.85±5.35) in comparison with group I, (77.55±5.47). Also results revealed a statistical significant difference of BMI after 12 weeks of the study, that decreased significantly in group II as compared with group I, (29.26±1.42 kg/m^2 versus 30.23±1.33 kg/m^2 in group I. Also, at the end of the study period, waist / hip ratio was decreased significantly in group II (1.03±0.09) as compared with group I (1.13±0.16).

Table (5): Comparison of mean values of body weight, body mass index and waist/hip ratio in group I and II pre and post intervention.

Variables		Group I	Group II	t. value	P. Value	Significant level
Weight (Kg)	Pre	83.9±5.63	83.35±6.25	0.29	0.77	NS
	Post	77.55±5.47	73.85±5.35	2.16	0.03	S
BMI (Kg/m2)	Pre	32.98±1.5	32.45±1.58	1.08	0.28	NS
	Post	30.23±1.33	29.26±1.42	2.22	0.03	S
Waist/hip ratio	Pre	1.21±0.18	1.29±0.14	-1.56	0.12	NS
	Post	1.13±0.16	1.03±0.09	2.15	0.03	S

X=mean SD=standard deviations MD=mean difference Pre=at base line measurement
Post=after 12 weeks of intervention

Bone mineral density changes showed that the mean value of BMD after 12 weeks of training for group II (diet plus exercise) was 0.95±0.19 g/cm^2 that increased significantly when compared with the mean value of BMD in group I (diet) which was decreased significantly (0.91±0.19 g/cm^2) as shown in (table 6, Fig. 4).

Table (6): Mean value of BMD at baseline (Pre), and after 12 weeks (Post) between two groups group I (diet) and group II (diet plus exercises).

BMD				
	Pre		Post	
	Group I	Group II	Group I	Group II
X±SD	0.93±0.18	0.92±0.15	0.91±0.16	0.95±0.19
MD	0.01		-0.03	
t-value	-0.86		-2.87	
P-value	0.07		0.04	
Sig.	NS		S	

X=mean, SD=standard deviations, MD=mean difference, Pre=at base line measurement, Post=after 12 weeks of intervention, BMD=Bone mineral density.

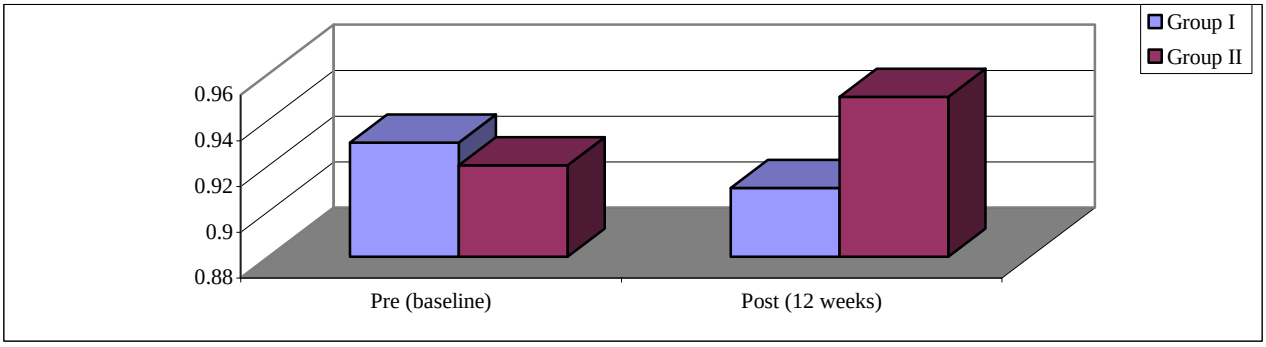

Fig. (4): Mean value of BMD, at baseline (Pre), and after 12 weeks (Post) between both groups.

DISCUSSION

Most obesity treatment involves a low energy diet to decrease energy intake and promote weight reduce. This may be associated with increased bone turnover, and decrease BMD, with associated high risk of hip fracture[7].Various dietary strategies have been used to achieve weight loss and no single treatment approach has been shown to be effective or appropriate for all people who are obese[6]. Thus the current study was conducted to investigate the efficacy of dieting with and without exercises on bone mineral density in obese premenopausal women. The results showed that, all women in the two intervention groups had significant reduction ($P<0.05$) of anthropometric measures (weight, body mass index, and waist / hip ratio) with greater percentage of reduction in group II (11.39%, 9.83% and 20.15%) in group I, (7.56%, 8.32% and 6.63%) for group II (diet and exercise). The BMD was significantly reduced in group I (diet) with a percentage of reduction (2.15%) after three months, while in group II it showed a significant increase with a percentage of improvement 3.2%. The present study did not consider the physiological mechanisms underlying the effect of exercise on BMD, but the study could speculate that the improvement of BMD in group II may be due to augmented effect of resisted and aerobic exercises that overweighed the effect of negative balanced diet on BMD (maintenance effect).

Effects of negative balanced diet: Many studies had shown that weight loss is associated with loss of bone mineral content. Unfortunately, no mechanism for the relation was mentioned or discussed. The reduction of body fat could affect bone mass through the effect of fat mass on serum leptin concentration. Leptin stimulates mineralization of bone matrix[4,5].

Ensurde et al.,[3] reported an average loss of BMD of 0.92% per year in women with weight loss of 5% from baseline body weight and increased risk of hip fracture secondary to decline of BMD. While Ricci et al.,[20] reported percentage of 10.2±5.5% for weight reduction in over of 20 weeks secondary to moderate energy restriction of diet with associated reduction of BMD of 1.2±1.2% over the same period in postmenopausal women.

Later on, Ensrude et al.,[4] reported annual changes of 1.1 g/cm^2 in femoral neck BMD with associated weight loss of about 5% per years from baseline weight, and this annual loss of BMD was decreased to 0.5% in women who had stable weight. The mechanisms by which moderate energy restriction increase bone loss and resorption are unclear, however several mechanisms have been postulated. The

weight reduction may result in a decline in mass and strength that decrease muscle force leading to associated bone loss. The decline in mechanical loading on the weight bearing skeleton may also result in increase in bone turn over, leading to bone loss.

In addition, weight loss may be associated with a decrease in nutritional intake, including calcium and protein, or may be linked to changes in levels of hormonal factors (lower levels of endogenous sex steroids), factors modulated by adipose tissue such as leptin. Any or combination of these alterations might mediate an increase of bone loss observed during weight reduction[2]. In another study, during moderate weight loss, the serum parathyroid hormone showed an increase within three to six months of weight reduction. This increase contributed to rise in bone resorption and this increase can be stimulated by reduction in calcium intake during weight loss[20]. Another explanation proposed by Tothil et al.,[25] for the decline in BMD may be partially due to artifact measurements. The magnitude of this effect had been evaluated and the results of the measured BMD are of small amount to consider when weight changes are moderate.

Beneficial effect of exercise training plus diet: Many studies had shown that physical activity is an important component of any weight management program[22,28,8]. Although energy restriction by dieting is largely responsible for initial weight loss, regular physical activity help to maintain weight loss and prevent weight gain. Also proper exercise can add new bone and /or reduce bone loss[3].

Walking is one of the most common forms of exercises and physical activities that have been shown to have a protective effect on BMD. It was found that femoral neck BMD loss was inversely proportional to physical activity. Sedentary life style had a greater reduction in BMD of 1.5±0.2% per year, however active women had no bone loss[19].

Heinonen et al.,[9] suggested that multi exercises (endurance and calisthenics) for premenopausal women revealed significant maintenance of femoral neck BMD. Also, Racette et al.,[18] confirmed that (diet plus exercises) reduce body weight by 10.8±3.2% versus 8.1±2.3% for non exerciseing group. The results of the present study contradicted with Kempen et al.,[11] and Racette et al.,[18] who found that addition of aerobic exercise to diet did not significantly enhance weight loss. The reported percentage of weight loss by Racette et al.,[18]. was 10.7±3.6%, which is smaller to the present study.

On the other hand, the percentage of reduction reported by Kempen et al.,[11] was similar to the results of the present study (9.11±1.1 and 7.1±0.9% for diet and exercise group versus diet group) respectively. The two studies concluded that addition of moderate exercises to energy restriction (diet) treatment did not accelerate weight loss, which contradicted with the results of the present study.

Recently, another studies like that conducted by Gozansy et al.,[7] and Bowen et al.,[2] agreed with the results of the present study, is that aerobic training group demonstrated a significant reduction of body weight (4.1% and 11.39% for the first and second studies respectively) over a period of six months and two months respectively. However their results contradicted with the results of the present study, in that Gozansky et al.,[7] showed an associated decline BMD and Bowen et al.,[2] showed no significant differences between diet plus exercise group and diet group.The lower rate of weight reduction and BMD observed by these previous studies may be attributed to the type and intensity of exercise as patients were

allowed to select the mode of exercise preferred (treadmill, running, cycling), also the patients who had received hormonal therapy. However, women in the present study did not received hormonal therapy and engaged in an exercise program consisted of aerobic plus resisted exercise with threshold intensity of 40-60% of one repetition maximum which resulted in improvement of BMD, decreased body fat as confirmed by Sellmeyer et al.,[21]. There are many beneficial effects of exercise training of BMD, each of them may be responsible for the increase of BMD. Training produces strain at high rate and with high peak force in versatile movements which is an effective osteogenic stimulus. Even walking may produce effective osteogenic stimulus for lower limbs skeleton by altering the loading direction and rate by shorter heel strike and higher ground reaction forces[9]. Brisk and intense walking which was a part of the training program in the present study can produce ground reaction force of 1.2 to 1.5 times of body weight during walking and 2 to 5 times during running. The bad leverage of the muscles involved the force acting across the hip joint allows fast walking to expose the lower limbs for loading with high magnitude and rate which may be enhanced by repetitive cycle[15].

Conclusion

The present study showed that twelve weeks of (diet plus exercises) resulted in significance reduction of body weight, body mass index, waist /hip ratio, with maintenance of BMD at femoral neck relative to (diet only). This form of exercises proved also to be safe and feasible among the subjects group of this study and therefore exercises should be considered as a prophylactic program for women at premenopausal period.

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الملخص العربي

تأثير التمرينات على كثافة العظام ونسبة توزيع الدهون في السيدات البدينات الخاضعة لنظام غذائي متوازن

أجريت هذه الدراسة لمعرفة تأثير نقص الغذاء المتوازن مع التمرينات أو بدونها على مدى كثافة العظام والمتغيرات الأنثروبومترية (الوزن ، كتلة الجسم ، نسبة الخصر إلى الحوض) وذلك في السيدات البدينات قبل مرحلة اليأس . وقد اشتملت الدراسة على أربعين سيدة تم تقسيمهن عشوائياً إلى مجموعتين : المجموعة الأولى تكونت من عشرين سيدة تم إخضاعهن لنظام غذائي متوازن بالتغذية تحت الإشراف الطبي . المجموعة الثانية تكونت من عشرين سيدة تم علاجهن بواسطة النظام الغذائي والتمرينات . وقد تم أخذ القياسات المتعلقة بالمتغيرات الانثروبومترية (السن ، الطول ، الوزن ، كتلة الجسم ، نسبة الخصر إلى الحوض) وكذلك كثافة العظام قبل البدء المباشر للتجربة وبعد الانتهاء المباشر منها (ثلاثة أشهر). وقد تم عمل التمرينات الهوائية لمدة أربعين دقيقة على سير الجري وبشدة 65% من ضربات القلب بالإضافة إلى تمرينات المقاومة لعضلات الأطراف السفلية . وقد تم عمل التمرينات بواقع ثلاث جلسات أسبوعيًا ولمدة أثنى عشر أسبوع ا . أظهرت النتائج وجد فروق ذات دلالة إحصائية معنوية يتعلق بالمتغيرات الانثروبومترية (السن ، الطول ، الوزن ، كتلة الجسم ، نسبة الخصر إلى الحوض) في كلا المجموعتين مع نسبة تحسن في المجموعة التي تم علاجها بالتغذية والتمرينات . كذلك أظهرت النتائج نقص ذات دلالة إحصائية في كثافة العظام بالنسبة للمجموعة التي تم علاجها بـالنظام الغذائي فقط بينما وجدت زيادة ذات دلالة إحصائية لكثافة العظام في المجموعة التي تم علاجها بالنظام الغذائي والتمرينات . وعليه فإنه يوصى باستخدام التمرينات بالإضافة إلى النظام الغذائي للمساهمة في التقليل من نقص كثافة العظام في السيدات البدينات فيما قبل مرحلة سن اليأس .