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Impact of resistive exercise versus aerobic exercise on bone mineral density

Engy Mohamed El Nahas[1], Heba Mohamed Embaby[2], Amir Arabi Gabr[3], Hamada Ahmed Hamada[4], Saud Mashi Alrawaili[5]
[1,2]Department of Physical Therapy for Woman's Health, Faculty of Physical Therapy, Cairo University, Cairo, Egypt,
[3]Department of Obstetrics and Gynecology, Faculty of Medicine, Cairo University, Egypt,
[4]Department of biomechanics, Faculty of physical therapy, Cairo University, Egypt,
[5]Department of Physical Therapy and Health rehabilitation, College of Applied Medical Sciences, Prince Sattam, Bin Abdulaziz University, KSA.

Abstract

Aim: Osteoporosis is a major public health problem and the most common skeletal disorder. It has been described as a silent disease affecting millions worldwide. This study was aimed to determine the impact of resistive exercise versus aerobic exercises on bone mineral density in post-menopausal women. Material and Method: Forty post-menopausal women participated in this study, ranging in age from 50 to 60 years. They were divided into two groups equal in number, Group (A) who performed combined upper and lower body resistive exercise for 30 minutes, three times per week, for 12 weeks in addition to their usual daily calcium intake and group (B) who performed aerobic exercise for 30 minutes, three times per week, for 12 weeks in addition to their usual daily calcium intake. All subjects in both groups (A and B) were assessed pre- and post-treatment through measuring bone mineral density (BMD) of hip and lumbar regions by DEXA. Results: The results of the present study revealed that there was a highly statistically significant increase in BMD of hip and lumbar regions after treatment, with $p<0.005$ in both groups (A&B). However, there was a non-statistically significant difference between groups after treatment in BMD of hip and lumbar regions, $p > 0.05$. Discussion: It can be concluded that there is no preference of resistive exercise or aerobic exercise in their effect on improving bone mineral density in post-menopausal women.

Keywords

Resistive Exercise; Aerobic Exercise; Bone Mineral Density; Post-Menopausal Women

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Corresponding Author: Hamada Ahmed, Lecturer of Biomechanics, Faculty of Physical Therapy, Cairo University, Cairo, Egypt.
T.: 00201117893697 E-Mail: Hamada.Ahmed@pt.cu.edu.eg

Introduction

At the onset of menopause, women begin a 5-10-year rapid reduction in bone density. During this period, 20-30% of trabecular bone is lost, as well as 5-10% of cortical bone, due to a dramatic reduction in circulating estrogen [1]. In post-menopausal women, osteoporosis pathogenesis occurs because of accelerated bone loss caused by decreased levels of circulating sex hormones, a disease characterized by low bone mass and micro architectural deterioration [2]. Decreases in bone mass in post-menopausal women, combined with age-related sarcopenia (degenerative loss of the muscle mass), and increased fall risk due to decreased postural stability, lead to dramatic increases in fracture risk for this population [3].

The most common form of osteoporotic fracture, accounting for 27% of total cases and 6% of total costs, is a vertebral fracture [4]. Current pharmacological and dietary interventions to prevent or delay bone loss work systemically. In other words, they promote overall increases in bone mass everywhere by delaying the removal of old bone in the skeleton. Nutritional supplementation does reduce rates of bone loss when combined with pharmaceutical treatment, but has not been found to correlate with spinal fracture risk [5].

Weightlessness and immobilization leads to loss of bone density and mass. Weight-bearing activities that recruit antigravity muscles can increase bone density and mass. Weight training can substantially alter bone mineral density. One study showed that individuals in sports requiring repeated high-force movements, such as weightlifting and throwing events, have higher bone densities than distance runners, soccer players, and swimmers [6].

Little research has been performed into site-specific treatments, but exercises causing large joint reaction forces or large ground reaction forces, such as resistance training or jump training respectively, seem to be the most promising way to target spine and hip bone mass accumulation and maintenance [7].

Sport or exercise that produces high joint contact forces within the lower extremity through jumping has been associated with increased bone mass of the hip but not the spine [8].

Exercise has a large effect on bone geometry as it increases periosteal apposition through increasing osteoblast formation [9]. In addition to influencing bone mineral density, exercise can improve muscle function to potentially decrease fall risk through improved balance and strength [10].

Although resistive exercise has been reported to improve muscle strength, power, and endurance, many studies revealed that it also places heavy loads on the skeleton during a training session that increases BMD. Some studies also reported its positive effect on body composition. In resistance exercise training, the exercise dose is usually described by the magnitude of resistance, the number of repetitions, the resistance moved in a single set of exercise, the number of sets done, and the length of the resistance training program [11,12]. So, the purpose of this study was to determine the impact of resistive exercise versus aerobic exercises on bone mineral density in post-menopausal women.

Material and Method

This study is a prospective, randomized, parallel group, active controlled study with a 1:1 allocation ratio. Forty physically untrained post-menopausal women were recruited from Faculty of Physical Therapy, Cairo University. The women participated in the study after reading and signing an informed consent form before data collection. Recruitment began after approval was received from the Faculty of Physical Therapy Ethics Committee.

Participants, whose ages ranged from 50 to 60 years and body mass indices ranged from 25–30 Kg/m2, were randomly divided into two groups. Group (A) performed combined upper and lower resistive exercises for 30 minutes, three times per week, for 12 weeks. Group (B) performed aerobic exercises for 30 minutes, three times per week, for 12 weeks.

The inclusion criteria included post-menopausal women (defined as amenorrhea for a minimum of one year), not on estrogen replacement therapy, estimated daily calcium intake of 500 mg/day or more, resting blood pressure ≤160/100 mm Hg, ability to follow the protocol, and free from disease or medication known to affect bone metabolism.

Patients were excluded if they had osteoporosis, osteoarthritis knee, previous surgery in upper or lower limbs, acute hernia; thromboembolism; any use of steroids; history of severe musculoskeletal problems; diabetes mellitus; engaged in high-impact activity at least twice a week (any weight-bearing activity or exercise more intense than brisk walking); smokers; or those who had cardiovascular disease, epilepsy, pacemaker, malignancy, or renal, liver, or thyroid disorders.

The participants were randomly assigned to group (A) (resistive exercise) (n=20) or group (B) (aerobic exercise) (n=20) by an independent person who selected blindly from sealed envelopes containing numbers created by a random number generator.

Dual energy x-ray absorptiometry (DEXA): It was used to measure the bone mineral density of the lumbar spine for each participant in both groups before and after the study.

Dumbbells (2.5 kg): They were used as weights during the exercise for group (A).

Back pack (4.5 kg): It was used by the participants in group (A) as weight for their back.

EN-TREAD electronic treadmill: (VEGAMAX 8000 c with serial number AC3208B59) was used to perform aerobic exercise in the form of walking for group (B).

Group (A) (Resistive exercise), which consisted of 20 post-menopausal women, performed combined upper and lower resistive exercises for 30 minutes, three times per week, for 12 weeks.

Warming up exercises: In the form of stretching exercises for five minutes. This stretching exercise included scapular muscle stretching, hamstring stretching, and quadriceps stretching.

Upper and lower resistive exercises:

1- A biceps curl using dumbbell: The participant was instructed to perform the biceps curl while standing with her feet in the marked positions and her weight evenly balanced between both feet. A 2.5 kg dumbbell was held in each hand. The participant was asked to have her shoulders in their neutral positions, her elbows fully flexed, and her palms facing her body. The exercise was begun with an eccentric lowering of the dumbbells, in such a manner that arm movement was isolated to the elbow. After the elbows reached maximal extension (with a 3 second hold), the direction of motion was reversed and the dumbbells were returned to their initial positions (with a 3 second hold). The participant remained standing throughout the exercise.

2-A squat using a weighted back pack: The participant stood with her feet in the marked positions wearing a backpack which added 4.5 kg to the upper body mass of the individual. A chair (seat height of approximately 43 cm) was located at a distance of approximately half of the participant's thigh length behind her heels. During the first part of the exercise, the participant lowered her hips backwards and towards the chair by flexing her hips, knees, and ankles. The participant lowered her hips as far as she felt she safely could, without her hips going lower than her knees (i.e. without flexing her knees more than 90 degrees) or her buttocks touching the chair (with a 3 second hold). Then she returned to a standing position by extending her hips, knees, and ankles (with a 3 second hold). The whole exercise occurred in one continuous motion, with the left and right sides of the body moving symmetrically. Throughout the exercise, the participant kept her weight approximately evenly balanced between feet, her knees, and shoulders behind the tips of her toes, her back straight, and her forearms against her chest.

3-A biceps curl using dumbbell combined with a squat using a weighted backpack: The participant began this exercise in the same body position as the biceps curl exercise, with a 2.5 kg dumbbell in each hand and her feet in the marked positions. The chair was behind the participant, as for the other squat exercises. During the first part of the exercise, the participant lowered the dumbbells by extending her elbows, as in the biceps curl exercise. At the same time, she lowered her hips backwards and towards the ground by flexing her hips, knees, and ankles, as in the bodyweight squat exercise. The participant was instructed to fully extend both elbow at the same time that the hips reached their lowest point, namely as low as she felt she could safely lower without touching the chair (with a 3 seconds hold). Then she was to return to the starting position, arms and legs moving together such that the dumbbells reached her shoulders at about the same time that she was returned to the upright standing position (with a 3 seconds hold). The exercise occurred in one continuous motion, with the left and right sides of the body moving symmetrically. The participant was instructed to keep her weight approximately evenly balanced between feet, her knees, and shoulders behind the tips of her toes, her back straight, and her upper arms near vertical throughout the exercise.

In each exercise the participant started with one set of 10 repetitions. This was progressed to two sets of 10 repetitions after 3 weeks and after that was progressed to three sets of 12 repetitions after 6 weeks until the end of the study.

Cooling down exercise: In the form of jogging in place for five minutes.

Group (B) (aerobic exercise) consisted of 20 post-menopausal women who followed aerobic exercise in form of walking on a treadmill for 30 minutes, three times per week, for 12 weeks. The graded treadmill walking exercise began with 5 minutes as warming up with gradually increased intensity until 70% of maximum heart rate (max heart rate = 220 minus age) was reached and then continued for 20 minutes, followed by 5 minutes cooling down with gradually decreased intensity.

Statistical Analysis

Data were represented as means and standard deviations. It was considered significant at P-value less than 0.05 and highly significant at P-value less than 0.001. Comparison between the mean values of different variables in the two studied groups (A and B) was made using the independent and dependent t-test. Statistical package for the social sciences (SPSS) computer program (version 16 for Windows; SPSS Inc., Chicago, AQ19 Illinois, USA) was used for data analysis.

Results

Demographic characteristics of the participants: Table 1 represents the physical characteristics of the participants in both groups (A and B) when first enrolled in the study. There was a non-statistically significant difference (P>0.05) between groups before the treatment in age, height, weight, and BMI.

Table 1. Physical characterstics of the participants.

		Mean±SD	t-value	p- value
Age (years)	Group (A)	52.85 ± 1.90	0.52	0.60
	Group (B)	52.55 ± 1.73		
Height (cm)	Group (A)	166.25 ±1.48	1.37	0.17
	Group (B)	166.95 ±1.73		
Weight (Kg)	Group (A)	79.25 ±5.46	0.32	0.75
	Group (B)	88.25 ±5.20		
BMI (Kg/cm^2)	Group (A)	28.39 ±1.27	0.31	0.76
	Group (B)	28.51±1.19		

Table (2) represents the BMD of hip and lumbar regions in both groups (A and B). There was a non-statistically significant difference (p>0.05) between groups before and after the treatment. However there was a highly statistically significant increase (p<0.005) in BMD of hip and lumbar regions post-treatment in both group (A) and group (B).

Table 2. BMD of hip and lumbar regions in both groups (A and B)

		Pre-treatment	Post-treatment	T-value	P-value
BMD of hip region (T score)	Group (A)	-1.50 ±1.04	-0.23 ±1.43	6.85	0.0001 (HS)
	Group (B)	-1.11 ±1.02	-0.24±1.14	4.14	0.0005 (HS)
	T-value	1.19	0.02		
	p-value	0.238 (NS)	0.976 (NS)		
BMD of lumbar region (T score)	Group (A)	-1.39 ±0.75	0.42 ±1.19	8.96	0.0001 (HS)
	Group (B)	-1.19 ±0.65	0.13 ±1.11	5.87	0.0001 (HS)
	T-value	0.89	0.81		
	p-value	0.374 (NS)	0.425 (NS)		

NS: non-significant HS: highly significant

Discussion

The results of the present study revealed that there was a highly statistical significant increase in BMD of hip and lumbar regions in both groups (A and B) after treatment, p<0.005. However, there was a non-statistically significant difference in BMD when comparing group (A) with group (B) after treatment of hip and lumbar regions, with p>0.05.

The current study results are supported by the work of Vacanti et al. [13] who suggested that aerobic exercise targeting a specific site has an effect on increasing bone density in the hip region in women after menopause. However, more studies are needed to detect the efficacy of aerobic exercise as a non-pharmacologic intervention for optimizing bone density in the hip region in women after menopause.

A previous study by Kelly [14] reported that bone remodeling is affected by exercise. Exercise increases the cortical enlargement periosteal and prevents age-related bone loss at the endosteal surfaces, so that it helps in the formation of structures that compensate for those lost. The size of the effects depends on the frequency, duration and intensity of the exercise.

The results of the current study are also consistent with the study of Gabrie et al. [15], which examined the effects of moderate aerobic exercise on bone mineral density (BMD) in healthy elderly subjects. The results indicated that moderate training increases BMD even in elderly persons. Assessment of BMD was done using DEXA and BMD measures which are reliable methods that help in the treatment of osteoporosis. Bone mineral density measurements indicate the fracture risk estimation and the availability of therapeutic options that can increase the BMD [16]**.** Resistance exercise has been shown to be effective in increasing BMD in older adults [17,18].

Regular exercises affect bone turnover by increasing bone formation and decreasing bone resorption, which means that moderate regular exercises have a conserving effect. This effect may be due to the higher activity of individual osteoblasts, while the total number of bone remodeling sites is reduced [19,20]. Although, there is no evidence regarding the type, intensity, duration, and frequency of the exercise programs, exercises have an increasing effect on BMD [21]. Aerobic exercise has been shown to increase the BMD in the neck of femur in osteopenic women [22]. Measurement of BMD is inadequate to detect acute changes in bone metabolism after physical activity because changes in bone mass usually occur at a slow rate. The skeletal response to exercise can be measured using blood markers to estimate the bone remodeling rate by comparing the resorption markers to formation markers [23].

Also, a study by Chien et al. [24] demonstrated that a 24-week program of aerobic high-impact exercise resulted in significant improvements in BMD of the femoral neck in Chinese post-menopausal women. Muscle strength, muscular endurance, and VO2max were also improved, which may have beneficial effects on physical fitness and reducing the risk of cardiovascular diseases and falling**.**

The present study results coincided with those of Engelke et al. [25] who compared two different exercise groups with a control group (without exercise). One group was given low volume high resistance training and the other group was given high-impact aerobic exercise. After carrying out a three-year schedule, it was revealed that there were pain reduction and BMD increase in vertebral column, hip, and heel with no changes in forearms in both exercise groups. There was no difference between the two exercise groups, and there was deterioration of the variables in the control group. A study of Suominen [26] was conducted on athletes who are active in the field of power events including weightlifting and hurdling. The findings of the study may be limited by psychological, physiological, and cultural issues and the lack of follow-up. It was concluded that these athletes have more bone mass with a stronger structure compared to athletes from other fields across all age ranges. It seems that the effect of exercise is more dominant in the period of growth than in other periods in life as the gain in BMC as well as BMD is estimated to be almost 2-5 percent per year, whereas the gain in BMD obtained from exercise is less in elderly people, at about 1-3 percent per year.

Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and human rights statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

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Conflict of interest

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