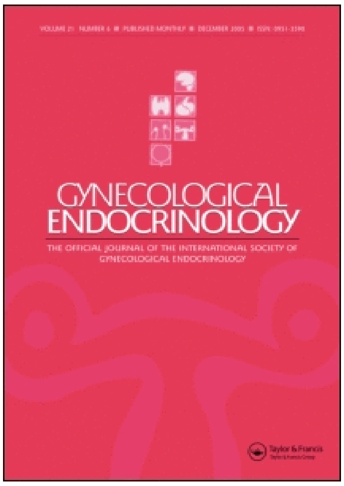

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ORIGINAL PAPER

Effect of specific exercise training on bone mineral density in women with postmenopausal osteopenia or osteoporosis

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Abstract
Aim. To analyse the effect of a specific program of weight training exercise with closed kinetic chain in bone mineral density in postmenopausal women with osteopenia or osteoporosis.
Methods. A total of 59 postmenopausal women with osteoporosis or osteopenia were included in this prospective study. Subjects were divided into two groups: the study group (SG, $n = 30$; 57.5 ± 5.1 years) and the control group (CG, $n = 29$; 56.6 ± 4.6 years). In the study group was applied a weight exercise protocol (longitudinal forces in closed kinetic chain) during 12 months, whereas in the control group no weight exercise protocol was applied. Bone mineral density at the lumbar spine and hip was assessed at baseline and at the end of follow-up by dual energy X-ray absorptiometry.
Results. Although no significant intragroup differences were found, patients in SG showed a 1.17% increase in the lumbar spine whereas in CG a 2.26% decrease in bone density was detected.
Conclusion. This protocol of weight training exercise did not significantly improve bone mineral density in postmenopausal women with osteopenia or osteoporosis, but in comparison to the control group, the results showed the importance of practising the specific exercise program for maintenance of bone health in postmenopausal women.

Keywords: *Osteoporosis, osteopenia, postmenopausal, bone mineral density, closed kinetic chain, longitudinal forces*

Introduction

Several studies have demonstrated the association between bone mineral mass (BMD) levels and fracture risk [1]. However, there is currently no agreement on the extent to which an increase in BMD is associated with a reduction in fracture risk [2]. Exercise can increase BMD, though to a lesser extent than some antiresorptive drugs, and it is not clear whether they help to prevent fractures [3]. In addition to increased BMD, other factors may also play a role in determining bone quality and fracture risk. These include the conservation of trabecular and connective tissue, bone microarchitecture, thickness of the cortical tissue, and the fat and lean mass [4,5]. It is generally agreed that exercise should be recommended to patients with osteopenia or osteoporosis [6].

The physical activity can be an important instrument in prevention and auxiliary treatment to osteoporosis, not only by reducing the chances of fracture due to bone loss maintenance but also by increasing neuromuscular capacity, improvement of core stability thus to aid in preventing falls and reducing its impact [7]. Yet, there are some exercise prescriptions that use body weight maintenance as main factor for gain of BMD without making a difference between equipment and methodology that should be applied in physical activity [8]. As the maintenance to body weight is common in studies for BMD, the body mass index (BMI), also shows its relationship to the maintenance of bone mass [9].

As for the use of weight training in treating osteoporosis, studies have shown a great concern with subjectivity related to the number of repetitions and weight percentage to be applied, but have disregarded

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the effort from different force incidence acting at bone micro architecture under the effect of mechanic stress [10–13].

The exercise in closed kinetic chain involves functional movements (like squat, leg press or lifting) with weight support through contraction of both agonist and antagonist muscular groups [14]. However, up-to-date there are no studies on application of specific exercises in weight training with incidence of longitudinal force in closed kinetic chain in postmenopausal women with osteoporosis or osteopenia.

The aim of the present study was to assess the effect of a specific weight training exercise protocol in the values of bone mineral density in the lumbar spine and hip in women with postmenopausal osteopenia or osteoporosis.

Material and Methods

Subjects

The sample consisted of 59 Portuguese postmenopausal women with osteoporosis (32.2%) or osteopenia (67.8%) without any associate diseases. The subjects were divided in two groups: the study group (SG) ($n = 30$; 57.5 ± 5.1 years) having 23.3% with osteoporosis and 76.7% with osteopenia, and the control group (CG) ($n = 29$; 56.6 ± 4.6 years) having 41.4% with osteoporosis and 58.6% osteopenia (Table I).

The study group was formed by volunteer women whereas the control group was formed by women that did not want to take part in the exercise program. At the first meeting they were showed the facilities and were exposed to the research methods and objectives, to evaluate weight and height, to verify the BMI and to record clinical data. Afterwards, those who agreed, signed the Helsinki Protocol.

Methods

The densitometry assessment was carried using a Hologic QDR-4000, which evaluates the lumbar spine (L1–L4) and hip (neck, trochanter, intertrochanter, ward's). The total values were obtained by the average of four vertebrae and four regions of the hip, respectively, and from it are derived the standard-deviation in *T*-score and *Z*-score. To the spine assessment, the DEXA shows a coefficient variation of 1.5–2%, therefore being necessary an alteration about 4.2–5.6% in between two measures to make it significant; to the hip (neck) that amount varies from 2 to 3% with significant alteration in between 5.6 to 8.4% [15]. For this equipment, the clinical range is 0.60 g/cm^2; in comparison with average adulthood values equal 1.047 g/cm^2; to the hip are 0.72 g/cm^2 in comparison to adulthood equal 0.975 g/cm^2.

After the exercise protocol application in equal length to both SG and CG, the subjects returned to the same place where the first assessment was made and carried a new densitometry.

Table I. Clinical characteristics and baseline data in both groups.

Variables	Study group $n = 30$	Control group $n = 29$
Age (years)	57.5 ± 5.1	56.6 ± 4.6
Menopausal age (years)	47.9 ± 5.0	49.2 ± 3.2
Height (cm)	158.3 ± 4.3	159.4 ± 7.6
Body Mass (kg)	59.8 ± 7.6	65.0 ± 8.3
BMI (kg/m^2)	23.9 ± 3.3	25.6 ± 3.1
BMD spine (g/cm^2)*	0.845 ± 0.09	0.796 ± 0.08
BMD hip (g/cm^2)*	0.838 ± 0.11	0.831 ± 0.10

No significant differences were detected between study and control groups.
*First moment assessment.

Exercise program

The methodology used during the exercise program had a direct appliance at the longitudinal compression load with exercises in closed kinetic chain through selecting the weight equipment that promoted a compressive force over both axial and apendicular skeleton, which are the main area of bone loss.

Therefore, the intervention followed the general principles of classic weight training in each session, starting with the warm-up and aerobic exercises, then performing the weight exercises using either machines or free weights (from 30–40 min) and then warm-down followed by stretching for about 5 min.

As shown in Table II, the periodization follow a gradual-monthly increase in the number of repetitions, except in phase four, where there were no changes at all. Despite the objective of an increase in fitness as the main result of using it, this equipment was chosen because of its capacity of favouring the longitudinal pressure load during the exercise.

Statistical analysis

Results were expressed as means ± standard deviation and minimum and maximum values. The data were analyzed using a personal computer based software package (SPSS 15.0, IL). Normal distribution and variance homogeinity was verified by the the Shapiro-Wilk test, Levene and Bartlett tests. Differences between groups were estimated with the Mann–Whitney *U* test. To test intra-group differences the *t* test of dependents measures or Wilcoxon test were used. Finally, to test the correlations between bone mass and BMI in both groups, Spearman's coefficients (ρ) were calculated. The significance level was established at 5% ($p < 0.05$).

Results

The mean age of the subjects included in the study was 57.1 ± 4.9 years ranging from 45- to 65-years old. The time elapsed since menopause was 9.6 years in the SG group and 7.4 years in the CG group. No significant differences in basal characteristics were detected between study and control group. The baseline characteristics of the women finally included (30 SG, and 29 CG) are shown in Table I.

Table III shows changes in BMD during the study follow-up in absolute numbers (g/cm^2) and *T*-scores. A non-significant increase in BMD for the lumbar spine (1.17%) was found in SG. Accordingly, a corresponding decrease in the *T*-score (3.25%) was observed. Additionally, non-significant decreases in BMD (0.71%) were detected in the hip among the SG. On the opposite, the CG showed a significant loss in the spinal BMD (2.26%, $p = 0.019$). This significant reduction in bone mass also implied that *T*-scores raised from a situation of osteopenia to another close to osteoporosis (−2.26 to −2.44) according to the WHO criteria [16]. As expected, changes in the hip were minor than those observed in

Table II. Cardio fitness and weight training program.

Program	Stage 1	Stage 2	Stage 3	Stage 4
Cardio fitness	Bike	Bike treadmill	Bike treadmill stepper	Treadmill stepper
Length	10–15–20 min	10–10–10 min	5–5–5 min	
		10–15–20 min	10–10–10 min	15–15–15 min
			5–10–15 min	15–15–15 min
Speed	45–55 rpm	45–55 rpm	45–55 RPM 45–	
		4.0–5.0 km/h	5.0–6.0 km/h	5.0–6.0 km/h
			55 steps/h	45–55 steps/h
Borg scale intensity	4–5	4–5	4–5	
		4–5	5–6	5–6
			4–5	5–6
Weight	1 kg	2 kg	3 kg	
		0	0	0
			2 kg	4 kg
Weight program	1. Inclined chest press with Dumbbells	1. Leg extension	1. Triceps extension	1. Horizontal leg press
	2. Seated shoulder press	2. Row (high handle)	2. Leg curl	2. Calves (leg press)
	3. Squat with dumbbells	3. Row (closed chain)	3. Gluteus (chin weight)	3. Vertical row
	4. Closed chain chest press (machine)	4. Lunges	4. Frontal pulley	4. Leg press (Gravitron)
	5. Abductor chair	5. Oblique (low handle)	5. Squat (Barbell)	5. Seated chest press
	6. Adductor chair	6. Standing shoulder press	6. Calves (standing)	6. Back extension (machine)
	7. Calves (step)	7. Chest press (machine)	7. Shoulder press (machine)	7. Alternated shoulder press (machine)
	8. Biceps curl	8. Adapted peck deck	8. Inclined chest press (machine)	8. Steper
	9. Sit-ups	9. Sit-ups	9. Sit-ups	9. Declined sit-ups

Duration: 3 months each stage.
Change of Exercises: At the beginning of each stage.
REPS: 10 (1st month), 12 (2nd month), 15 (3rd month).
Time: 3 seconds (concentric phase) and 3 seconds (eccentric phase).
Rest: One minute in between sets and exercises.

Table III. Changes in bone mineral density (BMD) in hip and spine in the study (SG) and control group (CG) expressed as g/cm^2 and T-score.

	BMD				*T*-score			
	Spine		HIP		Spine		HIP	
	SG	CG	SG	CG	SG	CG	SG	CG
PRE	0.845 ± 0.09	0.796 ± 0.08	0.838 ± 0.11	0.831 ± 0.10	−2.15 ± 0.62	−2.26 ± 0.79	−1.07 ± 0.92	−0.93 ± 0.87
POST	0.855 ± 0.09	0.778 ± 0.08	0.832 ± 0.11	0.826 ± 0.10	−2.08 ± 0.62	−2.44 ± 0.74	−1.12 ± 0.90	−0.96 ± 0.84
Δg/cm^2	0.010	−0.018	−0.006	−0.005	0.07	−0.18	−0.05	−0.04
Δ %	1.17%	−2.26%	−0.71%	−0.60%	3.25%	−7.37%	−4.46%	−4.1%
P	0.219	0.019*	0.261	0.373	0.285	0.016*	0.345	0.360

Data are means ± standard deviation and percentages when specified.
*$p < 0.05$.

the spine showing CG group a 0.60% non-significant decrease in hip BMD scores. Changes in g/cm^2 observed at the end of follow-up in spine in the SG (0.010 ± 0.043) were significantly different to those observed in the CG group (-0.018 ± 0.039; $p < 0.013$). No differences were observed for hip between SG and CG groups (-0.006 ± 0.032 and -0.005 ± 0.031, respectively).

Correlations plotted between BMD (spine and hip) and BMI in the two groups (SG – CG) demonstrated a slight association between the lumbar spine and BMI in SG ($r = -$s0.18), in all the other situations, no statistical differences were found.

Discussion

The benefits of exercise are widely recognized, however physically active women during reproductive years can develop exercise associated menstrual cycle disturbances such as amenorrhea (i.e., estrogen deficiency). On the other hand, the menopausal onset is a crucial point to assess BMD, since in the first years of climacteric bone loss starts to decline [17–19]. The mean time elapsed since menopause in the subjects included in this study was 9.6 years for SG and 7.3 years for CG. These values corroborate that both groups weren't within the age range of major bone loss that usually occurs in the first years of climacteric [17,18] when the loss of bone mass is around 4% per year [19]. Changes in BMD observed in both groups during this study didn't reach such values. This might be due to the positive effects in bone of the exercise program as well as in the non-practice of this program to the adjustment in the bone turnover with aging.

Many studies describe the relationship between total body mass and BMI as protection factors to osteoporosis [20–22], but in the present study, these variables showed slight correlation. One limitation of the present study was the lack of data of final BMI. For this reason, the BMI values should only be related to initial densitometry in both groups.

Subjects in SG group amended the trend of bone loss that was expected during de postmenopausal years in the spine [23,24] and in the hip showed a minor loss that was less than 1%, therefore being not clinically significant. Despite the lack of statistical significance in some variables, this change of tendency strengthens the importance of exercising focusing specific areas of body overload as a main target. These positive results in the lumbar spine and this lack of impairment in the hip are in agreement with other studies [25]. All this changes might put the subjects into a situation of less risk of developing fractures in the future. The CG group showed a significant decrease in bone mass in the spine ($p = 0.019$), that define not only a statistic difference but also the tendency to BMD loss during postmenopausal stage. Despite the strength of the decrease, these high rates of bone loss are in the normal range [26]. This data represents the importance of practice of exercise programs in this period of life to try to reverse the loss tendency.

Intense exercise has been associated with amenorrhea that may have an impact on anthropometric parameters [27]. Both situations, intense exercise and menopause, are related to a low estrogen levels and this situation may influence in a similar way bone turnover. In this sense, a recent study assessing the effects of exercise status and estrogen deficiency on osteoprotegerin (OPG) and its relationship to bone resorption in premenopausal exercising women suggesting that OPG responds to the bone loading effect of exercise, and that suppressed OPG may play a role in the etiology of increased bone resorption observed in exercising women with chronic estrogen deficiency [28].

In general, studies of the effect of exercise programs on bone mass appear inconsistent. In a systematic review and meta-analysis of randomized trials on the effect of exercise on bone mass in pre- and postmenopausal women 35 randomized trials were identified to statistically pool results of studies of the effect of impact (e.g., aerobics) and non-impact (e.g., weight training) exercise on the lumbar spine and femoral neck [29]. In the lumbar spine both impact [1.6% bone loss prevented, 95% confidence intervals (CI): 1.0%–2.2%] and non-impact (1.0%, 95% CI: 0.4%–1.6%) exercise programs had a positive effect in postmenopausal subjects. Impact exercise programs appeared to have a positive effect at the femoral neck in postmenopausal women (five studies), 1.0% (95% CI: 0.4%–1.6%) bone loss prevented. In the present study, the inter-group analysis, clearly demonstrated an improvement in bone mass in the lumbar spine in SG group after the accomplishment of the proposed exercise program, mainly when these BMD assessments were compared to the ones showed at the CG. Our data suggested that the exercise program had a minor influence in the hip and are in agreement with previous data [29,30].

In conclusion, our results support the hypothesis that kinetic exercise programs probably have a positive effect at the spine and femoral neck. This notwithstanding, it should be noted that our study included a low number of subjects, and factors such as lifestyle, nutritional aspects, drug use, toxins, and other medical or endocrine conditions that may have an important effect on bone mass were not evaluated in the investigation. Thus, at present, the real effect of exercise training on osteoporosis remains unclear, and further studies are warranted to clarify its exact role and to determine the optimal intensity and type of exercise. Finally, this study adds evidence to the importance of carry out specific exercise programs for bone health maintenance in postmenopausal women.

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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