BALNEO RESEARCH Balneo and PRM Research Journal
English Edition
e ISSN 2734 - 8458 p ISSN 2734 - 844X ROMANIAN ASSOCIATION OF BALNEOLOGY

Research article

The role of the Dual X-Ray Absorptiometry investigation in the design of personalized training programs for women with postmenopausal osteopenia / osteoporosis

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Citation: Holubiac I.Ș., Leuciuc F.V. - The role of the Dual X-Ray Absorptiometry investigation in the design of personalized training programs for women with postmenopausal osteopenia / osteoporosis
Balneo and PRM Research Journal **2023**, *14(4): 598*

Academic Editor(s):
Constantin Munteanu

Reviewer Officer:
Viorela Bembea

Production Officer:
Camil Filimon

Received: 08.09.2023
Accepted: 04.12.2023
Published: 20.12.2023

Reviewers:
Himena Zippenfening
Daniela Profir

Abstract: Osteoporosis affects many postmenopausal women and represents an economic burden. The purpose of the study was to observe the effects of a 1-year strength program on the bone mass at the level of the femur. Twenty-nine women were included in the randomized study, being divided into an exercise group (56±2.9 years old, n = 20) and a control group (56.4±2.1, n = 19). After 12 months of participation in the strength program (twice a week, using intensities of 70% of 1RM and 50% of 1RM) the exercise group showed statistically significant increases in all areas of interest of the femur as follows: femoral neck (+2.05%, p = .001, η_p^2 = .45), trochanteric area (+3.80%, p < .001, η_p^2 = .75), intertrochanteric area (+0.97%, p = .013, η_p^2 = .37), Ward's triangle (+1.77%, p = .023, η_p^2 = .24) and femur's total bone mineral density (+1.97%, p < .001, η_p^2 = .51). After 12 months, at the femoral neck region, the increase in bone density was 7.3 times higher compared to the control group (p = .01, F(1, 36) = 6.62, η_p^2 = .15, 95% CI [0.002, 0.020], at the trochanteric area the increase was 8 times higer compared to the control group (p < .001, F (1, 36) = 16.48, η_p^2 = .31, 95% CI [0.009, 0.027] and at the total level of the femur, the increase in bone density was 8.6 times higher compared to the control group (p = .01, F (1, 36) = 7.09, η_p^2 = .17, 95% CI [0.003, 0.024]. In conclusion, alternating the intensities of 70% of a maximum repetition with those of 50% of a maximum repetition within the same set of 12 repetitions, bone mineral density at the level of the femur can undergo improvements.

Keywords: osteoporosis; strength training; bone density.

1. Introduction

Osteoporosis can be defined as a disease that affects the bone by decreasing its density and that is associated with an increase in the risk of fracture [1]. It affects approximately 10.2 million Americans and by 2030 the number of people who will suffer from either osteoporosis or osteopenia may reach 71 million [2]. Osteoporotic fractures have a relatively low incidence [3] but fracture costs are estimated to reach $253 billion per year by 2025 [4], with 1 in 3 women over the age of 50 suffering fractures from osteoporosis. Among people with osteoporosis, fractures can occur after a slight fall from a short height, with the most common fractures being in the spine, hip, and wrist. The costs involved in osteoporotic fractures are higher than the costs involved in other diseases such as stroke, breast cancer and myocardial infarction combined [5]. There are three types of cells in bone: osteocytes, osteoblasts and osteoclasts. The replacement of old or damaged bone tissue is done with the help of osteoblasts, osteoclasts being involved in bone resorption. Both types of cells release RANKL (receptor activator of nuclear factor kappa B ligand), which is essential in the process of osteoclast genesis. In addition, osteoblasts also produce OPG (osteoprotegerin), which binds to the ligand and prevents the interaction of RANKL with RANK (receptor activator of nuclear factor kappa B), resulting in the prevention of osteoclast genesis and therefore the prevention of bone loss. Estrogen plays a protective role in maintaining bone mass by maintaining a balance between RANKL/RANK/OPG. With the onset of menopause, the level of estrogen decreases and this balance is disturbed, resulting in an acceleration of osteoclast genesis and implicitly a more pronounced loss of bone mass. Among the recommendations to prevent osteoporosis are vitamin D3 supplementation (1000 IU to 2000 IU), adequate calcium intake (1200 mg/d) for women aged 50 or over, limiting alcohol consumption, smoking cessation and practicing physical exercises (30 minutes daily) [6], since weight-bearing exercises represent an effective and inexpensive means for increasing or maintaining bone mineral density [7]. Low body weight accelerates bone loss [8] and high-load exercise is effective in increasing bone mass among women with this condition [9]. However, early screening is recommended for menopausal women who are underweight or who have a family history of osteopenia or osteoporosis [10]. A better understanding on the part of the population regarding the risks of osteopenia or osteoporosis, as well as the implementation of customized physical exercise programs, depending on the age and gender of the patients, would substantially reduce the burden of osteoporosis both for patients and for health systems around the world. Dual X-Ray Absorptiometry (DEXA) is considered to be the reference method when it comes to measuring bone mineral density or diagnosing osteopenia/osteoporosis [11]. DEXA estimates BMD by taking advantage of the differential absorption of high- and low-energy X-Rays as they pass through bone and soft tissue [12]. The advantages of using the DEXA investigation for the diagnosis of osteopenia or osteoporosis are the short time of approximately 1 – 2 minutes required for the investigation and the exposure of the patient to a small dose of radiation (between 0.5 – 5.0 mSv) compared to other investigations. The areas of interest to assess bone mineral density using DEXA are (1) lumbar spine, (2) femoral neck, (3) or (4) one-third radius. Other techniques, such as ultrasonography, have been evaluated to predict fracture risk. Although fracture risk is predicted, it is not clear that such technologies are valid for identifying candidates for pharmacotherapy, and the WHO Criteria cannot be used for such techniques. Considering the efficiency, costs and radiation dose, DXA is the standard method for diagnosing osteoporosis compared to ultrasonography (US), peripheral quantitative computed tomography (pQCT), high-resolution peripheral quantitative computed tomography (HRpQCT), quantitative computed tomography (QCT), magnetic resonance imaging (MRI). For example, quantitative computed tomography (QCT) can be used to quantify BMD; although not comparable to DXA, QCT software packages can convert QCT to DXA equivalent values, valid for using WHO diagnostic categories [13]. The disadvantages of QCT are the higher cost and exposure to higher doses of radiation compared to DXA [11].

The aim of the study was to observe the impact of a strength training program implemented over a period of 1 year on femur bone mass density using Dual X-Ray Absorptiometry as a method of efficacy assessment.

2. Materials and Methods

The study participants were 39 postmenopausal women suffering from osteopenia/osteoporosis divided into a group that followed the strength training program (exercise group, n = 20, 56±2.9 years old) and a group that did not participate in the strength program or other physical activities (control group, n = 19, 56.4±2.1 years old). The inclusion criteria were the following: sedentary women, non-smoker, age 50 or older, no hormone therapy in the last 5 years, T-score between -1.5 and -3. Subjects who were receiving treatment based on corticosteroids, as well as subjects who exceeded the BMI (body mass index) value of 35, were also excluded (figure 1). For the statistical power of the sample size, G power software version 3.1.9 was used and the total number of participants was calculated at 31 (effect size = 0.9, α-error probability = 0.05, power = 0.9). The subjects were randomly divided into two groups using Excel version 2019 software, using the "=RAND()" formula, each subject being assigned a random number; the first 20 numbers were assigned to the exercise group, and the next 19 to the control group. The initial and final assessments of bone density at the level of the femur were made by the same specialized technician, using DEXA analysis (Hologic Horizon, USA), without knowing which subjects were in the control group and which subjects were in the exercise group.

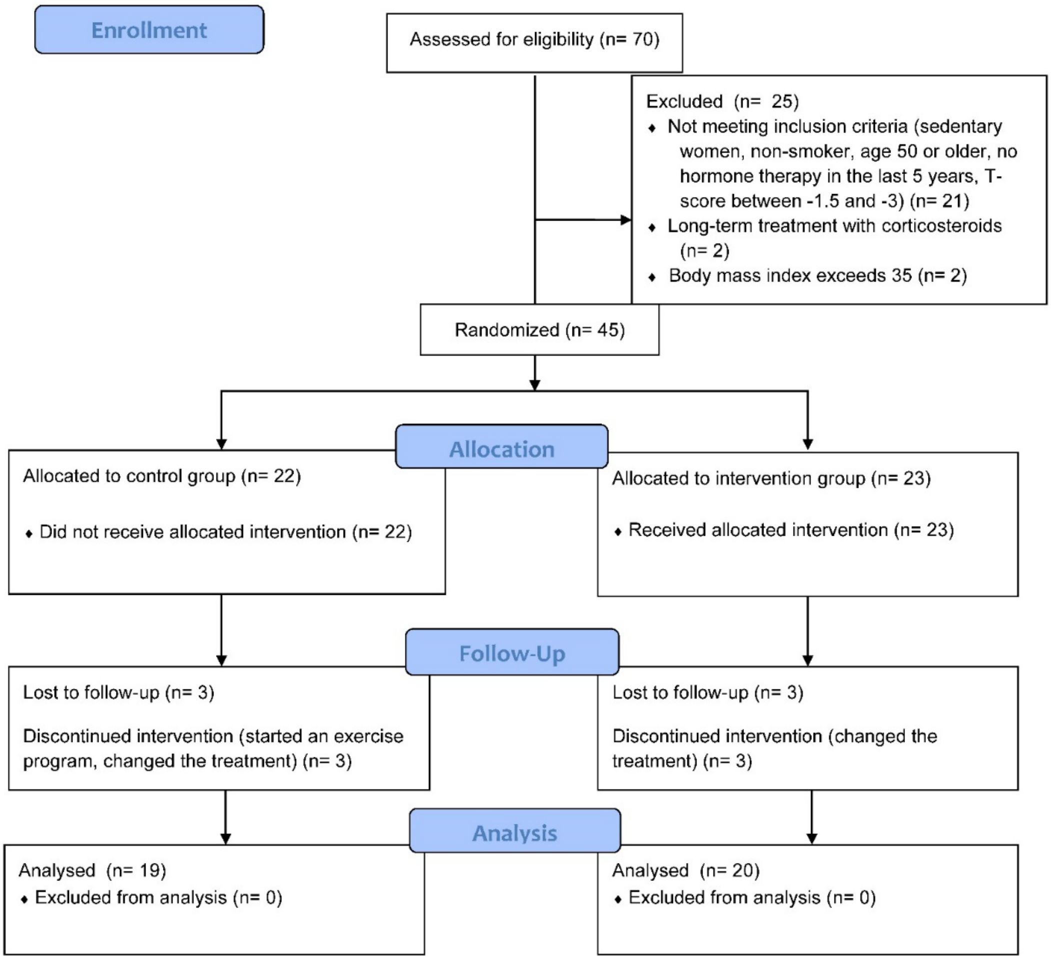

Figure 1. CONSORT flowchart representing the enrollment of subjects in the study

The output data from DEXA scanners include the region of interest area (cm^2), bone mineral content (g) and the calculated BMD (g/cm^2), an image for evaluating positioning and artifacts, and a graphic illustrating the patient's BMD as a function of age. Because the absolute bone density in g/cm^2 varies between skeletal sites and the measurement of BMD on different DXA instruments is not comparable, the use of T-scores simplifies interpretation of BMD data. Bone mineral density was measured before starting the exercise program and after 12 months. Following the DEXA investigation, valuable information is obtained regarding BMD (bone mass density), the T-score (defined as the difference between a patient's BMD and the mean of the young normal population at peak BMD divided by the SD of the young normal population) and the Z-score (which results from the comparison of the bone mass of the subject with that of a person of the same age and gender). Risk of osteoporotic fracture has been estimated to be increased by about twofold for each SD decrease in BMD [14]. The term osteoporosis would apply if the BMD T score is -2.5 or less with one or more fragility fractures. T-scores of -1 or greater were deemed to be normal, and T-scores between -2.5 and -1.0 were termed osteopenia (low bone mass). The software used to calculate BMD, T-score, BMC etc. was Hologic Horizon W, SN: 301226M, Version 13.6.0.5 :5. The coefficient of variation was 1%. All subjects followed daily treatment, namely 0.5 μg alfacalcidol.

The strength program was carried out for a period of 12 months (twice a week), never on consecutive days, to allow the body to recover between training sessions. The first training of the week included the following exercises: seated hip adduction, seated hip abduction, standing hip extension, seated triceps dips, seated hip flexion, seated back extension (figure 2). All exercises were performed on machines, each exercise being performed in 2 series x 12 repetitions (6 x 70% of 1RM + 6 x 50% of 1RM). The second training protocol included Scott bench biceps curl, leg press, bodyweight squats, prone leg curls, seated machine row, seated leg extension. The rest between sets were 90 seconds and during the entire training period they were supervised by a physiotherapist with experience in strength training. In the second week, subjects were tested for one repetition maximum (1RM) to determine the intensity used for the following weeks. Once a month, the subjects repeated the test for a maximum repetition, in order to adjust the intensity of the exercises for the following weeks. The selection of exercises was made in such a way as to target the muscles that originate or insert on the greater trochanter, the lesser trochanter, the diaphysis of the femur, so that, through muscle stimulation, mechanical stress is applied to the areas of insertion or origin of the muscles, thus stimulating the region of the bone in question. Also, the reasoning behind using intensities of 70% and 50%, respectively, was not to put too much pressure on the knee and hip joints, since, as we already know, excessive mechanical stress is a risk factor for developing osteoarthritis in the knee and hip, and using weights that exceed 70% could put more pressure on the joint cartilages. The training program, the description of the exercises, the muscles involved in the action, as well as pictures of each exercise were published in a chapter dedicated to this topic [15].

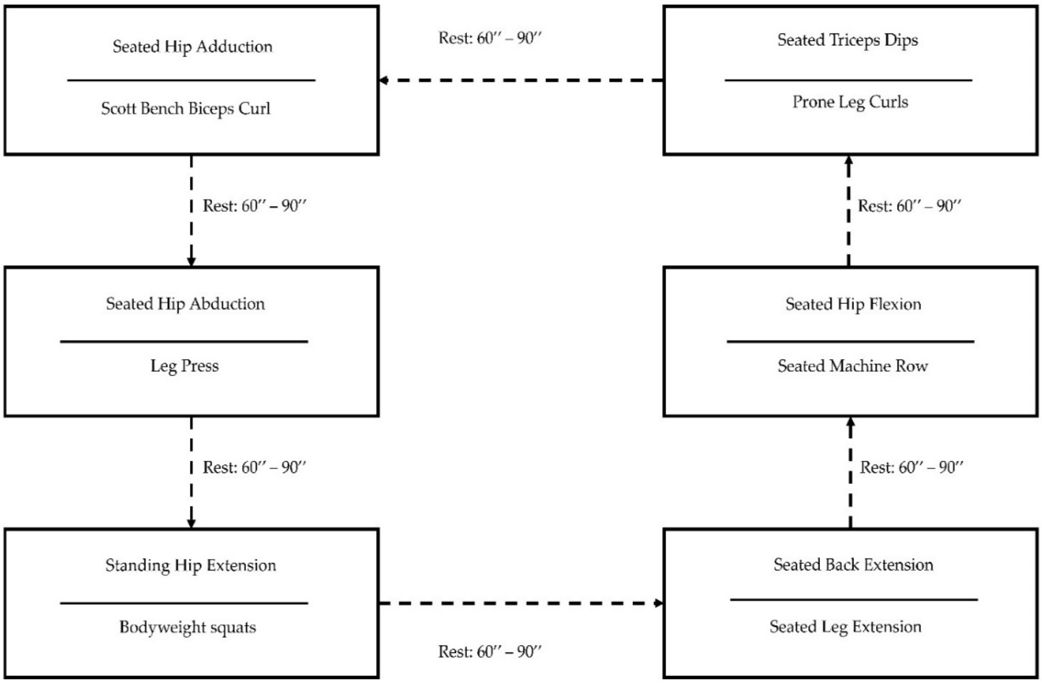

Figure 2. The exercises performed and their order; the exercises above the line were performed in the first training of the week, and the exercises below the line were performed in the second training of the week.

SPSS Statistics program (version 26) was used for statistical analysis with a significance level of 5% (significance was accepted when $p < .05$). Normal distribution parameters and homogeneity were checked with the Shapiro–Wilk and Levene tests, respectively. One-way ANOVA was used to measure pretest intergroup comparison and repeated measures ANOVA was used for intragroup comparisons (pre vs. post). One-way ANCOVA was used to measure posttest intergroup comparison, pretest variables being the covariate. Effect size (partial eta squared, η_p^2) was also calculated when differences were significant ($p < .05$). An effect size of 0.14 or more is considered large; 0.06 or more is considered medium; 0.01 or more is considered small. The study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics Committee of Stefan cel Mare University of Suceava (protocol code 35 from 28.05.2021). Informed consent was obtained from all subjects involved in the study. Written informed consent has been obtained from the patients.

3. Results

At the beginning of the study, no significant differences were recorded regarding the bone mineral density at the level of the femur (Table 1). Femoral neck bone mineral density increased significantly (Δ% = 2.05) after 12 months in the exercise group, $F(1, 19) = 15.46$, $p = .001$, $\eta_p^2 = .45$, 95% CI [-0.021, -0.006] as well in the control group (Δ% = 0.28) but the increase was 7.3 times lower compared to the exercise group, $F(1, 18) = .60$, $p = .45$, $\eta_p^2 = .03$, 95% CI [-0.007, 0.003]; between groups there was a significant difference after 1 year, $F(1, 36) = 6.62$, $p = .01$, $\eta_p^2 = .15$, 95% CI [0.002, 0.020].

Table 1. Baseline results regarding the BMD (bone mineral density) at the level of the femur

	Exercise	Control	*p*
Age (years)	56±2.9	56.4±2.1	.56
Height (cm.)	160.7±6.1	159.3±4.6	.57
Weight (kg.)	65.7±6.6	64.2±7.4	.51
BMI	25.4±2.3	25.9±2.3	.53
BMD_{Neck}	0.683±0.070	0.702±0.081	.45
BMD_{Troch}	0.605±0.065	0.629±0.073	.30
BMD_{Inter}	1.032±0.079	1.057±0.120	.45
$BMD_{Ward's\ triangle}$	0.508±0.107	0.513±0.110	.88
BMD_{Total}	0.864±0.069	0.887±0.095	.39

Note. BMI = Body Mass Index; BMD = bone mineral density (g/cm^2).

Bone mineral density in the trochanter region registered a significant increase (Δ% = 3.80) in the exercise group (0.628 ± 0.067 vs. 0.605 ± 0.065), $F(1, 19) = 56.07$, $p < .001$, $\eta_p^2 = .75$, 95% CI [-0.029, -0.016]. A much smaller increase was also observed in the case of the control group (Δ% = 0.48) in bone density (0.632 ± 0.067 vs. 0.629 ± 0.073), $F(1, 18) = 0.82$, $p = .38$, 95% CI [-0.010, 0.004]. Between the groups, there was a significant difference at the end of the study, $F(1, 36) = 16.48$, $p < .001$, $\eta_p^2 = .31$, 95% CI [0.009, 0.027] (Table 2).

The subjects in the exercise group registered a significant increase in bone mass at the intertrochanteric region (Δ% = 0.97) ($M = 1.042$, $SD = 0.075$) compared to baseline results ($M = 1.032$, $SD = 0.079$), $F(1, 19) = 3.13$, $p = .013$, $\eta_p^2 = .37$, 95% CI [-0.022, -0.003]; a decrease of bone density (Δ% = -0.28, $p = .49$) was observed amongst subjects of the control group (1.054 ± 0.108 vs. 1.057 ± 0.120). The difference between the two groups was not statistically significant, $F(1, 36) = 2.70$, $p = .11$, 95% CI [-0.002, 0.023].

Table 2. Baseline and final results regarding femur's bone mineral density

	Exercise	Control

	Pre	Post	p^a	Δ%	Pre	Post	p^b	p^c	Δ%
BMD Neck	0.683±0.070	0.697±0.069	**.001**	+2.05	0.702±0.081	0.704±0.077	.45	**.01**	+0.28
BMD Troch	0.605±0.065	0.628±0.067	**.001**	+3.80	0.629±0.073	0.632±0.067	.38	**.001**	+0.48
BMD Inter	1.032±0.079	1.042±0.075	**.013**	+0.97	1.057±0.120	1.054±0.108	.49	.11	-0.28
BMD Ward's triangle	0.508±0.107	0.517±0.107	**.023**	+1.77	0.513±0.110	0.517±0.112	.19	.47	+0.78
BMD Total	0.864±0.069	0.881±0.071	**.001**	+1.97	0.887±0.095	0.889±0.085	.47	**.01**	+0.23

Note.The Δ% symbol represents the percent change; The pa value measures the intragroup difference in the exercise group (pre vs. post); The pb value measures the intragroup difference in the control group (pre vs. post); The pc value measures the post-test difference between groups.

In the exercise group, an increase of 1.77% was observed in bone mineral density at the level of Ward's triangle, F (1, 19) = 6.09, p = .023, η_p^2 = .24, 95% CI [-0.017, -0.001]. A smaller increase (Δ% = 0.78) was observed in the control group, F (1, 18) = 1.86, p = .19, 95% CI [-0.011, 0.002]; the difference between the groups was not significant (p = .47).

After 12 months, both groups showed improvements in bone density at the total femur. However, the exercise group showed a statistically significant increase (Δ% = 1.97) after 1 year (0.881 ± 0.071vs. 0.864 ± 0.069), F (1, 19) = 20.06, p < .001, η_p^2 = .51, 95% CI [-0.024, -0.009], while the control group showed a statistically insignificant increase (Δ% = 0.23), (0.889 ± 0.085 vs. 0.887 ± 0.095), F (1, 18) = 0.09, p = .77, 95% CI [-0.009, 0.007], the ANCOVA test (using the pretest result as covariate) showing an statistically significant difference between the two groups, F (1, 36) = 7.09, p = .01, η_p^2 = .17, 95% CI [0.003, 0.024] (figure 3).

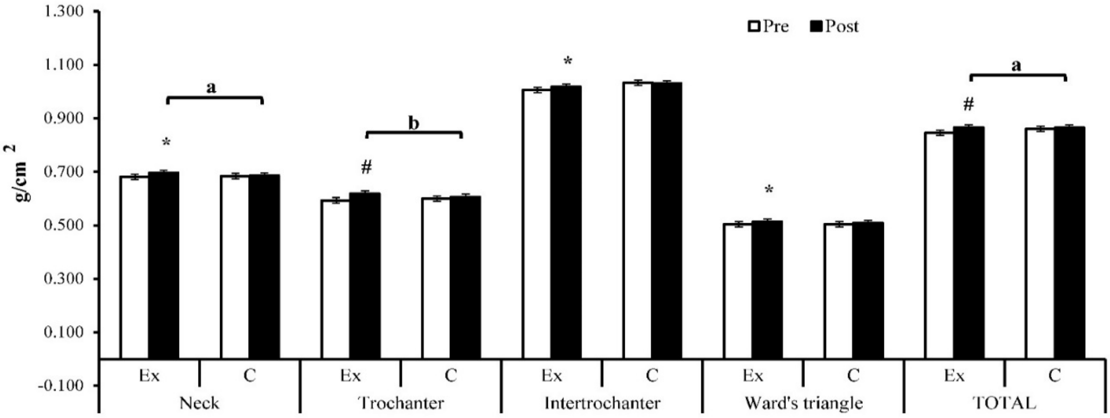

Figure 3. Pre and post-test results with 95% confidence interval regarding BMD (g/cm2) at the level of the femur after 12 months; The intragroup difference (p < .05) is marked with the symbol (*); The intragroup difference (p < .001) is marked with the symbol (#); The intergroup difference (p < .05) is marked with the letter (a); The intergroup difference (p < .001) is marked with the letter (b); Ex = exercise group; C = control group.

4. Discussion

There is no ideal exercise program for the prevention of osteoporosis [16]. Normally, it is not recommended to create an exercise program for osteoporotic individuals based on the technique and physiology of sports or high-performance exercise [17]. However, exercises can be classified into two categories: those aimed at optimizing the process of osteogenesis and bone strength and those aimed at preventing falls. Those in the first category can also arouse some adverse opinions, because most of the exercises used here (to stimulate osteogenesis) use jumping and climbing stairs, which are not always safe for certain categories of patients, due to the risks they are exposed to. Walking has little or no effect on preventing bone or muscle loss [18]. However, there are studies that confirm that dynamic loads (walking, running and strength-building exercises) are superior in terms of stimulating osteogenesis compared to static loads (isometric exercises) and can be safely used [19, 20]. While some articles state that bone-loading activities may help postmenopausal women [21, 22], a meta-analysis shows that walking, as well as other activities with a low intensity, have no effect on bone, or if they have any effect, it is a low one [23]. And in the elderly, a 12-month vigorous exercise program leads to increased bone mineral density at the femoral neck [24]. Physical exercises can produce changes in the cortical and trabecular area of bone, which influence bone strength independently of bone mineral density [25]. The best results at the spine and hip level were recorded following the practice of physical exercises with progressive resistances, when the load increases progressively over time, the magnitude of the load is high (around 80% – 85% of a maximum repetition – 1RM) and the muscle groups targeted were the large ones from the hip and spine [26]. In a study having as main objectives was observation the effects/results of strength exercises on bone density in postmenopausal women suffering from low bone mass, the exercise group (average age being 57.5 years; $n = 30$) participated in an exercise program and included exercises such as: dumbbell chest press, overhead military press, squats, seated hip adduction, calf raises, dumbbell elbow flexion etc. The control group (average age being 56.6 years; $n = 29$) did not take part in the training, and the subjects did not follow drug treatment. At the end of 12 months, the exercise group registered a decrease (Δ% = -0.71) at the femur region (0.838±0.11 vs. 0.832±0.11, $p = .26$); the control group also showed a decrease (Δ% = -0.60, $p = .37$) [27]. A one-year study [28] of 39 postmenopausal osteoporotic women aged 50 to 70 years found that the exercise group (61.1±3.7 years; $n = 20$) had a 4.5% improvement in femoral neck bone density; the control group (57.3±6.3 years, $n = 19$) showed a decrease of -3.8%, $p = .02$. The training program in which the exercise group participated was carried out 2 times a week and included hip extension, arm adduction, knee extension, trunk flexion and back extension using pneumatic resistance machines. The exercise intensity was 80% of 1RM, and in the first 2 weeks the exercise intensity was between 50 – 60% of 1RM. The duration of the training session was 45 minutes, and the training sessions were not performed on 2 consecutive days, to allow the body to recover from the previous session. Mosti and colleagues conducted a study over a period of 12 weeks [29] to observe the effects of their proposed program on femur bone density. The participants in the study were 21 women with osteopenia/osteoporosis aged over 60 years, squats with load being the main exercise, the program being performed 3 times a week. The intensities used were between 85 – 90%, with a number of 4 series and 3 – 5 repetitions for each series (after a warm-up series with an intensity of 50% and 8 – 12 repetitions). In the exercise group, bone mineral content registered a significant increase at the femoral neck (Δ% = 4.9, $p = .043$) compared to the initial results.

Another study conducted over a period of 12 months on postmenopausal women, recorded significant increases in femoral neck bone mass (Δ% = 1.5, $p < .01$) and trochanter (Δ% = 2.1, $p < .01$) in the exercise group. The training program was carried out 3 times a week, and included stretching, balance and weight-bearing exercises. Weight-bearing exercises were performed on machines or using dumbbells, weight vests, or barbells and included: leg press, Smith machine squats, pull-ups, horizontal arm abduction, back extension, elbow flexion, and trunk rotations. The exercises were performed in 2 series of 6 – 8 repetitions, two days a week. The intensity was 70% of 1RM and one day a week the intensity was 80% of 1RM. In the case of the group that did not participate in the resistance exercise program, there was a -0.4% ($p < .02$) decrease in bone density of the femoral neck [30]. Compared to our study, which also took place over a period of 12 months, the increases in bone mineral density obtained by these authors are lower compared to those obtained by us, but it must be specified that in the study led by Going et al., the subjects underwent hormonal treatment.

Another 12-month study conducted in 2013, divided 63 postmenopausal women into 3 groups and the group that participated in resistance training program ($n = 15$; 51.4± 2.7 years) showed an increase by 8.73% ($p < .05$) in femoral neck bone density. The resistance exercise program was carried out 3 times a week, lasting approximately 60 minutes, and included the exercises: press extension, seated knee extension with weight machine, prone knee flexion with weight machine, horizontal bench press, lat pulldown, elbow flexion and exercises for toning the paravertebral and abdominal muscles (10 – 15 repetitions for each exercise). The subjects did not follow treatment based on vitamin D as in our case, but followed hormonal treatment [31]. The improvements obtained by Balsamo and colleagues are higher compared to those obtained by us, but it should be specified that the bone mineral density at the beginning of the study was much higher among these subjects compared to the subjects included in our study. It has been shown that bone mineral density can increase between 0.6% and 1.3% following a 6-month exercise program that involves resistance exercises and jumping [32]. Hande Basat and colleagues [33] observed an increase ($\Delta\% = 1.6$) in bone density of the femoral neck among women with postmenopausal osteoporosis after 6 months of practicing resistance exercises. The training program was carried out 3 times a week, with a duration of 60 minutes each training session and in addition, they were treated with vitamin D and calcium (800 IU and 1200 mg, respectively). The exercises were performed only once per session, with a number of 10 repetitions and included hip abduction, push-ups, hip extension, jumping rope, knee flexion, knee extension etc. Intensities were not mentioned, but it is noted that the training programs followed the recommendations of the American College of Sports Medicine.

A study published in 2000 found no significant difference in femur bone mineral density after 6 months of resistance exercise. Twenty five postmenopausal women (41 – 60 years old) participated in the study and were divided into 3 groups: one group ($n = 10$) participated in a resistance exercise program, 3 times a week, using high intensities of 80% of 1RM and a number of 8 repetitions per set, 3 sets in total per training session; another group ($n = 7$) participated in a resistance exercise program using intensities of 40% of 1RM and a number of 16 repetitions per set, 3 sets in total per training session; a control group ($n = 8$), sedentary. The exercises used were the following: seated knee extension on the machine, knee flexion on the machine, leg press, overhead military press, arm abduction, dumbbell elbow flexion, dumbbell elbow extension, machine pull-ups, machine lunges, hip extension, hip flexion, hip abduction and hip adduction. All groups received the same treatment: 125 IU of vitamin D and 600 mg calcium daily [34].

Another study conducted by Rhodes and colleagues [35], over a one-year period, evaluated the effect of a resistance exercise program performed 3 times per week, using intensities of 75% from 1RM, but without specifying the number of sets and repetitions. The study participants were volunteers, aged between 65 and 75 years, divided into 2 groups: the exercise group (68.8±3.2 years; $n = 20$) and the control group (68.2±3.5 years; $n = 18$). The program included the following exercises: bench press, leg extension, dumbbell elbow flexion, resistance elbow extension, machine seated knee extension, and prone machine knee flexion. At the end of the study, there were no significant differences in the exercise group, regarding the bone mineral density at the trochanter level ($\Delta\% = 1.4$, $p > .05$), femoral neck ($\Delta\% = 1.2$, $p > .05$) and Ward's triangle ($\Delta\% = 1.4$, $p > .05$). The results obtained in this study are lower compared to those obtained by us, but the training period was only 6 months, and the subjects did not follow vitamin D treatment.

Chilibeck and colleagues conducted a study with 48 women with osteoporosis, who were divided into 4 groups, but we will compare the results obtained within the experimental group (56.8±2.0 years; $n = 10$), as it is related to our topic. There were no significant differences regarding bone mineral density at the femoral neck ($\Delta\% = -0.1$, $p > .05$), trochanter ($\Delta\% = 0.2$, $p > .05$), Ward's triangle ($\Delta\% = -0.9$, $p > .05$) and total femur ($\Delta\% = -0.2$, $p > .05$) after 12 months of resistance exercise using intensities of 70% of 1RM, with a number of 2 series of 8 – 10 repetitions per series. The program was carried out 3 times a week and included 5 exercises for the muscles of the upper body area and 4 exercises for the muscles of the lower body area, and the subjects were treated with 400 IU of vitamin D and 500 mg calcium daily [36]. This study presents the results obtained in all areas of interest at the level of the femur, and after 12 months there were decreases in bone mineral density compared to the increases in our case, although the subjects also followed treatment based on calcium and vitamin D.

Another study conducted in America divided 28 women aged 75 to 85 years into an exercise group (81±3 years; n = 14) and a group who participated in a home exercise program (81±3 years; n = 14). Both groups followed the same treatment with 0.625 mg estrogen and 5 mg progesterone daily, and were additionally given calcium (1.200 mg/day) and vitamin D (800 IU/day) supplements. The duration of the study was 9 months, the training frequency being 3 times a week, the intensity used in the exercises being 75 – 85% of 1RM, with a number of 2 – 3 sets of 6 – 8 repetitions each, and the duration of one session being between 90 and 120 minutes [37].

In 2009, Verschueren and colleagues conducted a 6-month study in Belgium, in which 70 volunteers (58 – 74 years old) were divided into 3 groups: a group that performed the exercise program on a vibration platform (64.6 ±3.3 years; n = 25), a group that participated in a resistance exercise program (63.9±3.8 years; n = 22) and a control group (64.2±3.1 years; n = 23). The program was carried out 3 times a week (3 sets x 10 – 15 reps), the intensity increasing progressively during the 6 months from 25RM to 8RM. The exercises included only the leg press and the knee extension from the seated position on the isometric machine. After six months, the exercise group showed a 0.14% increase in total femur, compared to a -0.28% decrease in the control group, the increases being much more modest than those obtained by us [38].

Also, research carried out in this regard shows us that exercises that involve weights-bearing exercises, can improve bone health, in premenopausal [39] and postmenopausal women [26], and in elderly men [40]. There is research that demonstrates that bone loss can be prevented or bone mineral density can be gained among adults by performing physical exercise programs for a period between 24 and 104 weeks, with bone mineral density increasing between 1% - 3% [41]. Even in pathological conditions, the mechanical loading induced by the practice of physical exercises has a positive effect on the proliferation and activity of osteoblasts; therefore, leading to bone formation [42]. Bone has the ability to adapt to the pressures exerted on it, and this makes exercise a highly effective mechanical stimulus for developing and maintaining optimal bone mass throughout life. Although there are no studies to recommend an exact exercise dosage or intensity used for skeletal maintenance and development, exercise remains an effective means of improving bone health [17]. Antonio et al. conducted a study over a period of 24 weeks, a study that included women with postmenopausal osteoporosis (65 years old), and women who participated in high-intensity jump-based aquatic exercise recorded increases in bone mineral density at the femoral level (6.52 ± 2.71%). The exercise program lasted 30 minutes (5 minutes warm-up - stretching exercises, 20 minutes of jump-based exercises and 5 minutes of relaxation exercises - stretching exercises) performed 3 times a week, but not in consecutive days [43]. A meta-analysis from the year 2021 shows that women with osteopenia or postmenopausal osteoporosis who participated in a high load resistance training exercise program recorded significant increases in mineral density at the level of the femoral neck (standardized mean difference = 0.86%, p = .04) and at the total hip level (standardized mean difference = 1.26%, p = .002) compared to the control group [44]. Mosti et. al [45] did not register significant intragroup or intergroup differences after 12 weeks of resistance training consisting of 4 series of 3 – 5 repetitions with 85 – 90% of 1 RM (after a warm-up series in which the subjects used intensities of 50% with a number of 8 – 12 repetitions) and the duration of the breaks was 2 – 3 minutes between sets. The study participants were 16 women with osteopenia or postmenopausal osteoporosis divided into 2 groups: training group (61.9 ± 5.0 years old, n = 8) and control group (66.7 ± 7.4 years old, n = 8). Postmenopausal women who participated either in the high-impact exercise group or in the strengthening group in the study led by Basat and Eskiyurt [46] recorded increases of 1.2% and 1.6% respectively after 6 months regarding the mineral density at the level of the femoral neck. Another study carried out in 2016 for a period of 13 months included 52 women with postmenopausal osteoporosis and who were divided into 3 groups (a group that trained 3 times a week, a group that trained 2 times a week and a control group). The group that participated in resistance training 3 times a week recorded increases in mineral density by 0.12% at the level of the femoral neck, by 0.09% at the level of the trochanter and by 0.12% at the level of the total femur. The subjects who had a T score < -2.5 followed treatment with bisphosphonates (70 mg) weekly and vitamin D3 (5600 IU) daily, and those who had a T score between -1 and -2.5 followed only the treatment based on vitamin D3 [47]. Watson et al. al [48] recorded increases of 0.3% in the mineral density at the level of the femur among postmenopausal women over 60 years old (n = 12) after 8 months of resistance training in which they used intensities of 80 – 85% of 1RM. A 2020 meta-analysis [49] that included 18 training groups did not record significant differences between the intensities used (<65% of 1RM, 65 – 80% of 1RM or ≥80% of 1RM), while the meta-analysis conducted by Kemmler et. from 2020 [50] states that dynamic resistance exercise and weight bearing exercise are effective for increasing bone mineral density at the level of the femoral neck, but there are no significant differences regarding the increase in bone density at the level of the femoral neck between the two types of exercises. Another meta-analysis from 2020 [50] concludes that exercise programs with higher intensities and that use multiple exercises tend to have a greater impact on bone density at the level of the femoral neck (standardized effect 0.24). Also, the findings suggest a dose-response relationship with exercise programs that have a session duration of 60+ minutes, performed 2 – 3 times a week, over a period of more than 7 months [51]. Resistance training exercises can be performed by women with osteoporosis having beneficial effects on bone mineral density as shown by a 2023 meta-analysis [52], the risk of vertebral fractures being minimal as long as the exercises are performed correctly, and the women are supervised by a specialist with good training in the field [53]. To increase bone density, the most effective exercises are those that use higher intensities, as long as the subjects do not suffer from vertebral fractures [54-56] and a meta-analysis concluded that exercises performed with high intensities were more effective for the lumbar spine compared to exercises using moderate intensity [57]. A cross-sectional study from 2023 suggests that moderate to intense physical exercises are effective when it comes to increasing bone density at the level of the lumbar spine among women with postmenopausal osteoporosis [58]. However, if it is about patients with osteoporosis who have suffered vertebral fractures and surgical interventions, the physical exercises must be adapted, and the intensity of the exercises must be low [59]. Another meta-analysis that compared the effect of high-intensity physical exercises with moderate-intensity physical exercises concluded that high intensities are favorable for increasing bone density among women with postmenopausal osteoporosis [60], the same conclusion being reinforced by a review article that highlights the fact that exercises with increased intensities produce the greatest pressures and loads on the bone, a fact that ultimately leads to bone remodeling [61].

As limitations of the study, it can be represented by the fact that the subjects in the control group verbally confirmed that they did not participate in any exercise program during the 12 months, but we could not verify this aspect at all times of the study. Also, another limitation is represented by the fact that we could not control the diet of the subjects. Also, we could not control all the physical activity of the subjects (since they were subjects from both urban and rural areas). However, all these limitations can be taken into account by future authors who want to evaluate the effects of physical exercises on bone mineral density among women with postmenopausal osteoporosis.

5. Conclusions

Specifying the optimal type of exercise remains a challenge, especially when considering bone, due to the wide range of exercise parameters to be considered (duration, frequency, number of sets, rest periods). The training protocol implemented by us in our research, alternating intensities of 70% of 1RM with those of 50% of 1RM within the same set, represents an efficient and inexpensive method of increasing bone mineral density at the level of the femur among postmenopausal women with osteopenia or osteoporosis, increases of 2.05% at the level of the femoral neck and 1.97% at the total level of the femur.

We could suggest that women with osteoporosis or postmenopausal osteopenia participate in an exercise program with weights 2 times a week, using intensities that do not exceed 70% of 1RM. The program should include exercises for the muscles of the lower limbs (extensors, flexors, abductors, adductors), for the muscles of the back and upper limbs. In terms of volume, the subjects can reach a total volume of 12 series per session, with a number of 12 repetitions per series. Since the risk of vertebral compression fractures (and the occurrence of kyphosis) is quite high with the progression of osteoporosis and advancing age, it would be good to avoid spine flexion exercises and focus more on back extension exercises.

The results achieved by subjects confirmed that moderate load used are beneficial for women with osteopenia or osteoporosis in order to improve the bone mineral density.

Author Contributions: Conceptualization, H.I.S and L.F.V.; methodology, H.I.S. and L.F.V.; software, H.I.S. and L.F.V.; validation, H.I.S. and L.F.V.; formal analysis, H.I.S.; investigation, L.F.V.; resources, H.I.S. and L.F.V.; data curation, L.F.V.; writing—original draft preparation, H.I.S. and L.F.V.; writing—review and editing, H.I.S. and L.F.V.; visualization, H.I.S; supervision, L.F.V.; project administration, H.I.S. and L.F.V. All authors have read and agreed to the published version of the manuscript.

Funding: The APC was funded by Stefan cel Mare University of Suceava.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics Committee of Stefan cel Mare University of Suceava (protocol code 35 from 28.05.2021).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. Written informed consent has been obtained from the patient(s) to publish this paper.
Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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