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Physical activity and bone turnover in women with osteopenia

Fizička aktivnost i povećanje volumena kostiju kod žena sa osteopenijom

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Abstract

Background/Aim. Osteoporosis is a systemic disease of the skeleton characterized by a decrease in bone mass and changes in the bone structure. An increased tendency of the bone tissue for fractures occurs as a consequence of these changes. The initial phase of physiological aging of the bones that gradually leads to osteoporosis is osteopenia. This paper tracks the effects of a specific kind of physical exercise program in women with osteopenia. The aim was to quantify the impact of this program on: the concentration of bone metabolism blood markers, muscle strength, aerobic capacity, and physical dimensions. **Methods**. The sample consisted of 26 women in postmenopause (age 46–58) divided into two groups – experimental group (n = 15) and control group (n = 11). A combined program of exercise consisting of aerobic activities and strength training was applied in the experimental group, while the control group did not join in the exercise program. The program lasted for 7 weeks, three times a week with a break day between the trainings. The intensity of the aerobic training was in the span of 60% to 70% of heart rate reserve (HRR), and the intensity of the strength training was in the span of 60% to 85% of one repetitive maximum (1RM). Osteopenia was diagnosed prior to the experiment by applying a dual energy X-ray absorptiometry of the lumbar spine and the hip. The following was measured before and after the experiment: the level of biochemical markers in the serum [Beta-aspartic acid -cross laps (CTx), total procollagen type 1 N-terminal peptide (tP1NP) and bone isoenzyme of alkaline phosphatase (ALP), 1RM of leg extensors, maximum oxygen consumption (VO_2 max), bodily height and mass, and a calculated Body Mass Index (BMI). **Results.** Significant changes were determined only in the experimental group. During the experimental period, there was a significant increase of muscle strength and VO_2 max, with a decrease of Beta-CTx concentration. No statistically significant changes were recorded in the control group. **Conclusion.** A 7-week period of systematic exercise showed to be sufficient to increase muscle strength and VO_2 max, partially also to decrease bone resorption, but insufficient to alter bone volume, bodily mass, and BMI.

Key words:
bone diseases, metabolic; osteoporosis, postmenopausal; exercise; densitometry; blood chemical analysis; muscle tonus; serbia.

Apstrakt

Uvod/Cilj. Osteoporoza je sistemska bolest koštanog sistema koju karakteriše smanjenje koštane mase i promene u koštanoj strukturi. Povećana sklonost ka prelomima kostiju posledica su gore navedenih promena. Početna faza fiziološkog starenja kostiju je osteopenija, koja postepeno dovodi do osteoporoze. Cilj ovog istraživanja bio je utvrđivanje efekata aerobnih aktivnosti i vežbi snage na volumen kostiju žena sa osteopenijom. Efekat je utvrđivan procenom efekta vežbi na koncentraciju markera koštanog metabolizma u krvi, jačinu mišića, aerobni kapacitet i fizičke parametre. **Metode.** Uzorak je činilo 26 žena u postmenopauzi, koje su podeljene u dve grupe – eksperimentalnu (n = 15) i kontrolnu (n = 11). U eksperimentalnoj grupi primenjen je kombinovani program vežbanja koji se sastojao iz aerobnih aktivnosti i vežbi snage, dok kontrolna grupa nije učestvovala u programu vežbanja. Program je trajao sedam nedelja, tri puta nedeljno sa danom pauze između treninga. Intenzitet aerobnog treninga kretao se između 60% i 70% srčane rezerve, a intenzitet u treningu snage između 60% i 85% jednog repetitivnog maksimuma (1RM). Mineralna gustina kostiju lumbarnog dela kičme i kukova merena je metodom apsorciometrije X zraka (DEXA). Izmereni su nivoi beta-*cross laps* (CTx), ukupnog prokologen tipa 1 N-terminalnog peptida (tP1NP) i koštanog izoenzima alkalne fosfataze (ALP) u serumu. **Rezultati.** Rezultati pokazuju da je eksperimentalni tretman doveo prvenstveno do značajnog povećanja mišićne sposobnosti u eksperimentalnoj grupi. Takođe, utvrđeno je značajno smanjenje koncentracije Beta CTx, uz neznačajne promene nivoa tP1NP i ALP. U kontrolnoj grupi nisu nađene značajne promene ispitivanih

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parametara. **Zaključak.** Na osnovu rezultata možemo da zaključimo da je period od sedam nedelja dovoljan za smanjenje koštane resorpcije, ali nedovoljan za promenu koštanog volumena, telesne mase, indeksa telesne mase.

Ključne reči:
kosti, metaboličke bolesti; osteoporoza posle menopauze; vežbanje; denzitometrija; krv, hemijske analize; mišići, tonus; srbija.

Introduction

Osteoporosis is a systemic disease of the skeleton characterized by a decrease in mineral bone density (BMD) and by a disruption of microarchitecture of the bone tissue [1, 2]. These changes lead to a lower bone density and increased chance of fracture [3, 4]. Osteoporosis is widespread and is reaching epidemic scales. Currently, there are over 200 million people in the world suffering from osteoporosis, primarily women of older age. After the age of 40, mineral bone density progressively decreases for about 0.5% per year, particularly in women [5]. The prevalence of osteoporosis increases from 4% in women ages 50–59 to 52% in women over the age of 80 [6]. Osteoporotic fractures show a growing trend. The possibility of these fractures occurring during one's lifetime is 50% in women and 25% in men [7].

Osteopenia is the initial phase of physiological aging of the bones that leads to osteoporosis with age. Osteopenia and osteoporosis are diagnosed by applying a dual energy X-ray absorptiometry of the lumbar spine and the hip (DXA) that is used to acquire the values of bone mineral density (BMD) and T-score [8]. T-score is the difference between the current bone mass and the average value of bone mass maximum in young persons [9]. Indication of normal condition is a T-score between -1 and 1. When the values of T-score are between -1 and -2.5 the person suffers from osteopenia, while values lower than -2.5 indicate osteoporosis [9]. Around the age of 25 bones achieve maximum density (peak bone mass). After this, the BMD stagnates and begins to decrease after menopause as the resorption quickens and surpasses bone formation. This leads to osteopenia and it usually occurs in premenopause when BMD decreases for about 2% per year in women. In postmenopause, BMD decreases for about 1%–1.5% a year. In their eight decade, women have about 30% lower BMD than in their third decade of life, which significantly increases the risk of fracture [10, 11]. Osteopenia is a safe indication to start applying therapy treatments [12].

The best way of combating premature osteopenia is prevention [12]. There is a significant link between increased physical activity and BMD. It plays an important role in increasing bone mass during childhood and early adolescence [13]. After the age of 35, dosed physical activity significantly contributes to maintaining bone mass, slows down its loss and decreases the risk of fracture [14] in the elderly. Bone quality gained by exercising cannot be permanent if the exercise is not regular [9]. The evidence of this is the reduction of bone mass even in younger women that occurs as a consequence of immobilization due to injury of movement apparatus [15] (locomotor apparatus). Several scientific studies indicate a positive influence of systematic physical activity on bone mass [16–18]. On the other hand, physical inactivity (hypokinesia) negatively influences bone turnover and increases resorption [19]. Apart from having a direct impact on the bones, hypokinesia decreases muscle strength, which decreases the ability of the locomotor apparatus and increases the risk of falling and fractures [20].

Physical activity shows a significant connection with osteopenia and osteoporosis indirectly through body weight (BW), the amount of fat tissue and body mass index (BMI). BW lower than 63.7 kg and MBI lower than 19 kg/m^2 are believed to be a risk factor for osteoporosis [21]. Some studies also show that obesity is a risk factor considering it is connected with cardiovascular diseases, hypertension and a lowered vitamin D level [22]. Apart from that, fat tissue secretes cytokines, which has an influence on increasing bone resorption and adipokines that change the effect of sympathetic nervous system on the bone tissue [23]. The possibility of using regular aerobic exercise to efficiently influence the decrease of fat tissue and the regulation of BW and MBI is an additional reason for researching the impact of physical activity on osteopenia. The aim of this study was to determine precisely the reaction of the bone system to the 7-weeks exercise program in menopausal women with osteopenia. The exercise program consisted of a combination of aerobic activities and strength exercises with own weight and resistance training.

Methods

Study design

The study was performed in accordance with the Declaration of Helsinki. All examinees were patients of the Department of Endocrinology, Diabetes and Metabolic Diseases, Clinical Center of Vojvodina in Novi Sad, Serbia and have all signed an agreement to voluntarily participate in the experiment.

The research was realized as an experiment with two parallel groups (experimental and control) and it lasted for 7 weeks. The experiment consisted only of the persons diagnosed with osteopenia by DXA. In the experimental group a special program of exercise adapted to menopausal women of low physical fitness was applied. The program was realized at the Faculty of Sports and Tourism in Novi Sad. Both groups consisted of women whose age, physical fitness and BMD were approximately of the same values. During the experimental period, the examinees of the control group kept to their usual habits and conducted their usual daily activities. Furthermore, examinees of both groups had normal diets (ate in their usual way). None of the examinees took any special medical therapy that could have potentially disrupted the experimental factor.

Three days before and after the experiment, the examinees of both groups were measured for BW, had their BMI calculated, their maximum oxygen consumption, strength of leg extensors, and had blood sample drawn that resulted in three pieces of data: bone turnover blood markers: β-cross laps (beta-CTx) and total procollagen type 1 N-terminal peptide (tP1NP) and alkaline phosphatase (ALP) bone isoenzyme. Bodily height (BH) was measured only prior to the experiment. Initial values of the tracked variables (pretest) were compared with the corresponding final values (post-test).

Sample

The final sample consisted of 26 able-bodied women, age of 46 and 58 that completed all the necessary criteria. The condition for entering the final sample was that all the examinees are in postmenopause and had low physical activity in the past few years, that they underwent pretest and post-test, that they did not take any medical therapy during the experimental period and that their T-score on DXA analysis was between -1 and -2.5. Additional condition that was given to the examinees of the experimental group was that they participated in every training session. The examinees voluntarily agreed to be divided into the experimental and the control group. The examinees of the experimental group confirmed their willingness to undergo the experimental treatment and to regularly partake in every training session. The examinees of the control group did not wish to undergo systematic exercise, but they have agreed to take all measurements and to continue their usual activities during the experimental period.

The initial sample consisted of 35 examinees (20 in the experimental and 15 in the control group). There was a reduction in the number of subjects during the experimental period. Five women were excluded from the experimental group: 4 that did not participate in all training sessions due to sessional illnesses, and one that was diagnosed with the risk of increased straining (hypertension and tachycardia during the VO_2max test). Four women were excluded from the control group: three who began taking a hormonal treatment during the experiment, and one who did not show up for the final measurements. Therefore, the final number of women in the experimental group was 15, and 11 in the control group.

Instruments and material

Measuring of the bone mass was conducted at the Department of Endocrinology, Diabetes and Metabolic Diseases, Clinical Center of Vojvodina in Novi Sad. A modern device for osteodensitometry of the „Hologic Explorer QDR" type was used. DXA procedure (Dual X-Ray Absorptiometry) was used as a reliable and quick method, as it is considered to be a „golden" standard of measurement for mineral bone density [8]. For the needs of this study, the data regarding BMD recorded on the lumbar spine and the hip were used. Absolute values (g/cm^2) for each examinee were compared with the average values of the female population in menopause and on the basis of individual deviation, the relative values were automatically calculated (T-scores).

To analyze the level of bone resorption, blood marker beta-CTx was used. To analyze the process of bone formation, blood marker tP1NP was also used. As additional biochemical parameter, ALP bone isoenzyme was monitored, the heightened values of which can indicate increased bone turnover. Sampling of the blood and laboratory analysis of both bone markers (beta-CTx and tP1NP) and ALP bone isoenzyme before and after the experiment was conducted in the reference laboratory "Eurolab" in Novi Sad. Sampling of the serum was conducted in early morning hours after a nightly fast. To determine the concentration of bone markers, enzyme-related immunosorbent kit (Roche Diagnostics) was used.

The evaluation of the aerobic capacity was conducted based on VO_2max by applying Bruce submaximal test according to the protocol predicted by the American Collage of Sport Medicine (ACSM) [24]. Running was not applied, only walking on a treadmill of which the grade and speed were progressively increased. The brand of the treadmill was Trackmaster by JAS (model TMX425C). For all women, general indications for stopping an exercise test in low risk adults [24] were excluded. The test protocol consisted of three stages, each lasting 3 minutes. The initial speed was 3 km/h and grade 10%. At second stage speed was 4 km/h with grade of 12% and at the final stage, it was 5.5 km/h and 14%. The examinee's heart rate (HR) was measured every minute. The concept of steady-state HR (HR_{ss}) was applied (within 6 bmp). If the examinee was not at a steady state by the 3rd minute, then they would continue to walk at that same pace for another minute. The examinees should complete all three stages. The first stage was considered to be a warm-up stage. The HR_{ss} should be between 115 and 155 bmp for the last two stages. The maximal aerobic capacity (VO_2max) was calculated according to the ACSM formula [24], in which the HR_{ss} was the main parameter measured during the second and the third stage.

To test the muscle strength of the leg extensors, one repctitive maximum (1RM) testing protocol was used, as suggested by Baechle and Earle [25]. This test protocol was used even in earlier research [26, 27] and was recommended as suitable for mass use since it did not require complex laboratory equipment. The testing session consisted of recording the body weight and age, verification of the equipment adjustments, and performance of about 5–10 repetitions of a slightly heavier weight. Formal strength testing began on the third visit. After a warm-up consisting of 10 repetitions of a light weight, a rest, and 5 repetitions of a medium weight, subjects were tested for the concentric 1RM, the heaviest weight that could be lifted for one repetition. Testing included single attempts at progressively heavier weights until the 1RM was identified.

Experimental program (Combined training program)

The program was performed in 7 weeks with a frequency of 3 nonconsecutive days per week. Aerobic training intensity varied between 60% and 70% heart rate reserve (HRR, and resistance training intensity varied between 60% and 85% of 1RM. The program consisted of three parts. The

first part was performed for 2 weeks, and the aim of this part was to prepare the participants for further loads. In the resistance training section (Table 1) the participants performed exercise which develops muscle endurance of major muscle groups and core exercises. In the aerobic training section, the participants performed exercises such as walking, running, hooping and jumping, with intensity from 60% of HRR. Aerobic exercises were applied during the first and last 10 minutes of each workout. To control the intensity of the activity, meaning HR monitoring, „Polar FT60" Holter pulsemeter monitor was worn by each examinee during the workout.

Table 1

Resistance training program

First part	Second part	Third part
Push-up	Leg press	Leg press
Curl-up	Bench press	Bench press
Trunk extension	Deadlift	Deadlift
Squat	Seated row	Seated row
Core exercise	Abdominal crunch	Abdominal crunch

The percentage of HRR was determined by Karvonen formula [30], the key elements of which were the maximum heart rate (HR_{max}), and resting heart rate (HR_{rest}). HR_{max} was calculated using the formula 220–age [31]. Target heart rate (THR) was calculated using the formula:

$$THR = [(HR_{max} - HR_{rest}) \times \% \text{ intensity}] + HR_{rest}$$

The second part was performed within 3 weeks and in the resistance training section the participants performed resistance exercise with intensity ranging from 60% of 1RM (first week) and in aerobic section from 70% HRR. In the second week, resistance exercise intensity was 65% 1RM and in the third week 70% 1RM. The third part lasted two weeks and in the resistance training section, the participants performed resistance exercises with intensity varying between 75% 1RM (first week) and 85% 1RM (second week) and in the aerobic section with intensity from 70% HRR.

Statistical analysis

For all variables tracked in the research, representative descriptive parameters were calculated (Mean and standard Deviation). *T*-test for independent samples was applied to test the significance of differences between the results of the experimental and the control group on the pre-test and the post-test. To analyze the effects of the experimental treatment, analysis of variance with repeated measures that combined two subjectswas used: the time and the specificity of groups. This statistical procedure is called Mixed between-within subjects ANOVA by Tabacnick [28] and Pallant [29]. Portable IBM SPSS v.19 application was used for the analysis and all the conclusions were drawn based on 0.05 level of significance ($p \leq 0.05$).

Results

DXA analysis showed that all examinees had a minimum of two points with T-score below -1. Far more, such points were registered on the lumbar spine than on the hip, as it was expected and was in accordance with the results of previous studies [10, 32]. Both average T-scores gained from the hip analysis on the level of the total sample were above -1, but all average T-scores gained from the lumbar spine analysis were below -1. This confirmed that both groups (experimental and control) were typical representatives of middle age women with osteopenia. The average values of BMD of the experimental and the control groups did not show a statistically significant difference (Table 2). This is the evidence that the groups were homogenous compared to the bone status. Homogeneity of the groups prior to the experiment was also confirmed by the results of other analyses (Table 3). Arithmetic means of anthropometric variables – body height, weight and mass index (BH, BW and BMI, respectively), biochemical markers (beta-CTx, tP1NP i ALP), VO_2max and 1RM of the experimental and the control group also did not show a statistically significant difference on the pre-test. In this way, numerous factors that could influenced the reliability of the conclusions were eliminated.

Table 2

Dual energy X-ray absorptiometry (DXA) indicators of the bone mass status for two groups of examinees

Variable	Experimental (n = 15)		Control (n = 11)		*t*-test	
	mean	SD	mean	SD	*t*	*p*
L1 BMD (g/cm^2)	0.891	0.063	0.987	0.177	-1.938	0.065
L1 T-score	-1.9	0.5	-1.2	1.4	-3.102	0.005
L2 BMD (g/cm^2)	0.977	0.123	1.001	0.154	-0.435	0.668
L2 T-score	-1.9	1.0	-1.1	1.5	-1.532	0.139
L3 BMD (g/cm^2)	1.020	0.112	1.023	0.1437	-0.055	0.956
L3 T- score	-1.5	0.9	-1.1	1.3	-0.874	0.391
L4 BMD (g/cm^2)	0.993	0.121	1.001	0.183	-0.124	0.903
L4 T- score	-1.3	1.5	-1.2	1.5	-0.143	0.888
L-Total BMD (g/cm^2)	0.973	0.096	1.004	0.159	-0.609	0.549
L-Total T- score	-1.7	0.8	-1.0	1.4	-1.567	0.131
Hip-Neck BMD (g/cm^2)	0.876	0.110	0.830	0.117	0.984	0.335
Hip-Neck T- score	-0.9	0.9	-0.9	0.6	-0.029	0.977
Hip-Total (g/cm^2)	0.924	0.126	0.903	0.087	0.461	0.649
Hip-Total T- score	-0.453	1.138	-0.610	0.604	0.398	0.695

L1-5 – Lumbar vertebral 1-5; BMD – Bone Mineral Density; SD – standard deviation.

Table 3

Descriptive statistics of pretest and post-test for experimental (n = 15) and control group (n = 11)

Variable	Group	Pretest		Post-test	
		mean	SD	mean	SD
Beta-CTx (pg/mL)	Experimental	550.87	164.474	489.09	175.662
	Control	489.09	175.662	438.00	157.425
	t-test	*t* = 0.920	*Sig.* = 0.367	*t* = 0.055	*Sig.* = 0.957
tP1NP (mcg/L)	Experimental	68.27	19.295	64.78	24.1653
	Control	55.12	14.167	52.29	15.716
	t-test	*t* = 1.911	*Sig.* = 0.068	*t* = 1.494	*Sig.* = 0.148
ALP (U/L)	Experimental	77.07	18.425	74.47	19.272
	Control	72.55	26.909	74.73	27.626
	t-test	*t* = 0.509	*Sig.* = 0.615	*t* = -0.028	*Sig.* = 0.978
Leg-Press (kp)	Experimental	118.93	40.006	168.53	40.977
	Control	119.70	40.255	118.10	34.936
	t-test	*t* = -0.063	*Sig.* = 0.951	*t* = 3.333*	*Sig.* = 0.003
VO_2 max (mL/kg/min)	Experimental	29.77	4.831	32.76	4.317
	Control	28.82	3.882	28.61	3.787
	t-test	*t* = 0.530	*Sig.*= 0.601	*t* = 2.514*	*Sig.*= 0.019
Body height (m)	Experimental	1.629	0.060	/	/
	Control	1.649	0.092	/	/
	t-test	*t* = -0.678	*Sig.*= 0.504		
Body weight (kg)	Experimental	71.17	9.482	69.90	8.970
	Control	74.54	14.478	74.33	14.160
	t-test	*t* = -0.720	*Sig.*= 0.479	*t* = -0.974	*Sig.* = 0.340
Body mass index (kg/m^2)	Experimental	26.79	3.082	26.32	2.899
	Control	27.39	4.804	27.31	4.704
	t-test	*t* = -0.385	*Sig.*= 0.704	*t* = -0.663	*Sig.* = 0.513

Beta-CTX – beta-cross Laps; tP1NP – total procollagen type 1N-terminal peptide; ALP – alkaline phosphotase; *Statistically significant difference; *Statistical significant.

Table 4

Statistics of mixed between-within subjects ANOVA

Variable	Wilks' Lambda	F	*p*	Partial Eta Squared
Beta CTx				
Time^Group impact	0.913	2.280	0.144	0.087
Time impact	0.578	17.553	0.000	0.422*
Group difference		0.226	0.639	0.009
tP1NP				
Time^Group impact	0.999	0.025	0.876	0.001
Time impact	0.915	2.227	0.149	0.085
Group difference		3.035	0.094	0.112
ALP				
Time^Group impact	0.930	1.807	0.191	0.070
Time impact	0.999	0.014	0.907	0.001
Group difference		0.058	0.812	0.002
Leg-Press				
Time^Group impact	0.329	49.028	0.000	0.671*
Time impact	0.357	43.281	0.000	0.643*
Group difference		54.993	0.000	0.817*
VO_2 max				
Time^Group impact	0.478	25.105	0.000	0.522*
Time impact	0.548	18.947	0.000	0.452*
Group difference		10.388	0.013	0.216*
Body weight				
Time^Group impact	0.608	15.501	0.001	0.392*
Time impact	0.428	32.023	0.000	0.572*
Group difference		0.714	0.406	0.029
Body mass index				
Time^Group impact	0.585	17.037	0.000	0.415*
Time impact	0.416	33.761	0.000	0.584*
Group difference		0.272	0.606	0.011

Beta-CTX – beta-cross laps; tP1NP – total procollagen type 1N-terminal peptide; ALP – alkaline phosphatase; VO_2max – maximum oxygen consumption; *Statistical significant.

The results of the post-test indicate that after 7 weeks of systematic exercise, statistically significant differences between average values of the experimental and the control group were recorded only on two variables: Leg-Press and VO_2max. However, by inspecting the results of the variance analysis, as many as 5 variables can be noticed that time impact had proven to be statistically significant: beta-CTx, Leg-Press, VO_2max, BW and BMI (Table 4). Group differences were not significant for variables beta-CTx, BW and BMI. Using combined interpretation of values Wilks' Lambda and Partial Eta Squared, it was concluded that no significant change occurred in the control group during the experimental period. At the same time, the exercise program in the experimental group had an influence of significantly decreasing bone resorption, increasing muscle strength, increasing aerobic capacity and decreasing BW and BMI. However, the degree to which bone resorption and bodily dimensions decreased was not sufficiently clear and because of that the post-test missed significant differences between the experimental and the control group. Variance analysis indicated that the 7-weeks physical exercise experimental program was only sufficient for a significant increase of muscle strength and aerobic capacity. Despite a substantial decrease of beta-CTx, BW and MBI in the experimental group, these changes can only be interpreted as the start of the process of positive changes caused by physical activity.

Discussion

Previous research showed that a long-term effect of physical activity on the skeletal system was manifested through increasing of the MBD measured by the DXA method. As the changes of the BMD are very slow, markers of biochemical processes in the bones are used to explain the short-term effects in research. Until now, the most used markers of bone tissue formation have been as follows: ostocalcium, alkaline phosphatase bone isoenzyme, N and C propeptides of procollagen type 1. The most used biomarkers of bone degradation have been: deoxypyridinoline, pyridinoline, N and C telopeptides [33, 34]. The results of most previous research studies indicated that these biochemical markers were sufficiently sensitive to detect bone reaction to training stimuli caused by physical activity. In this research, the effects of the specific 7-week exercise program were quantified by using three parameters taken from the serum of the examinees: beta-CTx (bone resorption marker), tP1NP (bone formation marker) and ALP (metabolism and turnover marker). The results confirmed the findings of previous studies which described a positive influence of dosed physical activity on bone remodeling and metabolism. However, speaking strictly in statistical terms, the recorded changes were not significant, but were only the indications of an initial trend of positive changes. Compared with most of the previous studies where the experimental period lasted much longer (most frequently 6–12 months), the experimental period in this research was much shorter. Even though we were aware beforehand of the risk that shortening the experimental period could cause an absence of significant changes, the advantage was given to consistent control of the activity of all examinees. Such control was possible only with a smaller number of examinees and in a shorter period. Despite the shortened duration, there was a noticeable reduction of subjects in the sample. Some examinees were excluded due to irregular exercise and others for taking hormonal therapy. A small sample and a short duration of the experiment were the basic limiting factors of this study. The lack of a larger number of statistically significant changes was most probably due to the insufficient duration of the training stimuli.

The research registered a significant decrease of bone degradation (decreased concentration of beta-CTx). However, in practice, that piece of data was insufficient to recommend systematic exercise that lasts only 7 weeks as efficient. As expected, this period of systematic training resulted only in a significant increase of muscle strength and aerobic abilities. This data probably proves a positive influence of the applied exercise program on slowing down the process of bone degradation, but not on complete bone remodeling.

Apart from a direct influence on BMD, there is evidence that physical activity also has an indirect effect on the bone metabolism through the fat tissue [22, 23]. Aerobic exercise can be successfully used to regulate the percentage of fat in the organism, due to which BW and BMI were also monitored in this study. Some researches [35, 36] show that thinner women with BMI lower than 19 kg/m^2 are at a higher risk of osteoporosis. Persons with higher BW also have higher BMD and are at a lower risk of osteoporosis [37, 38]. This is explained by increased mechanical load that enables bone formation [39]. Mechanical load stimulates the flow of extracellular fluid through canaliculi and lacunae of the bones that transfer mechano-chemical signals to osteocytes [14]. Yet, excess body weight cannot be interpreted as protection from osteoporosis. On the contrary, newer studies indicate that overweight persons have an increased risk of osteopenia [22, 23]. Osteopenia in overweight persons is primarily connected with hypokinesia and decreased aerobic abilities.

The women that formed the sample in this study had BMI over 25 kg/m^2, but significantly less than 30 kg/m^2, which is the borderline for obesity. According to the World Health Organization (WHO) [40] standards, that puts them into the Overweight group (Pre-obese). Even though heightened BW increases the mechanical force and theoretically spurs bone formation [37–39], all our examinees still had osteopenia. At the same time, they were all measured for low values of VO_2max which indicates weak aerobic capacity. Based on these data, it can be concluded that insufficient physical activity of our examinees was a significant contributing cause for the onset of osteopenia. The level of VO_2max, less than 30 mL/kg/min measured prior to the experiment in both groups indicates low functional ability. This puts our patients in the typical group of sedentary women [41, 42]. Under the influence of applied training program, there was a significant increase in VO_2max in the experimental group. Such a rapid growth of aerobic capacity was not accompanied by the tempo of metabolic changes in the bones. This indicates that a longer application is necessary for a more serious indirect influence of aerobic training.

The influence of the training applied in this study has led to a significant increase of muscle strength in the experimental group. As it was previously proven that the mechanical load leads to increased BMD [39, 43, 44], it was realistic to expect that the increase of strength would be accompanied by changes in the concentration of biochemical markers in the serum. However, the only significant difference in the experimental group was in decreased level of beta-CTx, which indicated a slowing down of bone resorption. At the same time, for tP1NP and ALP, no significant changes were recorded compared to the original values. Based on these data, it was possible to conclude that the experimental program primarily impacted bone resorption, but did not increase the bone mass. The scale of this change was notably lagging behind the degree of which the muscle strength had increased. By comparing the final values of beta-CTx of the experimental and the control group, no statistically significant differences were noticed, which does indicate a small degree of progress. Decreased concentration of beta-CTx in the experimental group was only the initial signal that there were positive changes occurring in the bones. Obviously, for any serious changes to take place, a much longer training program is necessary.

This is also confirmed by the results of previous research in which the training period was much longer. All the experimental treatments lasted for 6 months minimum, which is at least three times longer than the period applied in this research. The results of each study had confirmed significant changes of bone markers in the blood of the examinees. The data were interpreted as a consequence of osteoblast stimulation, which resulted in increased MD. Vincent and Braith [45] applied training similar to that of this research for 6 months, difference being that the sample consisted of male persons older than 60 years old. The examinees were divided into three groups: a control group (without training), a control group with strength exercises of low intensity, and a group with strength exercises of high intensity. The trainings were performed three times per week, and they contained exercises that engage larger muscle groups from the areas most sensitive to changes in BMD. There was an increase in strength, regardless of the applied model of exercise. The results showed that after 6 months of strength training, biochemical markers of the bone formation in both experimental groups increased. As far as other biochemical indicators are concerned, there was a significant increase in osteocalcin (OS) in both groups exposed to strength training. The OS to pyridinoline ratio increased in both experimental groups, while it decreased in the control group. The changes in this ratio were interpreted by the authors as an indicator of the increased bone formation.

Yamazaki et al. [46] pointed out that by applying a 12-month aerobic training (load of about 50% of VO_2max), the concentration of bone resorption markers decreased and it happened only after the third month of exercise. The changes in the mineral bone density during this period were not recorded. These findings strongly correspond with the results of our study. All things considered, if the experiment lasted for several more weeks, the change in bone resorption markers (e.g. beta-CTx) would be statistically significant in our study as well. Here, it only announced positive changes in bone metabolism.

Taking into consideration the results of previous research, strength training combined with aerobic exercise can be considered a very efficient means of improving bone status, as is supported by our study. Until now, the time sufficient for the manifestation of positive effects has not been precisely defined. The different data regarding the period of training probably depend on the specificity of the examinee sample. In some studies focused on older persons, the decrease of bone resorption markers after applying strength training was recorded only after one year, but not after 4 years [47]. All things considered, the decrease in the process of bone resorption can be achieved in the earliest phase of strength training, during the first three months that are seen to be training adaptation. If there is no progression of load, training adaptation will probably not occur nor will the resorption further decrease. This is why it is necessary to conduct permanent control of training and gradually increase the volume and the intensity of training stimuli accordingly, of course, taking into consideration the general health of the person.

Even though there is evidence that aerobic training and strength exercises do have a significant influence on decreasing the consequences of osteoporosis, strength exercises were not proven to be more efficient in previous research studies. Particular attention was dedicated to exercises with one's own weight as they can be applied during the whole lifetime and do not require special equipment (weights and cross-trainers). These exercises include gravity-defying exercises in upright standing position [5]. These activities can be with stronger (high-impact) collisions with solid surfaces (e.g. jumping) and weaker (low-impact) collisions (e.g. walking). Several research studies proved high efficiency of these exercises for maintaining and improving BMD [5, 16, 48, 49]. The other model of exercise training is resistance training. The same authors tested its efficiency and compared it with the effects of exercise where one's own body was used as the resistance. Significant differences were not determined, which is why both models can be equally used when working with persons suffering from osteoporosis and osteopenia.

Conclusion

The results confirmed that regular physical activity has a positive effect on bone tissue. However, in this study, the training led only to a minimal decrease of bone degradation and did not have a significant impact on increasing bone formation. Even though using regular exercise led to a significant decrease in the concentration of beta-CTx markers in the blood, slowing down of bone resorption was not sufficiently manifested. The lack of significant changes can most probably be explained by insufficient duration of the experimental program. At the same time, 7-weeks training program was sufficient to cause a significant increase of muscle strength and aerobic capacity. To induce more serious adaptive processes in the bone metabolism of postmenopausal women, a far longer temporal period is necessary. Further research studies should be designed as experiments lasting for several months, by varying and progressively increasing the training stimuli.

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