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The Effect of Land versus Aquatic Exercise Program on Bone Mineral Density and Physical Function in Postmenopausal Women with Osteoporosis: a Randomized Controlled Trial

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SUMMARY

Background. Osteoporosis is a multifactorial progressive skeletal disorder characterized by reduced bone mass. Exercise is widely recommended to reduce osteoporosis, falls and related fragility fractures. The purpose of this study was to investigate the effects of land exercise (LE) and aquatic exercise (AE) on physical function and bone mineral density (BMD).

Material and methods. Fifty-eight postmenopausal women, aged 50-70 years, diagnosed with osteoporosis according to BMD measures, enrolled in this study. The subjects were randomly assigned to either the intervention group (LE group) or the control group (AE group). Physical function and BMD were assessed in all subjects in both groups before and after 10 months of intervention. Muscle strength, flexibility, balance, gait time and pain were measured to assess physical function. Bone mineral density at the lumbar spine was measured by dual energy X-ray absorptiometry (DEXA).

Results. There were no significant differences between the two groups in the baseline anthropometric data. The two groups were similar with respect to age, weight, height, and body mass index ($p>0.05$). After the exercise program, muscle strength, flexibility, gait time, pain, and bone density ($p<0.001$) improved significantly with LE compared to AE. There was no significant difference between the two groups with regard to balance at the 10-month follow-up.

Conclusion. Significant improvements in physical function and BMD suggest that LE is a possible alternative for postmenopausal women with OP.

Key words: randomized controlled trial, osteoporosis, exercises, women

BACKGROUND

Osteoporosis is a multifactorial progressive skeletal disorder characterized by reduced bone mass and a predisposition to increased fracture risk [1] and represents a serious and global public health problem [2].

Specifically, the most successful exercise programs to improve bone strength appear to be those that incorporate a diverse range of weight-bearing activities (e.g., skipping, dancing, jumping, and hopping) [3,4] ranging in magnitude from three to nine times body weight and which are performed three to five times per week, preferably on a daily basis, for 10-45 minutes per session [5, 6].

A few studies have demonstrated the effectiveness of various exercise programs (such as walking or strength training) in improving bone density. However, the effects of other types of exercises programmes, such as aquatic exercise (AE), remain unclear [7-11].

The effect of AE on bone density is controversial. Goldstein and Simkin reported that water exercises showed advantage over a land-based indoor program whereas Tsukahara et al found that water exercisers increased their bone density while the non-active control group registered an average decline. Bravo reported apparently opposite findings. He concluded that water exercise does not have a positive effect on bone density among women with osteoporosis [12, 13,14].

The impact of AE programmes in this population has led some experts to recommend AE for individuals with more severe OP as a well-tolerated exercise modality serving to improve function and balance [15].

The purpose of this study was to compare the effects of land exercise (LE) and AE on physical function and BMD in postmenopausal women with osteoporosis. Our hypothesis was that LE would result in greater improvement in physical function and BMD compared with AE.

It was a prospective, randomized, un-blinded study.

MATERIAL AND METHODS

Subjects

Sixty-four postmenopausal women diagnosed with osteoporosis (according to BMD measurements) were recruited from a group of 117 women aged 50-70 years who were admitted to the Physical Medicine and Rehabilitation outpatient clinic of the University Clinical Center in Kosovo. The inclusion criteria included: women recently diagnosed (within the past 6 months) with osteoporosis on account of a DEXA scan T score below -2.5, aged 50-70 years, who had no history of vertebral fractures or lower extremity fractures, did not have endoprostheses or fixation materials and were capable of signing written informed consent to participate in this study. The exclusion criteria included: cerebral vascular disease, musculoskeletal disorders such as arthritis, status post amputation, neurologic disorders such as peripheral neuropathy, visual and vestibular disorders or fractures of the spine or lower limbs, restrictions in physical activities, cardiopulmonary disease, liver disease, kidney disease, unstable diabetes mellitus, and unstable hypertension.

The subjects were randomly assigned to either an intervention group (n=31) or a control group (n=30). The random assignment procedure was performed using random numbers generated by a computer program.

Written informed consent was obtained from all participants. The study was approved by the Research Ethics Committee of the University of Prishtina.

Intervention

The LE program comprised three resistive exercise sessions per week for 10 months. Each sessions consisted of a warm-up period (10minutes), a period of exercise training (35 minutes) and a cool down period (10minutes). Participants started the exercise session with stretching and balance exercises for warm-up at 70-80% of the maximal heart rate. Stretching of hip/thigh flexors, hamstrings, lumbar extensors, pectoral stretching and stretching of the vertebral column were performed. Balance training consisted of a stepping exercise. Subjects stepped forward, backward, right, and left with one leg as quickly and safely as possible. The core set of exercises consisted of aerobic weight bearing and progressive, resistive exercises. For aerobic weight bearing, a weighted vest that was 10% of the participant's body weight was used for walking, stair climbing and step boxes training exercises. The training program was followed by progressive, resistive exercise for back extension in the prone position with a back pack that contained weights equivalent to 30% of the maximal back extensor strength (2 sets of 6-8 repetitions at 70% or 80% 1RM). Sessions ended with a 10-minute cool down period with relaxation, stretching, balancing and coordination exercises.

The subjects who were assigned to the control group (AE) exercised for 10 months, three times a week, in 35 min sessions. The general format was approximately 10 minutes of warm up, followed by 15 minutes of weight resistive activities and 10 minutes of cool down. Most exercises were performed in a vertical position in chest deep water. The water temperature was approximately 30.

For warm up subjects performed movements using their lower and upper limbs and stretching movements. The session continued with 5 minutes of exercises to improve balance (rising at the toe tips on one and both legs).

The main part of the program was designed to improve bone density and muscle strength: walking in water with weight belts attached to wrists and ankles, followed by 5 minutes of exercising in a horizontal position, floating with pool noodles used to strengthen the upper part of the body. Circuit and pool wall training was utilized for strengthening lower body muscles.

Ten minutes of cool down included stretching to promote posture and relaxation.

Participants were instructed to exercise at an intensity that was moderate to hard (12-14 on the 20-point Borg perceived exertion scale [16]). The content and intensity of the program in both groups remained the same throughout the 10-month intervention period.

During the sessions, exercises were supervised by a physiotherapist. In addition all subjects received dietary instructions motivating them to eat calcium-rich food. All participants received Ca (1000 mg daily) and Vitamin D (800-1000 IU daily) supplementation.

Measurements

Physical function and BMD were assessed in all subjects in both groups before and after 10 months of intervention.

Muscle Strength

The grip strength (GS) of the right hand was measured using a dynamometer (Hand Force, ANG 2010/01, Iskra Medical, Ljubljana, Slovenia) and right quadriceps strength (QS) was measured using a Hand-Held Dynamometer.

Flexibility

The bend reach performance test (BRPT) was used to measure muscle flexibility. The test is performed with the subject sitting on the floor with shoes removed and feet placed against the sit and reach box. Subjects were instructed to reach ahead with both hands as far as possible by bending the trunk and hip joint while sitting on the floor with their knee joints extended. The distance reached by the subjects was measured using a box and a ruler.

Balance

Berg Balance Scale (BBS) was used to assess functional balance. The test consists of 14 items that are frequently performed as activities of daily living. Scores in BBS were scaled from 0 (failure to perform task) to 4 (ability to perform task independently and safely) [17].

Gait Time

Walking endurance was measured with the Six-Minute Walk Test (6MWT). It is a functional walking test in which the distance that a patient can walk within six minutes is evaluated [18].

Bone Mineral Density

Bone mineral density was measured by dual energy X-ray absorptiometry (DEXA) with a GE Lunar Prodigy densitometer using standard protocols. The following variables were recorded: the T-score and the BMD value at the lumbar spine (L2-L4), measured in grams per square centimeter. The same measurements were made at baseline and after the intervention, post-treatment. The pre-post test measures were performed by the same technician.

Pain

A visual-analogue scale (VAS) was used to obtain self-assessment of the patients' pain intensity (from 0 to 10 cm) [19].

Statistical Analysis

The data were analyzed on an intention-to-treat basis. Descriptive statistics were used to show the participants' demographic profile. For balance, strength and bone density assessment, measurements of intervention influencing these calculations included means, standard deviations, within-subject percentage change and net within-subject percentage change (training effect). Mean percentage change was used to compare the results before and after intervention within each group. Differences between the two groups after intervention were compared using the unpaired T-test or the Mann-Whitney test. All of the statistical analyses were performed using SPSS for Windows, version 11. Statistical significance was established at the $p<0.05$ level.

RESULTS

A total of 117 women were assessed for trial eligibility. Sixty-four women were randomized and underwent a baseline assessment of balance, strength and bone mineral density. Of the 64 subjects initially

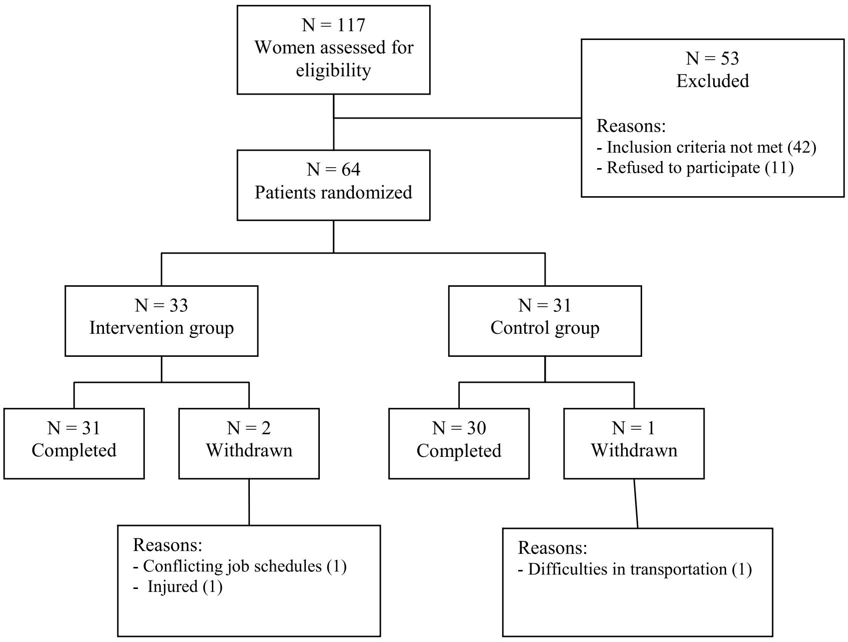

Fig. 1. Flow of subjects through the trial

recruited for the study, 3 subjects (2 from the intervention group and 1 from the control group) withdrew spontaneously after randomization for personal reasons: conflicting job schedules (n=1), injury (n=1), and difficulties in transportation (n=1). Thus, the remaining 61 subjects completed the study. Figure 1 shows a flow diagram of subject progression through the study.

The subjects' baseline characteristics are shown in Table 1. There were no significant differences between the two groups in the baseline anthropometric data. The two groups were similar with respect to age, weight, height, and body mass index ($p>0.05$).

Pre- and post-intervention scores in the test measures of balance, strength, flexibility, bone density, and pain for the two groups are shown in Table 2. At the completion of the trial all parameters: VAS, GS, QS, BRPT, BBS, 6MWT, BMD and T-score improved significantly in the intervention (LE) group ($p< 0.001$). In the control (AE) group, GS and QS improved significantly after 10 months compared to baseline ($p<0.01$), and 6MWT was longer after 10 months than at baseline ($p<0.001$). There were significant differences between the two groups in VAS, GS, QS, BRPT, 6MWT and T-score ($p<0.001$). There was no significant difference between the two groups in BBS at the 10-month follow-up (Table 2).

Tab. 1. Distribution of demographic data in groups

	Group 1 (n=31)		Group 2 (n=30)		P value
	Mean	SD	Mean	SD	
Age (year)	60.68	7.62	59.778	5.996	0.63
Weight (kg)	76.57	12.00	75.593	10.526	0.75
Height (cm)	165.54	4.18	165.778	4.677	0.84
Body Mass Index (kg/m2)	41.41	3.58	41.104	3.46	0.75

Group 1, intervention land exercise group, Group 2, control aquatic exercise group.

Tab. 2. Outcome measures at baseline and final assessment within group and between groups

Variable	Group 1 (n=31)			Group 2 (n=30)			%Change difference‡ training effect	P-value(#)
	Before	After	% change†	Before	After	% change†		
	Mean±SD	Mean ± SD		Mean ± SD	Mean ± SD			
VAS	2.96 ± 1.11	0.68 ± 0.72	-81.26*	3.074± 1.17	2.96 ± 1.19	-32.28	-48.98	<0.001*
GS	23.71 ± 1.17	24.6 ± 1.07	-4.54*	24.38 ± 0.85	24.4 ± 0.85	-2.35*	-2.19	0.002*
QS	18.91 ± 7.49	21.43 ± 6.05	4.4*	18.48 ± 6.16	19.13 ± 6.65	1.1*	3.3	0.002*
BBS	47.29 ± 7.05	48.79 ± 7.13	3.24*	46.7 ± 6.03	46.82 ± 5.97	3.04	0.2	0.38
6MWT	253.96 ± 47.4	299.37 ± 46.5	18.72*	270.2 ± 46.15	302.84 ± 49.7	12.29*	6.43	<0.001*
BMD	0.805 ± 0.097	0.854 ± 0.097	5.53*	0.814 ± 0.09	0.820 ± 0.088	3.92	1.61	<0.001*
T-score	-3.04 ± 0.4	-2.64± 0.4	-12.04*	-3.12 ± 0.48	-3.10 ± 0.50	-6.44	-5.6	<0.001*

† Mean percentage change expressed as [(post-intervention score - pre-intervention score)/pre-intervention score] x 100

‡Mean percentage change in exercise group minus mean percentage change in control group = net benefit of intervention or %difference between groups

* Significant
# unpaired t-test or Mann-Whitney test
Group 1, intervention land exercise group, Group 2, control aquatic exercise group.
VAS-Visual analogue scale, GS- Grip strength, QS- Quadriceps strength, BRPT- Bend reach performance test, BBS- Berg balance test, 6MWT- six minute walking test.

DISCUSSION

The purpose of this study was to assess differences in physical function and BMD following LE and AE programs in osteoporotic women. Our results corroborate the hypothesis that LE would result in better physical function and BMD compared with AE in a sample of osteoporotic women.

Our results concur with previous published evidence about the efficacy of land-based exercises in treating osteoporosis [20-24]. These study findings show that this program of resistive lifting exercise, weight-bearing exercise and specific balance strategy training thrice a week was of sufficient duration, intensity and appropriateness to result in significant improvements in physical functioning and BMD in postmenopausal women with osteoporosis. After 10 months, we identified significant improvements in the exercise group with regard to all parameters of physical function (GS, QS, BRPT, 6MWT) and decreased pain intensity after the exercise (p<0.001).

A number of studies have documented the advantages of aquatic therapy for osteoporosis symptoms. Water's buoyancy reduces injury risk as the joints are exposed to less stress and impact. A randomized, controlled trial from Australia found that aquatic therapy "resulted in less pain and joint stiffness, and greater physical function, quality of life, and muscle strength [25]. Another report of a randomized clinical trial concluded that significant improvements in balance and global change suggest that aquatic exercise is a viable alternative for older women with osteoporosis who have difficulty exercising on land [26].

The viscosity of water provides resistance for strength training. The reduction of gravitational forces in the pool allows the patient to stand and begin gait training and strengthening exercises without causing further damage to healing structures [27]. Cardoso and al. studied 34 postmenopausal women who did deep-water exercises for 12 weeks and they reported significantly improved muscle strength of their subjects [28]. Our results support this conclusion. The subjects allocated to the control group, who exercised twice a week for 30 minutes, showed significant improvements in GS, QS and 6MWT. Although aquatic exercises were not consistently found to result in greater improvements in flexibility, balance and BMD, we did find muscle strength and gait time to be significantly improved within the AE group, as compared at baseline and post-intervention.

In our study, the post-exercise T-score was higher in the intervention group. According to other studies in the literature, physical activities and exercises have positive effects on BMD, although they have documented the relative efficacies of different exercise regimens and types of programs [29-33].

There are different views in the literature on pool-based exercises for osteoporotic patients. Rotstein et al. examined the effect of a seven-month program of water exercises on BMD in thirty-five postmenopausal women exercising for seven months during three one-hour sessions per week [34]. DEXA test results for femoral neck mineral bone density indicated no significant differences between the groups pre- and post-treatment. Ay and Yurtkuran reported apparently opposite findings [35]. They found an anabolic effect of pool-based exercises on bone of 20 postmenopausal women, as evidenced by increased hormonal markers (insulin-like growth factor-1, growth hormone and calcitonin) and calcaneus ultrasound measurements. Also Goldstein and Simkin revealed a significant rise in bone density of the distal radius for the water exercise group [12].

Balance disorders are often a cause of falls and fractures in people with osteoporosis. Improvements in balance self-efficacy in women with osteoporosis have been reported after group-based exercise programs in the form of resistance training, weight-bearing exercises, tai chi, and task-oriented training programs [30,36,37].

Gunendi et al. showed that a 4-week sub-maximal aerobic exercise program (on a treadmill for 30 minutes twice a week) provided significant improvements in static and dynamic balances in postmenopausal osteoporotic women [19]. Madureira et al. evaluated the effect of balance exercises on the static and dynamic balance, ability to move, and the rate of falls in patients with osteoporosis compared with controls that did not practice [37].

In our study, although subjects in the intervention group presented higher balance scores on average than the control subjects, these differences were not statistically significant between the groups. Although warm water stimulates body awareness, balance, and trunk stability, the subjects from the AE group did not achieve statistically significant differential results.

The reason could be that the exercises, in both groups, were moderate impact activities which do not have a big influence on postural balance. Additionally, none of the Berg-balance score tests were part of the exercise program.

Low back pain in subjects with osteoporosis can influence postural control, and failure to maintain good posture due to pain stresses the spine, which over time can cause postural deformities and can decrease physical activity. In this case, physical rehabilitation will help reduce reactive anxiety and can alleviate pain as well [38,39]. Yavuzer et al. and Angin et al. have also reported lower intensity of pain after physical exercises in their studies [40,41].

In our study, neither of the treatment groups experienced fractures or serious orthopedic problems. This suggests that the pre-exercise pain in our subjects were due to osteoporosis and other age-related medical conditions caused by postural factors resulting from osteoporosis. Our observation of both groups also showed that the decrease in pain intensity was explained by the strengthening of back muscles, stretching, and posture exercises. Most likely, in the AE group, the pain decreased due to warm water and buoyancy.

The present study has a number of strengths and weaknesses. The strengths include the sampling method, which ensures a fair representation of Kosovar women consulted for osteoporosis in primary and secondary care as well as its randomized controlled design. The study drop-out rate was low and the attendance was relatively high. The main weakness relates to the duration of the study. The study spanned 10 months, which limits its full effectiveness. On the other hand, any longer duration of the program would have affected subject adherence. Another disadvantage is the small size of the study sample, which may affect the results. The limitations of this study may help to explain the BMD findings. The significant change in BMD within the exercise group over a short period can be also explained by the small size of the group and the fact that all participants received optimal individual osteoporosis supplements. Furthermore, the study was not single- or double-blind.

Although both LE and AE have beneficial effects on physical function and BMD in osteoporotic women, LE seems to be more effective. Despite the modest sample size, the results of the present study support the benefits of LE in the clinical management of patients with osteoporosis, but need to be confirmed in a larger sample.

CONCLUSION

Significant improvements in physical function and BMD suggest that LE is a possible alternative for postmenopausal women with OP.

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