A high-intensity jump-based aquatic exercise program improves bone mineral density and functional fitness in postmenopausal

women

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This paper has been peer-reviewed and accepted for publication, but has yet to undergo copyediting and proof correction. The final published version may differ from this proof.

A high-intensity jump-based aquatic exercise program improves bone mineral density and functional fitness in postmenopausal women (DOI: 10.1089/rej.2018.2069)

Abstract

The aim of this study was to verify the effects of a high-intensity jump-based aquatic exercise program (HIIAE) on bone mass and functional fitness in postmenopausal women. **Methods**: We randomly assigned 25 women (65 ± 7 years) into two groups: Training group (T, n=15) and Untrained group (Un, n=10). The T group was submitted to 24 weeks of a HIIAE program, where each session lasted for 30 minutes. The following parameters were assessed before and 6 months following the intervention: bone and physical fitness; lumbar spine (LS), total femur (TF) and whole body (WB) bone mineral density (BMD); as well as agility (Timed up-and-go, TUG), and leg strength (chair stand test, CS) Results: We observed a significant increase (p<0,01) in LS, (Un: -0.88 ± 3.55, T: 3.71 ± 3.68; %), TF (Un: -1.38 ± 17.76, T: 6.52 ± 2.71; %) and WB (Un: 2.09 ± 3.17, T: 3.23 ± 4.18) BMD in the T group. Regarding functional fitness, the T group showed improvements in both TUG (before: 6.86 \pm 1.24 versus after: 6.22 \pm 1.13 seconds, p< 0.05) and CS (before: 16 \pm 4 versus after: 19 ± 5 repetitions, p> 0.05) tests when compared to the U group's TUG (Before: 5 \pm 1, after: 6 \pm 1 seconds; p< 0.05) and CS (Before: 20 \pm 2, After: 19 \pm 2 repetitions; p> 0.05) scores. **Conclusion**: Our data suggest that a high-intensity, jumpbased interval aquatic exercise program is able to improve bone mineral density and functional fitness parameters in postmenopausal women.

Keywords: elderly, HIIT, bone mineral density, aquatic exercise

Rejuvenation Research

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Introduction

Hormonal changes resulting from the menopause contribute to a state of functional decline, body composition changes, impaired bone metabolism and an increased risk of chronic disease development in women ¹⁻². Osteoporosis is a whole body metabolic bone disease which affects almost 200 million people worldwide ³. Conceptually, it is characterized by substantial loss of bone mass and a decline in bone tissue microarchitecture, which damages the bone's resistance and quality. This renders the individual more susceptible to fractures and, consequently, chronic pain, functional disability and compromised quality of life ⁴.

Among possible treatments suggested, engaging in regular physical exercise has been considered as an efficient non-pharmacological strategy to maintain ⁵ or increase ⁶ bone mineral density. As bone has been classified as a dynamic tissue, regular physical exercise affects bone tissue positively by promoting adaptations through various stimuli, mainly mechanical, which contribute to bone formation ⁷. Thereby, resistance and impactbased physical exercise have been highlighted as major non-pharmacological strategies in the treatment of osteoporosis, influencing directly the preservation or improvement of bone mass and functional fitness ⁸⁻⁹.

Even though the effects of the mechanical stimuli resulting from physical exercises on bone tissue are quite clear, there are still doubts about the effectiveness of aquatic exercises on improving bone mineral density in postmenopausal women. Performing motor activities inside an aquatic environment is made easier due to flotation and the inertia of the water, which decreases the mechanical action of friction with the ground on bone tissue ⁸. Alternatively, the resistance promoted by the water during movements may increase the muscular demand on the body segments recruited, promoting a higher osteogenic effect ¹⁰⁻¹¹.

There are few studies ^{10,12-15} available which utilized an aquatic environment as a tool to improve bone mass. Therefore, the aim of this study was to assess the effects of an aquatic jump-based physical training program on the bone mineral density and the functional fitness of menopausal women.

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Methods

Participants

We recruited twenty five elderly women (aged 57-75 years) from the city of Natal, Brazil. We also searched for an aquatic fitness center as a possible venue to perform the experiment. We randomly assigned the subjects into two different groups: Training (T, n = 15) and Untrained (Un, n = 10). All participants were subjected to clinical examination and answered questionnaires regarding their medical history before being included in our study. Participants included in the study were women, 55 years of age or older, who were able to train 3 times per week during the 24 weeks of the exercise protocol.

Exclusion criteria included: participating in a regular and structured physical activity program for 3 months prior to experimentation; recent hospitalization; motor deficiency; symptomatic cardiorespiratory disease; non-controlled hypertension or metabolic syndrome; severe renal or hepatic disease; cognitive impairment or debilitating conditions; marked obesity with inability to exercise; recent bone fracture (during the past 2 years); and participating in fewer than 90% of the sessions stipulated in the Aquatic training program. Both Un and T groups were instructed to continue with their daily activity routines. However, only subjects in the T group participated in the Aquatic training sessions. Participants were also required to maintain normal dietary intake (monitored by nutrition professional). Participants in the training group were asked not to perform any additional physical activity exercises during the study period. Additionally, all subjects were instructed to refrain from any medication that may affect bone metabolism. All participants read and signed the terms of consent following the Declaration of Helsinki before being included in the study.

Water based exercise

The water-based exercise program consisted of 30-minute sessions three times a week, over a 24 week period. Training sessions were performed on three different and non-consecutive days in each week. The water level was fixed at xiphoid or near xiphoid level, with the temperature at 29°C. Each session was divided into three stages. The first stage consisted of 5 minutes warm-up, comprised of stretching and free movements in the water. The second stage comprised of jump-based (single-leg jump, ankle hops, tuck

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jumps, jump with hip abduction and adduction) exercises for 20 min, performed as high intensity interval exercise, consisting of 20 bouts for 30 seconds of all-out intensity as identified in previous studies by our group ¹⁶. The intensity, although required to be maximal was self-selected by the subjects, who performed 30 seconds of passive recovery between sets. Intensity was monitored using the rating of perceived exertion. Finally, the third stage consisted of cooling-down/relaxation exercises for 5 minutes, composed of slow walking and stretching.

Evaluated parameters

We evaluated both groups prior and following 24 weeks of training. On the test day, participants were instructed to correctly follow the orientations postulated by the researchers. Body mass index (BMI = height/weight²) was assessed, and body fat percentage was calculated according to previous studies ¹⁷⁻¹⁸. We used Dual-energy x-ray absorptiometry (DEXA) to scan lumbar spine (L1-L4), total femur and whole body mineral density. All exams were analyzed by the same researcher using the DEA–DTX 200 Osteometer (MediTech), blind to subject condition.

Functional fitness

Functional fitness evaluation was composed of two tests used in previous studies to assess the physical performance parameters of mobility and balance in older adults ¹⁷⁻¹⁸. We used the chair stand test (CS) test to evaluate lower limb strength, scored by the number of correctly executed stands within 30 seconds. We assessed agility through the time up-and-go test (TUG). The score was considered as the shortest time spent rising from a seated position, walking eight feet, turning back and returning to the seated position.

Statistical analysis

We analyzed comparisons between groups along the time periods using a two-way ANOVA with repeated measures, followed by Bonferroni's post-hoc test. Comparisons between groups concerning relative changes in variables after 24-weeks were performed using unpaired Student's t-test. The Cohen's d approach was used to calculate the effect size. Statistical analyses were performed with GraphPad Prism software (version 4.0, San Diego, CA, USA). Statistical significance was set at p< 0.05.

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Results

During the training period, no participants in either group left the study or presented any injuries as result of the exercise program. Before training, there were no significant differences between the groups for all assessed anthropometrics parameters (Tables 1 and 2).

Insert table 1

Figure 1 shows the BMD parameters before and after 24 weeks of exercise protocol.

Insert figure 1

The T group did not present significant (p> 0.05) reductions in total femur (before: 0.881 \pm 0.009 versus after: 0.790 \pm 0.15 g/cm²), lumbar spine (before: 0.850 \pm 0.016 versus after: 0.850 \pm 0.018 g/cm²) and whole body (before: 0.920 \pm 0.017 versus after: 0.900 \pm 0.018 g/cm²) BMD. However, differences (p< 0.01) were found in the hip (before: 0.860 \pm 0.070 versus after: 1.040 \pm 0.100 g/cm²), lumbar spine (before: 1.050 \pm 0.016 versus after: 1.090 \pm 0.015 g/cm²) and whole body (before: 1.000 \pm 0.011 versus after: 1.060 \pm 0.009 g/cm²) BMD when compared to the Un group. Similar results were found at % change in all BMD parameters as showed in table 2.

Insert table 2

Regarding functional fitness (Figure 2), we observed improvements of -11 ± 4 % on the TUG test (Before: 6.86 ± 1.24, After: 6.22 ± 1.13 seconds, p< 0.05) and 17 ± 3 % on CS test (Before: 16 ± 4, After: 19 ± 5 repetitions, p> 0.05; repetitions) in the T group. We did not observe any changes (p< 0.05) on the TUG test (before: 5 ± 1 versus after: 6 ± 1 seconds) or the CS test (Before: 20 ± 2, After: 19 ± 2 repetitions) in the Un group.

Insert figure 2

Discussion

Since flotation diminishes impact, aquatic exercises are typically classified as exercises of low osteogenic effect. However, the results from this study did not corroborate with this information. In our study, the protocol of all-out, jump-based impact exercises in water resulted in increased BMD and improved functional fitness in postmenopausal women.

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Over the lifespan, environmental factors, such as mechanical loading, nutrition, hormonal and genetic factors, may influence body mass ¹⁹. It is estimated, from clinical studies, that genetics correspond for between 60 to 80% of the variance of bone mass during a lifetime ²⁰. Nonetheless, according to Wolff's law, mechanical stimulus, as well as loading magnitude, is considered as an active osteogenic stimulus ²¹⁻²².

Impact or resistance-based physical activities using muscle traction generally result in strain stress, compression, and shear stress when the bone is strained by many different loadings ²³. These loadings via the bone tissue are detected via mechanotransduction, which is the conversion of a mechanical force into a cellular response, generating more complex biochemical reactions in bone cells ²⁴. However, it should be highlighted that bone formation only occurs if the physical exercise stimulus exceeds a certain threshold, being capable of generating a loading above the usual everyday standard to which the body has adapted ²⁵. Indeed, longitudinal studies analyzing the influence of physical exercise on bone mass have demonstrated that active and resisted physical activities can stimulate bone mass in postmenopausal women ²⁶⁻²⁹.

Additionally, the hydrodynamic effects of water in increasing resistance to movement, improving muscle and joint effort during walking, jumping or moving body segments in an aquatic environment, are already recognized ³⁰⁻³¹. Some studies suggest ³²⁻³³ that, even with the predominance of impact exercises such as jumping, the effect of muscle action still helps to decrease impact on joints during landing on the ground. This may promote a response in bone cells which may stimulate osteogenesis, since muscular contraction stresses the tendon inserted in the bone, creating deformation that can spread through the fluid flow, activating the osteocytes contained in the canaliculi ²⁴.

It is a consensus that muscle mass has a significant role in the acquisition and maintenance of bone structure, and increases in structure may explain the effects on BMD variance – from 6% to 16%, depending on the assessed bone site. Besides increasing bone mineral density, muscular strength development also promotes improvement in motor coordination, postural stabilization, dynamic balance and muscular strength, enabling physical autonomy and improving quality of life ³⁴. In addition to this, recruiting type II muscular fibers, which happens more often during high-intensity exercises, is more likely to stimulate bone tissue development ³⁵⁻³⁶.

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Similarly, to the findings of Nolasco et al. ³⁷, but in contrast to Takeshima et al. ³⁸, the protocol we used in this study did not promote significant changes in body composition parameters. It is possible that this was influenced by the short duration of the training sessions, as well as the lack of any monitoring of the food intake of the participants. However, this exercise program was efficient in improving the muscular strength of the lower limbs as well as agility, and is in agreement with previous studies ^{17-18, 39}. As such, our findings suggest that an aquatic exercise program based on high-intensity jumping may help to maintain body mass and improve muscular strength, both of which are parameters recognized as relevant to bone mass ⁴⁰. In addition, the findings also suggest that this type of activity maintains or promotes gains in body mass in elderly women.

was efficient in improving bone mass and functional fitness in postmenopausal women. However, some limitations in the study were present, such as a relatively small sample size of a specific population, which does not allow for further generalizations. Therefore, future research in this area should consider the association between diet/dietary restriction, inflammatory cytokines, as well as assessing functional fitness parameters.

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References

- Seeman E, Delmas PD. Bone quality the material and structural basis of bone strength and fragility. N Engl J Med 2006; 354: 2250–2261.
- Shin S, Lee K, Song C. Relationship of body composition, knee extensor strength, and standing balance to lumbar bone mineral density in postmenopausal females. J Phys Ther Sci 2016; 28:2105–2109.
- 3. Kanis JA. WHO Technical Report. University of Sheffield, UK, 2007.
- Cosman F, de Beur SJ, LeBoff MS, Lewiecki EM, Tanner B, Randall S, Lindsay R; National Osteoporosis Foundation. Clinician's Guide to Prevention and treatment of Osteoporosis 2014; 25: 2359-2381.
- Marques EA, Mota J, Carvalho J. Exercise effects on bone mineral density in older adults: a meta-analysis of randomized controlled trials. Age (Dordr) 2012;34:1493-1515.
- Mousa S M, Rasheedy D, Sorady K, Mortagy AK. Beyond mobility assessment: Timed up and go test and its relationship to osteoporosis and fracture risk. J. Clin. Gerontol. Geriatr 2016;7:48-52.
- 7. Vieira S, Lemes B, Silva Jr JA. Different land-based exercise training programs to improve bone health in postmenopausal women. Med Sci Tech 2013 ; 54:158-163.
- 8. Moreira LD, Oliveira ML, Lirani-Galvão AP, Marin-Mio RV, Santos RN, Lazaretti-Castro M. Physical exercise and osteoporosis: effects of different types of exercises on bone and physical function of postmenopausal women. Arq Bras Endocrinol Metab 2014: 58:514-522.
- Iwamoto J A role of exercise and sports in the prevention of osteoporosis. Clin Calcium. 2017;27:17-23
- 10. Ay A, Yurtkuran Y. Influence of aquatic and weight-bearing exercises on quantitative ultrasound variables in postmenopausal women. Am J Phys Med Rehabil 2005; 84:52-61.
- Gómez-Bruton A, Gónzalez-Agüero A, Gómez-Cabello A, Casajús JA, Vicente-Rodríguez G. Is bone tissue really affected by swimming? A systematic review. PLoS One 2013; 8:701-719.

This paper has been peer-reviewed and accepted for publication, but has yet to undergo copyediting and proof correction. The final published version may differ from this proof

A high-intensity jump-based aquatic exercise program improves bone mineral density and functional fitness in postmenopausal women (DOI: 10.1089/rej.2018.2069)

- 10
- 12. Tsukahara N, Toda A, Goto J, Ezawa I (1994). Cross-sectional and longitudinal studies on the effect of water exercise in controlling bone loss in Japanese postmenopausal women. J Nutr Sci Vitaminol 1994; 40:37-47.
- 13. Rotstein A, Harush M, Vaisman N. The effect of a water exercise program on bone density of postmenopausal women. J Sports Med Phys Fitness 2008; 48:352-359.
- 14. Balsamo S, Mota LM, Santana FS, Nascimento Dda C, Bezerra LM, Balsamo DO, Borges JL, Paula AP, Bottaro M. Resistance training versus weight-bearing aquatic exercise: a cross-sectional analysis of bone mineral density in postmenopausal women. Rev. Bras. Reumatol 2013; 53:193-198.
- 15. Moreira LD, Fronza FC, Dos Santos RN, Zach PL, Kunii IS, Hayashi LF, Teixeira LR, Kruel LF, Castro ML. The benefits of a high-intensity aquatic exercise program (HydrOS) for bone metabolism and bone mass of postmenopausal women. J Bone Miner Metab 2014; 32: 411-419.
- 16. Machado AF, Baker JS, Figueira Junior A, Bocalini DS. High intensity interval training using whole body exercises: training recommendations and methological overview. Clin Physiol Funct Imaging 2017 [Epub ahead of print]
- 17. Bocalini DS, Serra AJ, dos Santos L, Murad N, Levy RF. Strength training preserves the bone mineral density of postmenopausal women without hormone replacement therapy. J Aging Health 2009; 21:519–527.
- 18. Bocalini DS, Lima LS, de Andrade S, Madureira A, Rica RL, Dos Santos RN, Serra AJ, Silva JA Jr, Rodriguez D, Figueira A Jr, Pontes FL Jr. Effects of circuit-based exercise programs on the body composition of elderly obese women. Clin Interv Aging 2012;7:551–556.
- Seeman E. Bone quality the material and structural basis of bone strength. N. Engl. J. Med 2008; 26: 1-8.
- 20. Wagner H, Melhus H, Pedersen NL, Michaëlsson K. Genetic influence on bone phenotypes and body composition: a Swedish twin study. J Bone Miner Meta 2013; 31: 681-689.
- 21. Wolff I, van Croonenborg JJ, Kemper HC, Kostense PJ, Twisk JW. The effect of exercise training programs on bone mass: a meta-analysis of published controlled trials in pre- and postmenopausal women. Osteoporos Int 1999; 9:1–12.

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- Vainionpää A, Korpelainen R, Vihriälä E, Rinta-Paavola A, Sievänen H, Leppäluoto J, Jämsä T. Effect of impact exercise and its intensity on bone geometry in weightbearing tibia and femur. Bone 2007; 40:604–611.
- 23. Yang P, Brüggemann GP, Rittweger J. What do we currently know from in vivo bone strain measurements in humans? J Musculoskelet Neuronal Interact 2011; 1:8-20.
- 24. Klein-Nulend J, Bakker AD, Bacabac RG, Vatsa A, Weinbaum S. Mechanosensation and transduction in osteocytes. Bone 2013; 54:82-190.
- 25. Al Nazer, R. Lanovaz J, Kawalilak C, Johnston JD, Kontulainen S. Direct in vivo strain measurements in human bone—a systematic literature review. J Biomech 2012; 45:27-40.
- 26. Yamazaki S, Ichimura S, Iwamoto J, Takeda T, Toyama Y. Effect of walking exercise on bone metabolism in postmenopausal women with osteopenia/osteoporosis. J Bone Miner Metab 2004; 22:500-508.
- 27. Chien, MY, Wu YT, Hsu AT, Yang RS, Lai JS. Efficacy of a 24-week aerobic exercise program for osteopenic postmenopausal women. Calcif Tissue Int 2000;67:443-448.
- 28. von Stengel S, Kemmler W, Kalender WA, Engelke K, Lauber, D. Differential effects of strength versus power training on bone mineral density in postmenopausal women: a 2-year longitudinal study. Br J Sports Med 2007; 41:649-655.
- 29. Bemben DA, Bemben MG. Dose-response effect of 40 weeks of resistance training on bone mineral density in older adults. Osteoporos Int 2011;22:179-186.
- Barker AL, Talevski J, Morello RT, Brand CA, Rahmann AE, Urquhart DM. Effectiveness of aquatic exercise for musculoskeletal conditions: a meta-analysis. Arch Phys Med Rehabil 2014; 95:1776-86.
- Torres-Ronda L, Del Alcázar XS. The Properties of Water and Their Applications for Training. J Hum Kinet 2014;, 44:237–248.
- 32. Judex S, Carlson KJ. Is bone's response to mechanical signals dominated by gravitational loading? Med Sci Sports Exerc 2009; 41:2037-2043.
- Morseth B, Emaus N, Jorgensen L. Physical activity and bone: The importance of the various mechanical stimuli for bone mineral density. A review. Nor Epidemiol 2011; 20:173-178.

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- 12
- 34. Wilhelm M, Roskovensky G, Emery K, Manno C, Valek K, Cook C. Effect of resistance exercises on function in older adults with osteoporosis or osteopenia: a systematic review. Physiother Can 2012; 64:386-94.
- 35. Cheung WH, Lee WS, Qin L, Tang N, Hung VW, Leung KS (2010). Type IIB human skeletal muscle fibers positively correlate with bone mineral density irrespective to age. Chin Med J 2010; 123:3009-3014.
- 36. Colado JC, Garcia-Masso X, Rogers ME, Tella V, Benavent J, Dantas EH. Effects of Aquatic and Dry Land Resistance Training Devices on Body Composition and Physical Capacity in Postmenopausal Women. J Hum Kinet 2012; 32:185-195.
- 37. Nolasco R, Moreira LD, Bocalini DS, Fronza FC, Marin RV, Lazaretti-Castro M. Effects of vitamin D supplementation on pulmonary function in postmenopausal women following an aquatic exercise program. Arch. Endocrinol. Metab., 2016; 61:28-35.
- 38. Takeshima N, Rogers ME, Watanabe E, Brechue WF, Okada A, Yamada T, Islam MM, Hayano J. Water-based exercise improves health-related aspects of fitness in older women. Med Sci Sports Exerc 2002; 34:544-51.
- 39. Heywood S, McClelland J, Mentiplay B, Geigle P, Rahmann A, Clark R. Effectiveness of Aquatic Exercise in Improving Lower Limb Strength in Musculoskeletal Conditions: A Systematic Review and Meta-Analysis. Arch Phys Med Rehabil 2017;98:173-186.
- 40. Goodman A, Hornberger A, Robling A. Bone and skeletal muscle: key players in mechanotransduction and potential overlapping mechanisms. Bone 2015; 80:24-36.

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A high-intensity jump-based aquatic exercise program improves bone mineral density and functional fitness in postmenopausal women (DOI: 10.1089/rej.2018.2069)

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	Untrained		Trained	
	Before	After	Before	After
Height (m)	1.52 ± 0.06		1.51 ± 0.05	
Body weight (kg)	62 ± 13	62 ± 13	69 ± 10	69 ± 11
BMI (kg/m ²)	27 ± 7	27 ± 6	30 ± 5	30 ± 5
Body fat (%)	25 ± 10	26 ± 9	28 ± 8	29 ± 9
Lean mass (kg)	40 ± 6	41 ± 6	40 ± 9	41 ± 10
Fat mass (kg)	34 ± 4	33 ± 4	38 ± 5	37 ± 5

Table 1. Anthropometrics parameters for both groups before and after 24 weeks.

Values are presented as mean ± standard deviation of Untrained and Trained groups. There were no differences in any of the parameters after the two-way ANOVA with repeated measures, followed by Bonferroni's post-hoc test. BMI: body mass index.

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Table 2. Percent change and effect size after 24 weeks.

Parameters	Untrained		Trained	
	% Change	Cohen's d	% Change	Cohen's d
Body composition				
Body weight (kg)	0.09 ± 1.44	0.009	0.23 ± 2.40	0.024
BMI (kg/m²)	0.09 ± 1.44	0.011	0.23 ± 2.40	0.019
Body fat (%)	2.95 ± 2.81	0.066	0.75 ± 8.11	0.084
Lean mass (kg)	3.03 ± 2.67	0.219	0.57 ± 6.83	0.078
Fat mass (kg)	2.24 ± 2.46	0.199	2.07 ± 4.39	0.158
Bone mineral density				
Total femur (g/cm ²)	-1.38 ± 17.76	0.169	6.52 ± 2.71*	0.850
Lumbar spine (g/cm ²)	-0.88 ± 3.55	0.176	3.71 ± 3.68*	0.500
Whole body (g/cm ²)	2.09 ± 3.17	0.098	3.23 ± 4.18*	0.185

Values are presented as mean ± standard deviation in the Untrained and Trained groups.

*p<.01 trained versus untrained group.

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Figure 1. Levels of total femur, lumbar spine and whole body bone mineral density (BMD) before and after the 24-week follow-up.

*p< .001 before versus after.

[†]p < .01 Trained versus Untrained group.

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Figure 2. Functional fitness of Untrained and Trained groups before and after the 24-week follow-up of jump based exercise program.

*p<.001 trained versus untrained group.

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