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Case Report | OMICS International

Whole Body Vibration Training Attenuates Bone Loss in Osteoporosis: A Case Report

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Abstract

Osteoporosis increases risk for fracture, however weight-bearing exercise may influence bone health and reduce risk for falling. This case study involves an osteoporotic female (57 years) who underwent whole body vibration training which progressed to achieve 15 sets of 60 s at 26 Hz. Between sets of whole body vibration training, the participant performed 1 min of exercise aimed to reduce risk for falling.

Training occurred 3 days/week for 6 months, when the patient experienced bilateral radial fractures unrelated to training. After healing, whole body vibration training resumed for another 9 months. Physical fitness and risk for falls was assessed using the Senior Fitness Test at three time points across the intervention. Bone mineral density was measured via dual-energy x-ray absorptiometry at the hip and spine regularly for approximately 18 years; in the 16 years leading up to and including the 2 years of vibration training.

Six months of whole body vibration training, interrupted by 10 months for fracture healing, followed by another 9 months, corresponded to an 8% improvement in bone mineral density at the femoral neck and maintenance of bone mineral density at the spine. Improvements in the Senior Fitness Test indicate reduced risk for falling. Whole body vibration may be a viable treatment option for osteoporotic women averse to medications and/or those who cannot tolerate weight-bearing activity.

Keywords: Bone mineral density; Balance; Fracture; Fall

Introduction

Osteoporosis is a chronic disease of low bone mass which leads to skeletal fragility and an increased risk for fracture. Research data from the 2005-2010 National Health and Nutrition Examination Survey estimates that more than 10 million Americans over the age of 50 meet the criteria for osteoporosis while another 43 million Americans have low bone density [1]. Global assessments suggest that 1 in 3 women and 1 in 5 men over the age of 50 will experience an osteoporotic fracture in their lifetime [2]. By the year 2025, the 3 million osteoporosis-related fractures expected for aging Americans will cost approximately $25 billion [3]. Osteoporosis-related fractures are not only a financial burden; more importantly, osteoporotic injuries cause significant reduction in activities of daily living, quality of life and increase mortality [4].

In fact, Bliuc et al. reported that there is an increased risk for mortality for at least 5 years after experiencing a fracture and up to 10 years, depending on the injury site [5]. Diagnosis of osteoporosis and low bone mass is made using bone mineral density (BMD) measured via dual-energy x-ray absorptiometry (DXA). The World Health Organization established osteoporosis diagnosis as BMD of 2.5 standard deviations below that of a “young normal” adult, while low bone mass is 1.0-2.5 standard deviations below the “young normal” [6]. Due to changes in hormonal status, postmenopausal women experience between 1-3% loss in bone mass each year [7,8]. Weight-bearing exercise and resistance training have been shown to help maintain or improve bone health in adult women [7].

Antiresorptive medications, such as bisphosphonates, can be used to reduce bone loss, however reported compliance is poor and there are many concerns about potential side effects [9]. Osteonecrosis of the jaw, undesired ocular events, hypocalcemia, systemic inflammation, renal failure, and gastrointestinal adverse events are all reported side effects of bisphosphonate medication use which may raise concern for patients [10,11]. Furthermore, medications neglect a holistic approach and cannot increase muscular strength or reduce risk for falling which is often the precursor to fractures [12].

Whole body vibration (WBV) training is a novel exercise modality with underexplored potential to influence bone health and because it is a more recently recognized methodology, there is a lack of independent research explaining its effectiveness at improving BMD, attenuating bone loss, and reducing risk for falls particularly in susceptible populations [13]. Early research using animal models suggests that WBV may be effective in improving the quality and quantity of trabecular bone [14].

Further work involving humans suggests that WBV can increase BMD and improve muscular performance [15,16]. Exercise is not only important for improving bone health but also reducing risk for falls. Fall-related fractures have multifactorial causes; however modifiable risk factors for falls include leg weakness, limited range of motion, and poor balance. The American Geriatric Society recommends exercise programs for older adults that include balance and strength training to prevent falls [17].

Methods

A 57 year old osteoporotic woman contacted the Applied Physiology Laboratory inquiring about whole body vibration training. After discussion, it was agreed upon to initiate a pilot study examining the potential whole body vibration to improve bone mineral density and lower risk for falls in the osteoporotic female volunteer.

The research was approved by the University's Institutional Review Board for the Protection of Human Subjects and the participant provided written informed consent prior to the onset of experimental procedures.

Case participant

The volunteer was born with severe bilateral equinovarus (club feet), contributing to a lack of weight-bearing activity in youth. After many surgeries, and with the use of orthotics, her gait presented near-normalcy although the left calcaneus does not touch the floor during standing knee flexion movements.

Her medical history also included massive meningeal diverticula of lumbar-sacral spine associated with osteoarthritis of the spine, hips, knees, and feet with mobility limiting chronic pain. Despite these chronic conditions, the participant reported performing physical activity an average of five days per week, with modifications as pain allows. The participant has maintained a healthy body weight exhibiting a body mass index between 20.6 to 23.2 kg/m^2 from 1997 until 2015.

The participant was postmenopausal at the start of the exercise intervention. Her last menstrual period was in July 2008 at 52 years of age. After initial diagnosis of osteoporosis, she intermittently used medications known to affect bone health. She took an oral bisphosphonate medication (alendronate) for approximately 2.5 years from August 1997 to February 2000. Later, she was administered one infusion of zoledronic acid in February 2011. The participant chose to cease medication use due to concerns about side effects.

At baseline, calcium intake from food was estimated to be 630 mg/d, but combined supplemental and food sources together reach 2150 mg/d [18]. A review of supplement intake indicated 1500 IU/d of vitamin D. Intake of bone nutrients remained above recommended intakes during the study and at the conclusion of the study was measured at 1210 mg/d for calcium, with 59% (or 710 mg) coming from food sources, and 4400 IU/day of vitamin D.

Senior fitness test

The senior fitness test (SFT) was used to assess functional fitness before WBV training and after the intervention. The SFT is considered a valid and reliable functional outcome measure and has the ability to predict future risk of falling [19]. The SFT is a battery of six tests which include assessment of strength, aerobic endurance, flexibility, and agility/dynamic balance. While normative values for this test are available for adults ages 60 years and older, considering the history of physical limitations, comparison may relevant here to this participant who was 57 years old when training began.

Bone health

Bone mineral density was measured via DXA at the hip and spine regularly between 1997 to 2015 (ages 42 to 60). The first seven assessments, occurring from 1997 to 2006, were performed on a Lunar DPX-L bone densitometer (Madison, WI, USA). Beginning in 2008, the subsequent six assessments of bone health were performed on a Lunar Prodigy system (GE Healthcare, Little Chalfont, Buckinghamshire, UK).

Timeline

WBV training began in April 2013 and continued for 6 months until Oct 2013 when the participant fell and experienced bilateral distal radial fractures requiring subsequent surgery and extensive rehabilitation. The fall occurred at home and was independent of the training program. Due to the injuries, the participant performed negligible amounts of weight-bearing exercise until August 2014. Her rehabilitation program included physical therapy for the wrists and upper body. Once cleared for exercise by her physician, WBV training resumed in August 2014 and continued three times per week until May 2015 while taking breaks in accordance with the academic calendar for winter (3 weeks) and spring holidays (1 week in February, 1 week March). In total, the participant attended 81 exercise sessions across 27 weeks from September 2014 and ending in early May 2015.

Whole body vibration training and exercise protocol

The Vibraflex 550 (also called the Galileo 2000, Novotec, and Pforzheim, Germany) was used for whole body vibration training. This platform uses a "teeter-totter" motion created by side-to-side displacement based around a central fulcrum. Exercise was prescribed with the goal of increasing BMD; therefore weight-bearing exercises which especially target the hip and forearm were included. While there are some resistance-training exercises known to target the spine, such as deadlifts and bent-over rows, these were intentionally avoided because of the patient's history with back injuries and the fact that these exercises, if not performed properly, are known to be high risk for causing harm to the spinal region.

The progressive overload principal was incorporated, creating a nonlinear per iodized program that provided for increases in volume, intensity, and exercise difficulty over the training period. In effort to reduce displacement of the head during whole body vibration training, the participant was coached to avoid locked-out joint positions at all times by utilizing a small amount of flexion (~5°) at the ankles, knees, and hips during static standing and through the dynamic motion of each exercise.

Table 1 shows a detailed account of the WBV program with time in seconds, number of sets, and frequency in Hz (number of vibration cycles per second). The WBV prescription was based on results from previous publications demonstrating positive influence on bone health [20]. WBV training began in the first week with 9 sets of 30 s of exposure at 20 Hz and increased steadily over 8 weeks to reach a goal exposure of 15 sets of 60 s of exposure at 26 Hz. The protocol consisted of a combination of standing, toe-heel raises, squats, stationary lunges (sometimes referred to as split squats) and resting of the hand/forearm on the platform.

The participant placed her feet or hands at position 2, marked on the platform (Figure 1A), where she experienced a peak-to-peak displacement of 4.16 mm, leading to a maximum peak acceleration at the plate surface of 5.4 g. Every workout began with a warm-up of standing on the platform with slight flexion throughout the lower extremity as described previously. WBV squats on the platform were performed with support on the handlebars for assistance with balance.

	Standing			Toe & Heel Raise			Squats			Lunges			Arms On		
	Seconds (s)	Sets	Hz	Seconds (s)	Sets	Hz	Seconds (s)	Sets	Hz	Seconds (s)	Sets	Hz	Seconds (s)	Sets	Hz
Week 1															
	30	9	20												
Week 2															
	45	9	20												
Week 3															
	60	3	20				60	3	20						
Week 4															
	60	3	23	60	3	23	60	3	23						
Week 5-6															
	60	3	23	60	3	23	60	3	23				60	2	23
Week 7															
	60	3	23	60	3	23	60	3	23				60	3	23
Week 8															
	60	3	25	60	3	25	60	3	25	30	2	25	60	3	25
Week 9															
	60	3	25	60	3	25	60	3	25	60	3	25	60	3	25
Week 10-14															
	60	3	26	60	3	26	60	3	26	60	3	26	60	3	26
Week 15-16															
	60	3	26	60	3	26	60	2	25	45	2	25	60	3	26
Week 17-18															
	60	3	26	60	3	26	60	3	26	45	2	25	60	3	26
Week 19-28															
	60	3	26	60	3	26	60	3	26	60	3	26	60	3	26

Table 1: Whole body vibration training program.

Stationary lunges were performed with the front foot on the platform and the back foot on the ground (Figure 1B). After lunging with one foot on the platform for the allotted time, the exerciser changed to the other foot and repeated the exercise to complete the set.

Each exercise session lasted approximately 45 min and included at least 1 min of exercise aimed to reduce risk for falling in between sets of exposure to whole body vibration. These exercises can be grouped into five categories; 1) resistance training for lower body musculature, 2) strengthening of leg abductors, 3) abdominal core exercises, 4) footwork range of motion, and 5) balance training.

Three sets of one exercise from each of these categories were performed at each exercise session. Once per week, training included an agility exercise. Resistance bands, ankle weights, weighted balls, and varying step height were used to provide resistance.

Lower body exercises included wall sits, lunges, chair stands, and leg curls. Exercises for the leg abductors included lateral walking with resistance bands and resisted lateral leg lifts while standing or lying. Abdominal and core exercises included crunches, planks, and bridges. Footwork range of motion incorporated plantar/dorsi flexion, toe curls, ankle circles, and toe taps. Balance work included performing upper body tasks (i.e., ball toss) while standing tandem, on a single leg, or on altered surfaces such as foam pads or disks. Tasks to develop agility included marching/stepping with head turns, fast feet movements, and multidirectional stepping over/onto obstacles.

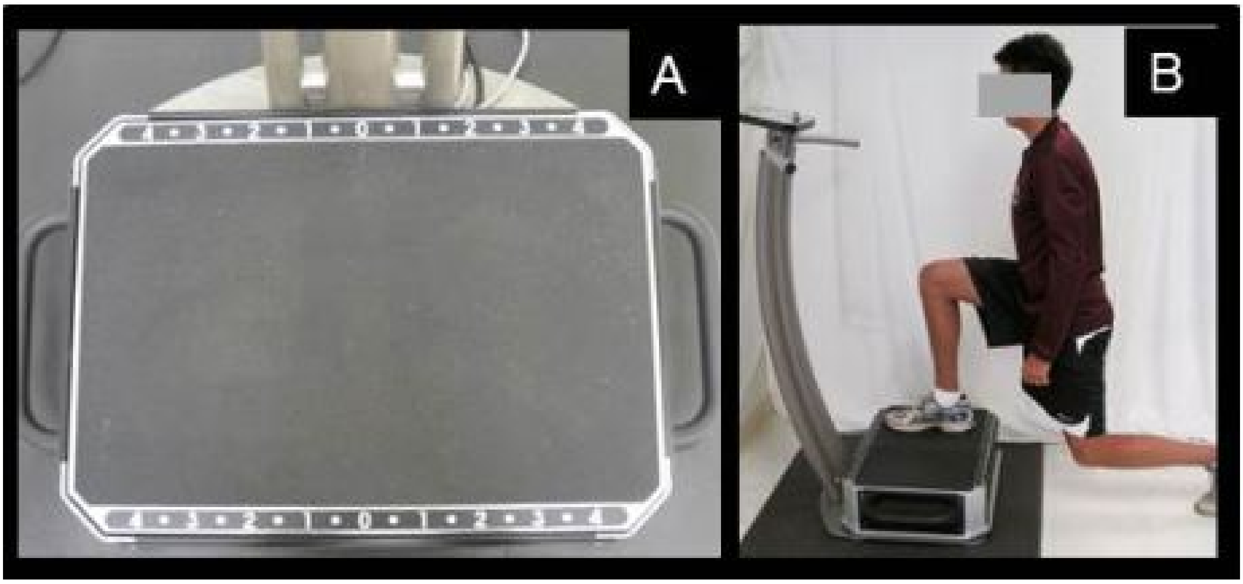

Figure 1: whole body vibration platform and exercises (Individual in photo is not the case study participant). A) Whole body vibration platform, training was conducted with feet and hands placed at position 2. B) Posture used for stationary lunge.

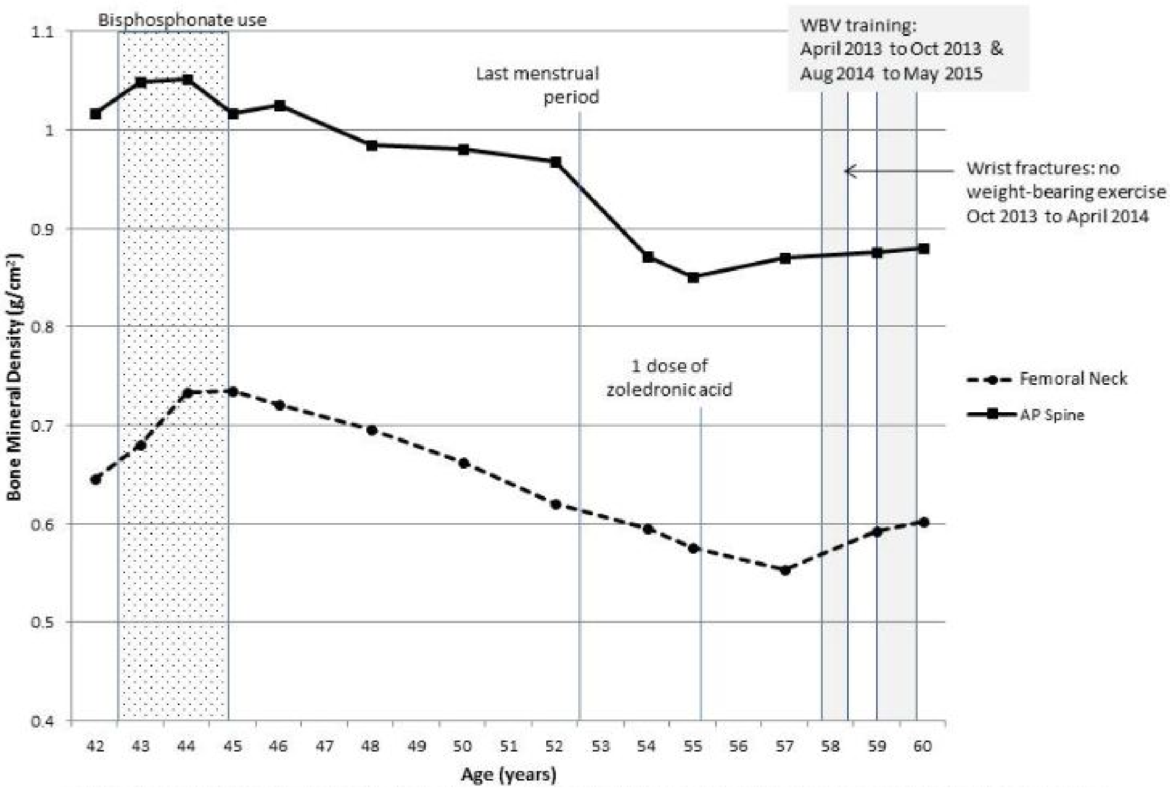

Figure 2: Bone mineral density results (Bone mineral density measurements in g/cm^2 at the femoral neck and anterior-posterior (AP) spine for case study participant from 1997 (at age 42) to 2015 (age 60). Medication use, hormonal changes, injuries and training intervention are labelled accordingly).

Results

Figure 2 displays BMD results from 13 testing occasions spanning nearly 18 years. The case participant met the diagnostic criteria for osteoporosis of the hip (T-score=-2.79) and osteopenia at the spine (T-score=-1.66) after her first bone scan in 1997, at age 42. Bisphosphonate use for 2.5 years may have helped increased BMD seen at ages 43-45, however bone mass progressively declined after cessation of use.

Test	Measure	Unit	13-May		14-September		15-May	
			Score	Percentile*	Score	Percentile*	Score	Percentile*
Chair Stand Test	Lower-body strength	# of stands	9	10	17	70	21	95
Arm Curl	Upper-body strength	# of repetitions	10	10	18	65	23	90
2 min Step	Aerobic endurance	# of steps	97	60	99	60	153	95
Chair Sit and Reach	Lower-body flexibility	+/- inches of reach	3	55	4	65	5	75
Back Scratch	Upper-body flexibility	+/- inches of reach	4	90	5.5	95	6	95
8 foot Up and Go	Agility and Dynamic Balance	# of seconds	7.16	5	5.96	30	4.72	65

Table 2: Senior fitness test results (*Compared to norms established for women ages 60-64; Case participant was 56.8, 58.8 and 59.5 years old at the May 2013, September 2014 and May 2015 time points, respectively).

As expected, there was a noticeable, accelerated decrease in BMD with menopause, displaying nearly 4% loss of bone mass at the femoral neck and almost 10% at the spine. Six months of WBV training, followed by another 9 months of training, interrupted by 10-months for fracture healing, corresponded to an 8% improvement in BMD at the femoral neck and maintenance of BMD (~1% increase) at the spine. No injuries occurred due to WBV training our exercises performed in the Applied Physiology Laboratory.

Results of the Senior Fitness Test are displayed in Table 2. The participant improved in every category measured while exhibiting above average levels of flexibility of the upper and lower body and aerobic endurance at all three time points. At baseline, the participant scored in the 5th percentile for the task of agility/dynamic balance, while improving to the 30th percentile and finally the 65th percentile during the course of the study.

Discussion

This case study reports maintenance of BMD at the spine and improvements in BMD at the femoral neck in an osteoporotic, postmenopausal female with a cumulative 15 months of WBV training. It is typical for women of this age and hormonal status to lose 1-3% bone mass per year [7,8], therefore this report in preservation of bone health is valuable and the 8% improvement at the femoral neck is particularly notable. It is not surprising to have found a greater improvement in BMD at the hip over the spine, as exercises included in the intervention such as squats and lunges would target the hip to a greater extent. Further work needs to be done to elucidate the best mechanisms for WBV to influence vertebral bone health.

The case participant has a history of antiresporptive medication use orally for 2.5 years and via a single infusion, however these medications were used 13 years and 3 years, respectively, before initiating WBV in our laboratory. Therefore, these results are not likely due to prescription medication use. These findings compliment the work of other recent observations of improvements in bone health for postmenopausal women with WBV intervention [21,22]. In contrast, there are several reports of a lack of improvement in bone health with WBV training although the discrepancy in findings may be explained by different methods of assessing bone health (ultrasound vs. DXA) [23] and by the duration of the intervention (11 weeks vs. 15 months) [24].

The participant improved in every category of the SFT measured while exhibiting above average levels of flexibility of the upper and lower body and aerobic endurance at all three time points. Results at the conclusion of our WBV intervention placed in the 65th percentile or above for each category. The normative percentiles should be interpreted with caution as they are established for women 60 years of age or older while this participant was 56.8-59.5 years old during this investigation. Substantial improvements were observed for lower-body strength and upper-body strength between the preliminary assessment in May 2013 and Sept 2014, despite the second assessment occurring directly after a time of relative inactivity. This may be a result of participation in physical therapy to help rehabilitate the wrist fractures. Of particular importance is the reduction in time required for the 8-foot up and go, at test known to predict risk for falling [25]. At baseline, the participant scored in the 5th percentile for this task of agility/dynamic balance, while improving to the 30th percentile and finally the 65th percentile during the course of the study. Santin-Medeiros [26] reported no improvements in the lower-body strength, upper-body strength, and agility/balance components of the SFT for 80-year old women who used vibration twice per week for 8 months [26]. Perhaps their null findings are due to the older age of their participants and limited WBV exposure of 7 min, twice per week. Our training worked up to 15 min of WBV, 3 times per week. It is likely that the exercises performed in between sets of WBV exposure contributed to improvements in SFT measures.

This case study suggests that WBV in combination with exercises aimed to increase agility/balance could help maintain or improve BMD while safely reducing risk for falls in older adults. WBV may be an ideal prescription for postmenopausal women with osteoporosis who refuse to take prescription medications and/or those who may not be able to safely tolerate high-impact bone-loading exercise, such as resistance training or activities which involve jumping.

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References

1. Wright NC, Looker AC, Saag KG, Curtis JR, Delzell ES, et al. (2014) The recent prevalence of osteoporosis and low bone mass in the United States based on bone mineral density at the femoral neck or lumbar spine. J Bone Miner Res 29: 2520-2526.
2. Kanis JA, Johnell O, Oden A, Sembo I, Redlund-Johnell I, et al. (2000) Long-term risk of osteoporotic fracture in Malmo. Osteoporos Int 11: 669-674.
3. Burge R, Dawson-Hughes B, Solomon DH, Wong JB, King A, et al. (2007) Incidence and economic burden of osteoporosis-related fractures in the United States. J Bone Miner Res 22: 465-475.
4. Pasco JA, Sanders KM, Hoekstra FM, Henry MJ, Nicholson GC, et al. (2005) The human cost of fracture. Osteoporos Int 16: 2046-2052.
5. Bliuc D, Nguyen ND, Milch VE, Nguyen TV, Eisman JA, et al. (2009) Mortality risk associated with low-trauma osteoporotic fracture and subsequent fracture in men and women. JAMA 301: 513-521.
6. NIH Consensus P (2001) Osteoporosis prevention, diagnosis and therapy. JAMA 285: 785-795.
7. Kohrt WM, Bloomfield SA, Little KD, Nelson ME, Yingling VR (2004) American college of sports medicine position stand: Physical activity and bone health. Med Sci Sports Exerc 36: 1985-1996.
8. Riggs BL (2002) Endocrine causes of age-related bone loss and osteoporosis. Novartis Found Symp 242: 247-259.
9. Compston JE, Seeman E (2006) Compliance with osteoporosis therapy is the weakest link. Lancet 368: 973-974.
10. Tadrous M, Wong L, Mamdani MM, Juurlink DN, Krahn MD, et al. (2014) Comparative gastrointestinal safety of bisphosphonates in primary osteoporosis: A network meta-analysis. Osteoporos Int 25: 1225-1235.
11. Tanvetyanon T, Stiff PJ (2006) Management of the adverse effects associated with intravenous bisphosphonates. Ann Oncol 17: 897-907.
12. Bemben DA, Langdon DB (2002) Relationship between estrogen use and musculoskeletal function in postmenopausal women. Maturitas 42: 119-127.
13. Rubin C, Judex S, Qin YX (2006) Low-level mechanical signals and their potential as a non-pharmacological intervention for osteoporosis. Age Ageing 35: ii32-ii36.
14. Rubin C, Turner AS, Muller R, Mittra E, McLeod K, et al. (2002) Quantity and quality of trabecular bone in the femur are enhanced by a strongly anabolic, noninvasive mechanical intervention. J Bone Miner Res 17: 349-357.
15. Dolny DG, Reyes GF (2008) Whole body vibration exercise: Training and benefits. Curr Sports Med Rep 7: 152-157.
16. Verschueren SM, Roelants M, Delecluse C, Swinnen S, Vanderschueren D, et al. (2004) Effect of 6 month whole body vibration training on hip density, muscle strength, and postural control in postmenopausal women: A randomized controlled pilot study. J Bone Miner Res 19: 352-359.
17. Panel on Prevention of Falls in Older Persons AGS; British Geriatrics Society (2011) Summary of the Updated American Geriatrics Society/ British Geriatrics Society clinical practice guideline for prevention of falls in older persons. JAGS 59: 148-157.
18. Henry MB, Almstedt HC (2009) Validity of a dietary calcium questionnaire modified to include supplement use in athletes. J Sport Sci and Med 8: 225-229.
19. www.humankinetics.com/
20. Ligouri GC, Shoepe TC, Almstedt HC (2012) Whole body vibration training is osteogenic at the spine in college-age men and women. J Hum Kinet 31: 55-68.
21. Lai CL, Tseng SY, Chen CN, Liao WC, Wang CH, et al. (2013) Effect of 6 months of whole body vibration on lumbar spine bone density in postmenopausal women: A randomized controlled trial. Clin Interv Aging 8: 1603-1609.
22. Stolzenberg N, Belavy DL, Beller G, Armbrecht G, Semler J, et al. (2013) Bone strength and density via pQCT in post-menopausal osteopenic women after 9 months resistive exercise with whole body vibration or proprioceptive exercise. J Musculoskelet Neuronal Interact 13: 66-76.
23. Slatkovska L, Beyene J, Alibhai SM, Wong Q, Sohail QZ, et al. (2014) Effect of whole-body vibration on calcaneal quantitative ultrasound measurements in postmenopausal women: A randomized controlled trial. Calcif Tissue Int 95: 547-556.
24. Gomez-Cabello A, Gonzalez-Aguero A, Morales S, Ara I, Casajus JA, et al. (2014) Effects of a short-term whole body vibration intervention on bone mass and structure in elderly people. J Sci Med Sport 17: 160-164.
25. Rose DJ, Jones CJ, Lucchese N (2002) Predicting the probability of falls in community-residing older adults using the 8 foot up-and-go: A new measure of functional mobility. J Aging Phys Activ 10: 466-475.
26. Santin-Medeiros F, Rey-Lopez JP, Santos-Lozano A, Cristi-Montero CS, Garatachea Vallejo N (2015) Effects of eight months of whole-body vibration training on the muscle mass and functional capacity of elderly women. J Strength Cond Res 29: 1863-1869.