

Osteoporosis: prevention and personalized physiotherapy

Tiziana Nava

Department of Translational Medicine and Surgery Program in Physical Therapy, University of Milano-Bicocca, Milano, Italy

Abstract

Osteoporosis is a systemic disease of the skeleton characterized by reduction and alteration of the qualitative bone mass, accompanied by an increased risk of fracture. Regardless of whether it is primitive regarding postmenopausal women and older people or secondary determined by many diseases and the assumption of some drugs, osteoporosis is a condition for which preventive measures are very important, as well as treatments according to a patient's personal characteristics and age. Prevention must start early and be subsequently adapted to the various life cycles. The aim of this paper is to propose exercises with an evidence-based physiotherapy approach to the different age populations.

Introduction

Osteoporosis is a disease characterized by a decrease in bone density (mass and quality). Bones become increasingly porous and brittle, leading to an increased risk of fracture. Bone is a living tissue that is constantly remodelled and replaced. Osteoporosis occurs when the creation of new bone does not keep up with the loss of old bone.¹

Osteoporosis affects men and women of all races, with white and Asian women, especially older women in menopause, at the

Correspondence: Tiziana Nava, Department of Translational Medicine and Surgery Program in Physical Therapy, University of Milano-Bicocca, Italy. Tel.: +39.02.2426282. E-mail: tiziananava.job@outlook.it

Key words: Osteoporosis; prevention; personalized physiotherapy; group rehabilitation.

Conflict of interests: the author declares no potential conflict of interests.

Received for publication: 16 April 2020.

Revision received: 4 September 2020.

Accepted for publication: 22 October 2020.

©Copyright: the Author(s), 2020

Licensee PAGEPress, Italy

Beyond Rheumatology 2020; 2:36

doi:10.4081/br.2020.36

This article is distributed under the terms of the Creative Commons Attribution Noncommercial License (by-nc 4.0) which permits any noncommercial use, distribution, and reproduction in any medium, provided the original author(s) and source are credited.

menopause. Medications, a healthy diet and weight-bearing exercise can help prevent bone loss or strengthen already weak bones. Osteoporosis is the most prevalent bone disease in the world with a strong socio-economic impact as defined by the World Health Organization (WHO). The International Osteoporosis Foundation shows that a femoral fracture occurs every thirty seconds in Europe. In elderly people, fractures cause serious disabilities and are the cause of many complications, such as pulmonary insufficiency, venous and embolic disorders, bedsores, skeletal, and cognitive muscle deterioration.

The annual cost in Europe for hospital care is three and a half billion euros per year, in Italy five hundred million euros. These costs do not include rehabilitation, orthosis and home care.²

The aging of the population leads to an increase in the absolute number of fractures, with femoral ones at about 1-3% per year. Prevention must start early and be subsequently adapted to the characteristics and needs of patients in different lifetimes. The way people develop osteoporosis depends partly on how much bone mass they have attained in youth. Exercise can help build strong bones and slow down bone loss. Strength training exercises should be combined with weight-bearing and balance exercises. Strength training helps strengthen muscles and bones in the arms and upper spine. Weight-bearing exercises - such as walking, jogging, running, stair-climbing, use of the skipping rope, skiing, and impact-producing sports - affect mainly the bones in the legs, hips and lower spine. Balancing exercises such as tai chi can reduce the risk of falling, especially at an older age.

The aim of this paper is to review the important steps in the prevention of disability and to promote physical activity as an intervention involving the different age population.

Osteoporosis prevention in young people

The Italian Society of Rheumatology (*Società Italiana Reumatologia*, SIR) defines Osteoporosis as a degenerative illness, with a reduction of density and quality of bone. As bones become more porous and fragile, the risk of fracture greatly increases. The loss of bone occurs silently and progressively. Often there are no symptoms until the first fracture occurs. For this reason, it is important to implement some prevention measures by promoting education in lifestyle during the different stages of life.

According to the Italian Society of Osteoporosis, Mineral Metabolism and Skeletal Diseases, it is important to start physical activity as soon as possible, at an early age. Physical programs must include exercises with an impact on the function of frequency, duration, intensity, and skeletal site under load. Studies show how sports practice can have a specific action aimed at increasing bone mass.

Works about osteoporosis prevention in young people are summarized in Table 1.³⁻¹⁰

McDonald and colleagues³ demonstrated how ten-year-old people who performed a daily jumping program on a bouncer and fifteen minutes a day of physical activity, in addition to the usual physical education, have increased distal strength of the tibia. Jakowski and colleagues⁴ showed how physical activity done during adolescence gives young adults greater structural bone strength of the femoral proximal part. This data emerged from a comparison between adult people who practiced physical activity in an active and regular way *versus* a non-active or irregular way.

Moreover, Erlandson⁵ *et al.* confirmed that gymnastics in the pre-menarchal age can affect health in adult women. The results show that, ten years after abandoning gymnastics, women who had practiced it maintained higher levels of bone mass than the control group.

Janz *et al.*⁶ showed that young people who performed forty minutes of vigorous physical activity each day had an average increase in bone surface area of 8% and bone strength by 10%, compared to those who performed less activity. Similar results were obtained by measuring the transverse area and the density of the femoral head. Children who performed forty minutes a day of vigorous physical activity had a 3-5% improvement, compared to those who carried out only ten minutes.

Maimoun and his colleagues' research aim was to evaluate the

bone mass and geometry on a sample of young athletes. In particular, Maimoun *et al.*⁷ analysed the effects of high impact sports such as artistic gymnastics, in relation to a medium and low impact sports activity. The study reported better results in participants who practiced higher impact sports.

Two types of exercises are important for stimulating and maintaining bone mass and density: weight-bearing exercises and muscle-strengthening exercises, as Farr *et al.*⁸ demonstrated in their work conducted on a sample of young girls between eight and thirteen years old. The study revealed an increase in bone values and showed that a low level of physical activity can impair bone development in growth.

Tan and colleagues⁹ review has shown how the best effectiveness of physical activity, in terms of volume and strength at the compression level on the bone, occurs in this age target.

A study by Nogueira and colleagues¹⁰ analysed the consequence of conducting a physical program for pre-pubertal girls in schools combined with a proper diet rich in calcium. The results showed marked improvement in bone metabolism, a decrease in weight in overweight subjects, and improvement in resting heart rate and oxygen consumption in vertical jumps. If the program were planned in large-scale in schools, it would confer a significant public health benefit.

Table 1. Recent literature about osteoporosis prevention in young people.

Population studied	Number	Type of study	Approach	Result	Author	Reference	Year
Children (10 years old)	410	Cluster randomized, controlled school-based intervention trial	Daily jumping program on a bouncer and fifteen minutes a day of physical activity	Distal strength of the tibia increased	McDonald	3	2007
Children	104	Longitudinal study	Physical activity done during adolescence	Structural bone strength of the femoral proximal part increased	Jakowski	4	2014
Women pre-menarche age	60	Longitudinal study	Artistic gymnastics	Higher levels of bone mass ten years after having retired from gymnastics, maintained	Erlandson	5	2012
Young people (mean age 5.2 years)	467	Cross-sectional study	Vigorous physical activity each day	Bone surface area and density of the femoral head increased	Janz	6	2004
Girls (aged 10-17.2 years)	65	Linear mixed models for longitudinal data	Artistic gymnastics	Increase in ABMD but also an improvement in bone geometry associated with an increase in bone remodeling	Maimoun	7	2011
Girls (aged 8-13 years)	465	Study population	Weight-bearing exercises and muscle-strengthening exercises	Physical activity duration, frequency, and load were all associated with bone geometry and strength, although their independent influences were modest and site specific	Farr	8	2011
Young		Systematic review	Physical activity	Prepuberty and peripuberty may be the most opportune time for boys and girls to enhance bone strength	Tan	9	2014
Pre- and early-pubertal girls (10.6±0.6years)	151	Controlled, school-based intervention trial	10 min bouts of thrice-weekly jumping plus capoeira (Brazilian sport)	Calcaneal broadband ultrasound enhanced; musculoskeletal and metabolic outcomes enhanced	Nogueira	10	2014

Osteoporosis prevention in adult people

In 2011, the Scientific Society within the Work Commission and Regional Secretariats (SIMFER) drafted Guidelines for rehabilitation treatment in postmenopausal and senile osteoporosis, dividing the population by risk classes as: i) healthy postmenopausal women; ii) osteopenic women after menopause [bone mineral density (BMD) within 2.5 T score]; iii) postmenopausal osteoporotic women with no history of fractures (BMD <2.5 T score); iv) postmenopausal women with an increased risk of falling; v) postmenopausal women with a history of fractures.

The recommendations and International Guidelines on the rehabilitation of osteoporosis suggest a personalized rehabilitation program, the adoption of correct hygiene rules of life, an adequate diet supplemented by calcium and vitamin D. In people with osteoporosis or with an increased risk of falling, rehabilitation must be preventive and/or carried out with other pharmacological treatments to optimize the quality of life, health and risk of fracture reduction and/or recurrences.¹¹

In 2019 the Guidelines published separately by the SIMFER, SIOMMMS/SIR, and SIOT associations, were harmonized to provide practical indications for the management of osteoporosis and for the diagnosis, prevention, and treatment of fragility fractures.¹²

According to the Guidelines, physical activities play an important role in incrementing bone mass. Through the practice of sports, aerobic training, resistance training, aquatic exercises based on repetitive sequences, and oriental disciplines such as Tai Chi Chuan, BMD increases in different districts of the body (radio, lumbar spine, femur, and heel). Moreover, balance training leads to proprioception and prevents falls and fractures.

Moreira and colleagues presented the effects of different types of exercises (in water or on the ground) on bone and physical function of postmenopausal women. They also mentioned how mechanical vibration has proven to stimulate bone metabolism and physical function in the postmenopausal period¹³ (Table 2).¹³⁻³²

In water, a high-intensity, jump-based interval aquatic exercise program was shown to improve BMD and functional fitness parameters in postmenopausal women.¹⁴

Chen and colleagues recently reported on osteoporosis and its nonpharmacological and nonsurgical treatment and provided evidence-based information on the assessment and management of osteoporosis, suggesting that nutritional support should be combined with lifestyle adjustments, fall prevention strategies, exercise and physical modalities. However, numerous issues regarding its treatment remain unexplored and warrant future investigation.¹⁵

Marín-Cascales *et al.* showed that whole-body vibration (WBV) is an effective method to improve lumbar spine BMD in postmenopausal and older women and to enhance femoral neck BMD in postmenopausal women younger than 65 years. The reviews and meta-analysis suggest further suitable studies to define the optimal protocol.¹⁶

As far as WBV intervention studies are concerned, the review by Marin-Puyalto and colleagues showed that WBV interventions seem to help children and adolescents with compromised bone mass to increase their BMD.¹⁷

Jepsen and colleagues identified randomized controlled trials examining the effect of WBV on fracture risk in adults ≥ 50 years of age; they showed how it reduces fall rate. Partial data found a trend towards falls reduction (relative risk=0.76, 95% confidence interval 0.48 to 1.20, $P=0.24$; $I^2=24\%$) (low quality of evidence) but WBV seems to have no overall effect on BMD or microarchitecture.¹⁸

The same Authors performed, additionally, a randomized controlled trial (RCT) on osteoporotic patients in combination with parathyroid hormone PTH 1-34 treatment alone or combined PTH 1-34 treatment and WBV and whole-body vibration exercise (PaVOS study). The combined treatment of WBV and PTH 1-34 may potentially have beneficial effects on bone and muscle strength and subsequently reduce fall risk.¹⁹

Jensen *et al.*,²⁰ with a program of individualized strategies in people over 65, showed how to prevent falls and fall damage. Dancing is training for agility and serves to reduce falls. Its effectiveness is similar to muscle strengthening exercises and can be offered to people who cannot undertake muscle-strengthening exercises. The study by Shigematsu and colleagues²¹ indicated the use of aerobic activity, in the form of dancing, as an exercise mode, for agility, static and dynamic stability, the monopodial support station with closed eyes, functional reach and walking around two obstacles.

A double-blind study, on 1004 Finnish women in their sixties and seventies at Pekkarinen's²² nursing home, demonstrated how non-drug treatment significantly reduces the risk of falling and hip fracture by 55%. The control group consisted of 1174 people. The program included the use of vitamin D, calcium, avoiding smoking, and regular physical activity. A ten-year follow-up demonstrated how the group of women who followed the program had twelve fractures, in comparison with the ones in the control group, who had twenty-nine fractures.

In adults a multi-modal exercise program of traditional and high velocity progressive resistance training (PRT) with multi-directional weight-bearing impact exercises and challenging balance/mobility training performed three times per week was effective in improving femoral neck and lumbar spine BMD, muscle strength, functional muscle power (timed stair climb) and dynamic balance.²³

Watson and colleagues led a trial in 2017 to determine the efficacy of high intensity resistance and impact training to reduce risk for fracture in post-menopausal women with low bone mass. The study was conducted on a total of 101 women (aged 65 ± 5 years, 161.8 ± 5.9 cm, 63.1 ± 10.4 kg). In postmenopausal women with osteopenia or osteoporosis, 30 min high intensity resistance and impact training twice a week maintained or improved hip and spine BMD.²⁴

Multicomponent exercise training, with emphasis on daily balance and spinal extensor muscle training and guidance of safe movements, is recommended by expert consensus for individuals with osteoporosis with or without vertebral fractures. The experts concluded, however, that for those patients with vertebral fracture, especially in the presence of pain, multiple fractures, or hyperkyphosis, the risks of many activities may outweigh the benefits, so physical therapist consultation is recommended.²⁵

Combined resistance training protocols, presented in a meta-analysis conducted in 2015, were effective in improving BMD at the femoral neck and lumbar spine BMD in postmenopausal women.²⁶

A recent meta-analysis (2017) showed that multimodal training (resistance, impact and multi-directional dynamic aerobic activities) positively affected proximal femur and lumbar spine BMD in 11 RCT. The authors suggested that future clinical investigations should include larger study samples and adhere to the current standards for conducting clinical trials.²⁷

The analysis of articles published between 2001-2016 to define the efficacy of physical activity for improving BMD in postmenopausal women highlighted the need to determine the precise training protocol for postmenopausal women.²⁸

A research article published in 2015 showed that Pilates exer-

cises are effective in increasing bone mineral density BMD, quality of life and walking distance.²⁹

The primary objective of the program is to meet the patients' needs, agreeing with them a program that considers, in addition to the physical aspects related to the pathology, also the specific risk factors.

In postmenopausal as well as in senile patients, osteopenia or osteoporosis medical and rehabilitative treatment aims reducing the risk of falling.

In the treatment of postmenopausal and senile osteoporosis or osteopenic patients, personal physiotherapy and rehabilitation assessment are essential to modulate a rehabilitative path suited to, and compatible with, patient's needs in a biopsychosocial perspective. This provides an accurate history including family history of bone diseases, reports referring to previous situations such as acci-

dents, previous pathologies affecting the skeletal muscle system, other pathologies such as diabetes, visual, auditory, cardiovascular, respiratory and respiratory deficits, and the acquisition of clinical and diagnostic reports. On the other side, the physiotherapist should take into account the International Classification of Functioning, Disability and Health.

The physiotherapist will take into consideration the particular characteristics of the patient and his/her habitat. In particular, interventions on the person will be focused on pain reduction, bone mass increasing, trophism and muscle strength image, hypokinesia and hypo-asthenia reduction, and tendon muscle retractions and joint stiffness improvement.

Postural re-education will then be performed. At the same time, indirect goals such as environment modifications, choice of suitable auditory and orthoses advice, can be assessed. The physiotherapist

Table 2. Recent literature about osteoporosis prevention in adult people.

Population studied	Number	Type of study	Approach	Result	Author	Reference	Year
Resident >65 years old	439	Cluster randomized, controlled, nonblinded trial	An interdisciplinary and multifactorial prevention program	Falls and femoral fractures reduced	Jensen	11	2002
Women (aged 72-87 years)	37	Exercise intervention trial	Dance-based aerobic exercise	Selected components of balance and locomotion/agility improved	Shigematsu	12	2002
Women (aged 60-70 years)	2178	Randomized controlled trial	Intervention group (1 week-22 hours) physiotherapist, physician, nutritionist, occupational therapist, podiatric, exercise leaders)	10-year follow-up: risk of falling and hip fracture reduced by 55%	Pekkarinen's	13	2013
Adult	162	Community-based RCT	Multi-modal exercise program	Femoral neck and lumbar spine BMD, muscle strength, functional muscle power improved	Gianoudis	23	2014
Postmenopausal women with osteopenia or osteoporosis	101	Randomized controlled trial	30 min high intensity resistance and impact training twice a week	Hip and spine BMD maintained or improved	Watson	24	2018
Postmenopausal women	1061	Meta-analysis	Multimodal training (resistance, impact and multi-directional dynamic aerobic activities)	Positively affected proximal femur and lumbar spine BMD	Zhao	27	2017
Individuals with osteoporosis		Delphi consensus	Multicomponent exercise training	Recommendations	Giangregorio	25	2015
2780 postmenopausal women and 2129 men aged 50 years or older	4909	Population-based prospective study	Walking	Older adults who adhered were not protected against fragility fractures, but more frequent walking was associated with an increased fracture risk	Nikander	31	2011
In perimenopausal and postmenopausal women		Meta-analysis	Walking	No significant effects on the lumbar spine on the radius and on whole body BMD; positive effects on femoral neck BMD are evident with interventions more than 6 months in duration	Giangregorio	25	2015

will give all relevant instructions on the correct use of motor/splint aids and ergonomic practices, education in hygiene rules of life, information about risk factors for falls, and education in awareness and acceptance of personal health status. All this can be carried out with a problem-solving training session or conferences.

In the presence of osteoporosis, the bones most exposed to the risk of fracture are: femoral neck, vertebrae, and distal radius. The response of the bone to the mechanical load is highly stimulus-specific, therefore it is useful to identify the bone on which to address the physiotherapy and rehabilitation program.

The axial pressures and dynamic loading exercises on high impact bone and muscle activation allow correct skeletal muscle dynamics, responsible for the orientation of the lines of force, sensitive to mechanical signal.

The physiotherapist will perform a program with exercises for muscle strengthening and for postural control. The exercises to improve postural control, movement and cognitive sequential control are those of proprioceptive bio-feedback including high compliance activity, such as fast walking for an hour a day, at least three times a week. One of the most common forms of aerobic exercise is walking but Meta-analyses, however, have highlighted the absence of significant effects of walking on lumbar and femoral BMD.³⁰ Frequent walking in an exercise program for sedentary or frail elderly has been associated with an increased risk of falls and fracture in some studies.³¹ The current evidence does not support walking as a single intervention for the prevention of osteoporosis, falls or fractures.

A recent randomized controlled trial (2018) performed on a total of 100 osteoporotic women with at least one previous fracture who were assigned a 12-month exercise program (3 times a week for 30 min) showed significantly improved postural balance and increased aerobic capacity in women with established osteoporosis.³²

In the case of vertebral fractures, the physiotherapist must pay particular attention to pain control and relief. The assessment of pain is very complex, requiring an understanding of its different aspects and correct evaluation of its characteristics *i.e.* nociception, perception, suffering and behavioral reactions. The introduction of rating scales represents the first step in studying the subjective component of pain. There are several scales including verbal, numerical, analogical visual.

At the beginning of any physiotherapy section, the respiratory exercises will be offered and performed as a prevention of lung problems.

In the first phase, an individual therapeutic training includes massage techniques such as relaxing, lymphatic drainage, connective tissue massage, and manipulation of the fascia.

Kinesio taping is also a useful method to guarantee a series of free movements, taking advantage of the concept of exteroception and proprioception, which is well placed on the musculoskeletal districts that have lost gestural memory due to the presence of pain protracted for a long time. Re-education in walking is important, possibly with aids, if necessary.

People who actively collaborate can access postural techniques, both on a cognitive and physical level, thanks to a good relationship with their body. Other postural exercises can be performed in a group of patients.

Conclusions

Non-pharmacological treatment by rehabilitation and physiotherapy practice plays an important role in the prevention of osteoporosis.

In older people where fractures are present in the spine of the upper and lower limbs, rehabilitation does not only affect the pain or recovery of the patient's gestures, but considers more complex aspects, which involve the affective-relational sphere, esteem, self-respect and personal dignity in relation to the external environment.

References

1. Adami S, Bertoldo F, Brandi ML, et al. Guidelines for the diagnosis, prevention and treatment of osteoporosis. *Reumatismo* 2009;260-84.
2. NIH Consensus Development Panel on Osteoporosis Prevention, Diagnosis, and Therapy. Osteoporosis prevention, diagnosis, and therapy. *JAMA* 2001;285:785-95.
3. Macdonald HM, Kontulainen SA, Khan KM, McKay HA. Is a school-based physical activity intervention effective for increasing tibial bone strength in boys and girls?. *J Bone Mineral Res* 2007;22:434-46.
4. Jackowski SA, Kontulainen SA, Cooper DM, et al. Adolescent physical activity and bone strength at the proximal femur in adulthood. *Med Sci Sports Exercise* 2014;46:736-44.
5. Erlandson MC, Kontulainen SA, Chilibeck PD, et al. Higher premenarcheal bone mass in elite gymnasts is maintained into young adulthood after long-term retirement from sport: a 14-year follow-up. *J Bone Min Res* 2012;27:104-10.
6. Janz KF, Burns TL, Levy SM, et al. Everyday activity predicts bone geometry in children: the iowa bone development study. *Med Sci Sports Exercise* 2004;36:1124-31.
7. Maïmoun L, Coste O, Mariano-Goulart D, et al. In peripubertal girls, artistic gymnastics improves areal bone mineral density and femoral bone geometry without affecting serum OPG/RANKL levels. *Osteoporos Int* 2011;22:3055-66.
8. Farr JN, Blew RM, Lee VR, et al. Associations of physical activity duration, frequency, and load with volumetric BMD, geometry, and bone strength in young girls. *Osteoporos Int* 2011;22:1419-30.
9. Tan VP, Macdonald HM, Kim S, et al. Influence of physical activity on bone strength in children and adolescents: a systematic review and narrative synthesis. *J Bone Min Res* 2014;29:2161-81.
10. Nogueira RC, Weeks BK, Beck BR. An in-school exercise intervention to enhance bone and reduce fat in girls: the CAPO Kids trial. *Bone* 2014;68:92-9.
11. Rossini M, Adami S, Bertoldo F, et al. Guidelines for the diagnosis, prevention and management of osteoporosis. *Reumatismo* 2016;68:1-39.
12. Nuti R, Brandi ML, Checchia G, et al. Guidelines for the management of osteoporosis and fragility fractures. *Intern Emerg Med* 2019;14:85-102.
13. Moreira LDF, Oliveira MLD, Lirani-Galvão AP, et al. Physical exercise and osteoporosis: effects of different types of exercises on bone and physical function of postmenopausal women. *Arquiv Brasil Endocrinol Metabol* 2014;58:514-22.
14. Aboarrage Junior AM, Teixeira CVS, Dos Santos RN, et al. A high-intensity jump-based aquatic exercise program improves bone mineral density and functional fitness in postmenopausal women. *Rejuvenation Res* 2018;21:535-40.
15. Chen LR, Hou PH, Chen KH. Nutritional support and physical modalities for people with osteoporosis: current opinion. *Nutrients* 2019;11:2848.

16. Marin-Puyalto J, Gomez-Cabello A, Gonzalez-Agüero A, et al. Is vibration training good for your bones? An overview of systematic reviews. *Biomed Res Int* 2018;2018:5178284.
17. Marín-Cascales E, Alcaraz PE, Ramos-Campo DJ, et al. Whole-body vibration training and bone health in postmenopausal women: A systematic review and meta-analysis. *Medicine (Baltimore)*. 2018;97:e11918.
18. Jepsen DB, Thomsen K, Hansen S, et al. Effect of whole-body vibration exercise in preventing falls and fractures: a systematic review and meta-analysis. *BMJ Open* 2017;7:e018342.
19. Jepsen DB, Ryg J, Hansen S, et al. The combined effect of Parathyroid hormone (1-34) and whole-body Vibration exercise in the treatment of postmenopausal Osteoporosis (PaVOS study): a randomized controlled trial. *Osteoporos Int* 2019;30:1827-36.
20. Jensen J, Lundin-Olsson L, Nyberg L, Gustafson Y. Fall and injury prevention in older people living in residential care facilities. *Ann Intern Med* 2002;136:733-41.
21. Shigematsu R, Chang M, Yabushita, N, et al. Dance-based aerobic exercise may improve indices of falling risk in older women. *Age Ageing* 2002;31:261-6.
22. Pekkarinen T, Löyttyniemi E, Välimäki M. Hip fracture prevention with a multifactorial educational program in elderly community-dwelling Finnish women. *Osteoporos Int* 2013;24:2983-92.
23. Gianoudis J, Bailey CA, Ebeling PR, et al. Effects of a targeted multimodal exercise program incorporating high-speed power training on falls and fracture risk factors in older adults: a community-based randomized controlled trial. *J Bone Miner Res* 2014;29:182-91.
24. Watson SL, Weeks BK, Weis LJ, et al. High-intensity resistance and impact training improves bone mineral density and physical function in postmenopausal women with osteopenia and osteoporosis: the LIFTMOR randomized controlled trial. *J Bone Miner Res* 2018;33:211-20.
25. Giangregorio LM, McGill S, Wark JD, et al. Too Fit To Fracture: outcomes of a Delphi consensus process on physical activity and exercise recommendations for adults with osteoporosis with or without vertebral fractures. *Osteoporos Int* 2015;26:891-910.
26. Zhao R, Zhao M, Xu Z. The effects of differing resistance training modes on the preservation of bone mineral density in postmenopausal women: a meta-analysis. *Osteoporos Int* 2015;26:1605-18.
27. Zhao R, Zhang M, Zhang Q. The effectiveness of combined exercise interventions for preventing postmenopausal bone loss: a systematic review and meta-analysis. *J Orthop Sports Phys Ther* 2017;47:241-51.
28. Segev D, Hellerstein D, Dunsky A. Physical activity-does it really increase bone density in postmenopausal women? a review of articles published between 2001-2016. *Curr Aging Sci* 2018;11:4-9.
29. Angin E, Erden Z, Can F. The effects of clinical pilates exercises on bone mineral density, physical performance and quality of life of women with postmenopausal osteoporosis. *J Back Musculoskelet Rehabil* 2015;28:849-58.
30. Ma D, Wu, L, He Z. Effects of walking on the preservation of bone mineral density in perimenopausal and postmenopausal women: a systematic review and meta-analysis. *Menopause* 2013;20:1216-26.
31. Nikander R, Gagnon C, Dunstan DW, et al. Frequent walking, but not total physical activity, is associated with increased fracture incidence: a 5-year follow-up of an Australian population-based prospective study (AusDiab). *J Bone Miner Res* 2011;26:1638-47.
32. Miko I, Szerb I, Szerb A, et al. Effect of a balance-training programme on postural balance, aerobic capacity and frequency of falls in women with osteoporosis: A randomized controlled trial. *J Rehabil Med* 2018;50:542-7.