Orthopedic & Muscular System: Current Research

Gray, Orthopedic Muscul Sys 2014, S2:S2-001
DOI: 10.4172/2161-0533.S2-001

Mini Review Open Access

Exercise and Osteoporosis Prevention

Michelle Gray*

Office for Studies on Aging, Human Performance Lab, University of Arkansas, USA

***Corresponding author:** Michelle Gray, Assistant Professor – Exercise Science, Office for Studies on Aging Human Performance Lab, University of Arkansas HPER 309Fayetteville, AR 72701, USA, Tel: 479-575-2975; E-mail: rgray@uark.edu

Received date: Mar 29, 2014, **Accepted date:** Apr 25, 2014, **Published date:** Apr 30, 2014

Abstract

Osteoporosis is known as the “silent disease” because there are no outward signs or symptoms until a fracture occurs. Low bone mineral density (BMD) is the leading cause of fracture among older adults and increases mortality and morbidity rates. Exercise interventions reduce fracture-risk; however, different types of exercises produce different results. Based on findings, daily physical activity, walking, running, resistance, and power training all promote BMD development. Yet, resistance training may be most effective of exercise interventions. More specifically, high-velocity resistance training leads to greater increases in BMD than traditional resistance training and results in fewer injuries than power training.

Keywords: Bone mineral density; Ground reaction forces; Trabecular; Cuboid bones

Mini Review

Osteoporosis is a disease characterized by dysregulation of bone formation and breakdown leading to more porous bone and greater risk of fracture. Bone quality, not bone quantity is the greatest predictor of osteoporosis-related fracture and is defined as bone mineral density (BMD), the diagnostic measure of bone quality. BMD is calculated as the mass of the bone by the area (g/cm^2). BMD accounts for 50-80% of the breaking strength of bones [1-4] and remains the best predictor of fracture risk [5-11]. Osteoporosis is the leading cause of fracture in older adults [12]. A reduction of one standard deviation of BMD results in a 1.5-fold increase in relative risk of fracture at most sites and reaches nearly 3-fold in the femoral neck [13-16]. The most common sites of breaks include the distal radius, vertebrae, pelvis, and femoral neck. Of all osteoporotic fractures, a break of the hip is the most devastating. Within the first six months after a hip fracture, there is a 10-20% risk of mortality [17] and 25-33% within the year in women over 65 years [18,19]. For those that survive, a full recovery is rare; 33% of women will enter a nursing home [20] and 50% will require assistance during ambulation [21]. Thus, it is imperative to increase or maintain BMD throughout life to reduce risk of fractures.

Peak bone mass occurs before the end of the third decade of life in young women [22] with rapid surges during puberty [23] and just before the cessation of longitudinal growth. It has been previously reported that 85% of bone mineral content is accrued within two years of puberty and ceased totally seven years after menarche [24]. BMD reaches steady state by the third decade of life and remains unchanged until the mid-forties then declines 0.5–1.0% per year after this point [25]. It should be noted that increasing physical activity during puberty will increase BMD and predict BMD in late life [26]. However, there is evidence that suggests BMD can be increased during and after this time.

In the human body, 80% of bone is trabecular, located in the long bones near the epiphyseal plates as well as the interior of the flat and cuboid bones. It was noted in 1892 [27] that the striations in the trabecular bone matched that of the direction of the strain. This is important to take into consideration when considering strategies for improving BMD. For this reason, exercise specialists prescribe exercise aimed to increase strain of the bone through high-impact activity especially in areas where trabecular bone is prominent such as the lumbar spine [28]. Currently the most widely used form of exercise prescribed to increase bone density is weight-bearing physical activity [29]. However, not all weight-bearing activities produce similar results.

Exercise has a long track record of benefitting BMD [30-40]. While not all exercise programs produce the same results, all support exercise training over a sedentary lifestyle. The results range from small decrements (0.8%) to large increases (2.7%) in BMD over the course of the various training interventions. However, the specific types of training programs found to be the most beneficial are controversial and have yet to be determined.

Observational studies support the fact that more physically active individuals have more BMD even in the absence of a formal exercise training program. Specifically, adults participating in moderate amounts of physical activity reduce their risk of fracture by nearly 30% and occupational standing results in a reduction of hip fracture by nearly 70% [39,41]. These studies suggest that unstructured physical activity is superior to leading a completely sedentary lifestyle. While any weight-bearing physical activity is beneficial for increasing or maintaining bone mass, various studies of aerobic, resistance, and power training have been implemented to determine the best prescription for improvements in bone mass. Physical activity is suggested to prevent osteoporotic-related fracture through the increase in BMD.

It is apparent that the key to maintenance of bone mass is weight-bearing physical activity as supported by studies of weightlessness [42-44]. Space flights lasting up to six months result in a decrease of BMD up to 11% [42]. Although, these results are reversed when re-introduced to the gravity environment and resuming their normal daily routines, after one year, bone mass regained was only 91% [42]. In addition, longitudinal studies examining paraplegic adults that do not return to weight-bearing ambulation lose nearly 40% BMD after only one year [43]. However, with both of these populations, the decline can be somewhat reversed or slowed even with passive exercises [44].

However, the type of exercise remains controversial. Among aerobic exercise studies the results are equivocal [45]. Most researchers concur that sports participation of any type is a positive predictor of BMD [46,47] and young adults that participate in sports as children significantly increase their BMD in late life [26,46]. Keay [46], observed identical twin girls and compared their level of activity and BMD over time. The results revealed that participation in sports or physical activities have a positive impact on BMD when compared to the sedentary sibling. In addition, comparisons between impact and non-impact sports favors running when compared to cycling or swimming among adolescents [47]. However, these results are controversial when compared to other sports (i.e. soccer, basketball, volleyball), runners have significantly less bone density [48-50]. Thus, not all sports have beneficial effects on BMD.

Other types of exercise have been studied recently to determine the type of training that will yield the greatest results. One type of exercise is resistance training. It is known that lean-tissue mass (muscle mass) is significantly correlated with BMD [33,51]. LTM decreases with age at a rate of 5 - 8% per decade after 30 years [52]. However, resistance training increases LTM and BMD significantly. Resistance training can be divided into different areas: high-intensity, low-intensity, high-velocity, and low-velocity. High-intensity resistance training (>70% 1-repetition maximum [1RM]) has been shown to produce modest to large improvements in BMD [31,33,34,37,40,53]. It should be noted that in the studies that compare resistance training to a non-exercise control group, resistance training is superior to the sedentary lifestyle [31,33,53]. Effects of low-intensity (40% 1RM) resistance training are not as favorable as high-intensity. Studies report similar changes to non-exercise control group. Therefore, when choosing resistive activities, it is important to keep in mind that intensity matters and a greater intensity will result in greater improvements in bone density.

Plyometric or high-velocity activities include jumping, stamping, heel-drops, and skipping. Performing these activities generates high ground reaction forces (GRF) causing a significant increase in strain of the weight-bearing bones; thus, increasing BMD [54]. Increased strain of the bone causes an increase in osteocyte activity resulting in an increased bone deposition [55]. This theory is supported by comparing power athletes (i.e. gymnasts) and non-power athletes [56]. Gymnasts have greater BMD when compared to other sports among adolescent girls. This type of training is beneficial among older women as well [30,48,57,58]. This training techniques works to increase bone strain by increasing GRF during the activities [59]. However, plyometric exercises increase risk of injury more than traditional resistance training; thus, more recently researchers have begun to use high-velocity resistance training to increase BMD [36,60]. This specific type of exercise requires the participant to perform the concentric phase of the activity as quickly as possible, while performing the eccentric phase in a slow, controlled manner. Performing the exercises in this manner reduces the risk of injury; however, increases bone mass by maintain a high strain of the bone's longitudinal axis [55,59,61,62](Mechelen, Twisk, Kemper, Snel, & Post, 1999). Based on these findings, high-velocity resistance training increases bone more than traditional resistance training.

There are many way to increase bone density, however, some are more detrimental and costly than others. The predictors of bone mass include peak bone mass, genetics, physical activity, and other environmental factors. Factors that are modifiable should be at the forefront of the research including physical activity. Weight-bearing physical activity is a cost-effective treatment with very little risk and has been researched extensively. Resistive exercise has been long prescribed as the "standard of care" for the prevention of osteoporosis or maintenance of bone density however, it has been suggested through cross-sectional studies that power or high-velocity training could be a more effective means of increasing bone mass.

References

1. Ammann P, Rizzoli R (2003) Bone strength and its determinants. OsteoporosInt 14 Suppl 3: S13-18.
2. Ammann P, Rizzoli R, Meyer JM, Bonjour JP (1996) Bone density and shape as determinants of bone strength in IGF-I and/or pamidronate-treated ovariectomized rats. OsteoporosInt 6: 219-227.
3. Genant HK, Glüer CC, Lotz JC (1994) Gender differences in bone density, skeletal geometry, and fracture biomechanics. Radiology 190: 636-640.
4. Turner CH, Burr DB (1993) Basic biomechanical measurements of bone: a tutorial. Bone 14: 595-608.
5. Hui SL, Slemenda CW, Johnston CC Jr (1989) Baseline measurement of bone mass predicts fracture in white women. Ann Intern Med 111: 355-361.
6. Huopio J, Kröger H, Honkanen R, Saarikoski S, Alhava E (2000) Risk factors for perimenopausal fractures: a prospective study. OsteoporosInt 11: 219-227.
7. Kanis JA, Delmas P, Burckhardt P, Cooper C, Torgerson D (1997) Guidelines for diagnosis and management of osteoporosis. The European Foundation for Osteoporosis and Bone Disease. OsteoporosInt 7: 390-406.
8. Kanis JA, Glüer CC (2000) An update on the diagnosis and assessment of osteoporosis with densitometry. Committee of Scientific Advisors, International Osteoporosis Foundation. OsteoporosInt 11: 192-202.
9. Kröger H, Huopio J, Honkanen R, Tuppurainen M, Puntila E, et al. (1995) Prediction of fracture risk using axial bone mineral density in a perimenopausal population: a prospective study. J Bone Miner Res 10: 302-306.
10. Marshall D, Johnell O, Wedel H (1996) Meta-analysis of how well measures of bone mineral density predict occurrence of osteoporotic fractures. BMJ 312: 1254-1259.
11. Melton LJ 3rd, Atkinson EJ, O'Fallon WM, Wahner HW, Riggs BL (1993) Long-term fracture prediction by bone mineral assessed at different skeletal sites. J Bone Miner Res 8: 1227-1233.
12. Seeley DG, Cauley JA, Grady D, Browner WS, Nevitt MC, et al. (1995) Is postmenopausal estrogen therapy associated with neuromuscular function or falling in elderly women? Study of Osteoporotic Fractures Research Group. Arch Intern Med 155: 293-299.
13. Broe KE, Hannan MT, Kiely DK, Cali CM, Cupples LA, et al. (2000) Predicting fractures using bone mineral density: a prospective study of long-term care residents. OsteoporosInt 11: 765-771.
14. Duppe H, Gardsell P, Nilsson B, Johnell O (1997) A single bone density measurement can predict fractures over 25 years. Calcif Tissue Int 60: 171-174.
15. Faulkner KG (2000) Bone matters: are density increases necessary to reduce fracture risk? J Bone Miner Res 15: 183-187.
16. Faulkner KG, Cummings SR, Black D, Palermo L, Glüer CC, et al. (1993) Simple measurement of femoral geometry predicts hip fracture: the study of osteoporotic fractures. J Bone Miner Res 8: 1211-1217.
17. Kelley GA (1998) Aerobic exercise and bone density at the hip in postmenopausal women: a meta-analysis. Prev Med 27: 798-807.
18. Jacobsen SJ, Goldberg J, Miles TP, Brody JA, Stiers W, et al. (1990) Regional variation in the incidence of hip fracture. US white women aged 65 years and older. JAMA 264: 500-502.

19. Magaziner J, Lydick E, Hawkes W, Fox KM, Zimmerman SI, et al. (1997) Excess mortality attributable to hip fracture in white women aged 70 years and older. Am J Public Health 87: 1630-1636.
20. Ray NF, Chan JK, Thamer M, Melton LJ 3rd (1997) Medical expenditures for the treatment of osteoporotic fractures in the United States in 1995: report from the National Osteoporosis Foundation. J Bone Miner Res 12: 24-35.
21. Riggs BL, Melton LJ 3rd (1995) The worldwide problem of osteoporosis: insights afforded by epidemiology. Bone 17: 505S-511S.
22. Theintz G, Buchs B, Rizzoli R, Slosman D, Clavien H, et al. (1992) Longitudinal monitoring of bone mass accumulation in healthy adolescents: evidence for a marked reduction after 16 years of age at the levels of lumbar spine and femoral neck in female subjects. J ClinEndocrinolMetab 75: 1060-1065.
23. Blumsohn A, Hannon RA, Wrate R, Barton J, al-Dehaimi AW, et al. (1994) Biochemical markers of bone turnover in girls during puberty. ClinEndocrinol (Oxf) 40: 663-670.
24. Sabatier JP, Guaydier-Souquières G, Benmalek A, Marcelli C (1999) Evolution of lumbar bone mineral content during adolescence and adulthood: a longitudinal study in 395 healthy females 10-24 years of age and 206 premenopausal women. OsteoporosInt 9: 476-482.
25. McGarry KA, Kiel DP (2000) Postmenopausal osteoporosis. Strategies for preventing bone loss, avoiding fracture. Postgrad Med 108: 79-82, 85-8, 91.
26. Rideout CA, McKay HA, and Barr SI (2006) Self-reported lifetime physical activity and areal bone mineral density in healthy postmenopausal women: the importance of teenage activity. Calcif Tissue Int 79: 214-222.
27. Borer KT (2005) Physical activity in the prevention and amelioration of osteoporosis in women : interaction of mechanical, hormonal and dietary factors. Sports Med 35: 779-830.
28. Bravo G, Gauthier P, Roy PM, Payette H, Gaulin P, et al. (1996) Impact of a 12-month exercise program on the physical and psychological health of osteopenic women. J Am GeriatrSoc 44: 756-762.
29. Wallace BA, Cumming RG (2000) Systematic review of randomized trials of the effect of exercise on bone mass in pre- and postmenopausal women. Calcif Tissue Int 67: 10-18.
30. Kemmler W, Engelke K, Lauber D, Weineck J, Hensen J, et al. (2002) Exercise effects on fitness and bone mineral density in early postmenopausal women: 1-year EFOPS results. Med Sci Sports Exerc 34: 2115-2123.
31. Kemmler W, Lauber D, Weineck J, Hensen J, Kalender W, et al. (2004) Benefits of 2 years of intense exercise on bone density, physical fitness, and blood lipids in early postmenopausal osteopenic women: results of the Erlangen Fitness Osteoporosis Prevention Study (EFOPS). Arch Intern Med 164: 1084-1091.
32. Kemmler WK, Lauber D, Engelke K, Weineck J (2004) Effects of single- vs. multiple-set resistance training on maximum strength and body composition in trained postmenopausal women. J Strength Cond Res 18: 689-694.
33. Rhodes EC, Martin AD, Taunton JE, Donnelly M, Warren J, et al. (2000) Effects of one year of resistance training on the relation between muscular strength and bone density in elderly women. Br J Sports Med 34: 18-22.
34. Jessup JV, Horne C, Vishen RK, Wheeler D (2003) Effects of exercise on bone density, balance, and self-efficacy in older women. Biol Res Nurs 4: 171-180.
35. Kemmler W, von Stengel S (2012) Dose-response effect of exercise frequency on bone mineral density in post-menopausal, osteopenic women. Scand J Med Sci Sports .
36. von Stengel S, Kemmler W, Kalender WA, Engelke K, Lauber D (2007) Differential effects of strength versus power training on bone mineral density in postmenopausal women: a 2-year longitudinal study. Br J Sports Med 41: 649-655.
37. Maddalozzo GF, Snow CM (2000) High intensity resistance training: effects on bone in older men and women. Calcif Tissue Int 66: 399-404.
38. Pruitt LA, Taaffe DR, Marcus R (1995) Effects of a one-year high-intensity versus low-intensity resistance training program on bone mineral density in older women. J Bone Miner Res 10: 1788-1795.
39. Thorpe DL, Knutsen SF, Beeson WL, Fraser GE (2006) The effect of vigorous physical activity and risk of wrist fracture over 25 years in a low-risk survivor cohort. J Bone Miner Metab 24: 476-483.
40. Kerr D, Ackland T, Maslen B, Morton A, Prince R (2001) Resistance training over 2 years increases bone mass in calcium-replete postmenopausal women. J Bone Miner Res 16: 175-181.
41. Cummings SR, Nevitt MC, Browner WS, Stone K, Fox KM, et al. (1995) Risk factors for hip fracture in white women. Study of Osteoporotic Fractures Research Group. N Engl J Med 332: 767-773.
42. Lang TF, Leblanc AD, Evans HJ, Lu Y (2006) Adaptation of the proximal femur to skeletal reloading after long-duration spaceflight. J Bone Miner Res 21: 1224-1230.
43. Wilmet E, Ismail AA, Heilporn A, Welraeds D, Bergmann P (1995) Longitudinal study of the bone mineral content and of soft tissue composition after spinal cord section. Paraplegia 33: 674-677.
44. Goemaere S, Van Laere M, De Neve P, Kaufman JM (1994) Bone mineral status in paraplegic patients who do or do not perform standing. OsteoporosInt 4: 138-143.
45. Humphries B, Newton RU, Bronks R, Marshall S, McBride J, et al. (2000) Effect of exercise intensity on bone density, strength, and calcium turnover in older women. Med Sci Sports Exerc 32: 1043-1050.
46. Keay N (2000) The modifiable factors affecting bone mineral accumulation in girls: The paradoxical effect of exercise on bone. Nutrition Bulletin 25: 219-222.
47. Duncan CS, Blimkie CJ, Cowell CT, Burke ST, Briody JN, et al. (2002) Bone mineral density in adolescent female athletes: relationship to exercise type and muscle strength. Med Sci Sports Exerc 34: 286-294.
48. Heinonen A, Kannus P, Sievänen H, Oja P, Pasanen M, et al. (1996) Randomised controlled trial of effect of high-impact exercise on selected risk factors for osteoporotic fractures. Lancet 348: 1343-1347.
49. Heinonen A, Oja P, Kannus P, Sievänen H, Haapasalo H, et al. (1995) Bone mineral density in female athletes representing sports with different loading characteristics of the skeleton. Bone 17: 197-203.
50. Taaffe DR, Robinson TL, Snow CM, Marcus R (1997) High-impact exercise promotes bone gain in well-trained female athletes. J Bone Miner Res 12: 255-260.
51. Hamrick MW, Ding KH, Pennington C, Chao YJ, Wu YD, et al. (2006) Age-related loss of muscle mass and bone strength in mice is associated with a decline in physical activity and serum leptin. Bone 39: 845-853.
52. Greenlund LJ, Nair KS (2003) Sarcopenia--consequences, mechanisms, and potential therapies. Mech Ageing Dev 124: 287-299.
53. Tsuzuku S, Shimokata H, Ikegami Y, Yabe K, Wasnich RD (2001) Effects of high versus low-intensity resistance training on bone mineral density in young males. Calcif Tissue Int 68: 342-347.
54. Vainionpää A, Korpelainen R, Vihriälä E, Rinta-Paavola A, Leppäluoto J, et al. (2006) Intensity of exercise is associated with bone density change in premenopausal women. OsteoporosInt 17: 455-463.
55. Lanyon LE (1992) Control of bone architecture by functional load bearing. J Bone Miner Res 7 Suppl 2: S369-375.
56. Nickols-Richardson SM, O'Connor PJ, Shapses SA, Lewis RD (1999) Longitudinal bone mineral density changes in female child artistic gymnasts. J Bone Miner Res 14: 994-1002.
57. Vainionpää A, Korpelainen R, Leppäluoto J, Jämsä T (2005) Effects of high-impact exercise on bone mineral density: a randomized controlled trial in premenopausal women. OsteoporosInt 16: 191-197.
58. Bassey EJ, Ramsdale SJ (1994) Increase in femoral bone density in young women following high-impact exercise. OsteoporosInt 4: 72-75.
59. van Mechelen W, Twisk JW, Kemper HC, Snel J, Post GB, et al. (1999) Longitudinal relationships between lifestyle and cardiovascular and bone health status indicators in males and females between 13 and 27 years of age; a review of findings from the Amsterdam Growth and Health Longitudinal Study. Public Health Nutr 2: 419-427.

60. Gray M, Di Brezzo R, Fort IL (2013) The effects of power and strength training on bone mineral density in premenopausal women. J Sports Med Phys Fitness 53: 428-436.
61. Yeh JK, Liu CC, Aloia JF (1993) Effects of exercise and immobilization on bone formation and resorption in young rats. Am J Physiol 264: E182-189.
62. Tuukkanen J, Wallmark B, Jalovaara P, Takala T, Sjögren S, et al. (1991) Changes induced in growing rat bone by immobilization and remobilization. Bone 12: 113-118.

This article was originally published in a special issue, entitled: **"Joint Replacement: Treatment of Arthritic Disease",** Edited by Moschos A. Papadopoulos, Aristotle University of Thessaloniki, Greece