Exercise and Osteoporosis Prevention

Michelle Gray

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

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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/cm²). 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 epiphysical 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 reintroduced 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


