

Bone Mineral Density and Associated Factors



Medical Science

KEYWORDS : Bone mineral density, Osteoporosis, Risk factors of osteopenia, Economic implications of osteopenia.

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ABSTRACT

Low bone mineral density, a cause of osteoporosis and fractures due to it is an alarming feature prevailing in the society and may take up the form of a bigger problem with increasing age expectancy, sedentary lifestyle and exposure to fast food industry which supplies energy dense and mineral-deficient food. This is turning out to be not only a biological health problem but has its social ramifications as well as economic costs and consequences. Making youngsters aware of the situation and providing them guidance for a healthy and physically active lifestyle could help to curb down the incidence of osteopenia, a ground reality for the age-related bone brittleness and vulnerability to bone fracture.

Introduction

Osteoporosis is characterized by low bone mass with micro architectural deterioration of bone tissue leading to enhanced bone fragility, thus increasing susceptibility to fracture. It is a bone disease in which amount of bone is decreased and structural integrity of trabecular bone is impaired. Cortical bone becomes more porous and thinner. This makes the bone weaker and more likely to fracture. In 1994, a committee of World Health Organization (WHO) defined osteoporosis based on bone density. It is a silent disease reflected only in a low bone density till a fracture occurs. With increasing longevity of Indian population, it is now being realized that, as in West, osteoporotic fractures are a major cause of morbidity and mortality in elderly and estimations suggest that 20% of women and 1015% of men would be osteoporotic. If the lower bone density is shown to confer a greater risk of fracture, the risk of fracture is expected to increase up to 50 million [1]. In addition to bone density, the factors like age, heredity, body weight, diseases, lifestyle, frailty and amount of trauma all play important roles. The risk of fracture due to osteoporosis can be estimated using these factors in addition to the bone density [2]. The individuals of both the sexes, more so the post-menopausal women, are at a risk of skeletal problems associated with bone mineral density. With changes in life style pattern, mineral deficient diet and physical inactivity, there occurs a predisposition of potential risk factors of low bone mineral density in young adults and therewith a foreground for osteoporosis in advancing age and increasing life expectancy.

Review

Osteoporosis is a systematic skeletal disease characterized by low bone mass and micro- architectural deterioration of bone tissue, with a consequent increase in bone fragility and susceptibility to fracture. These changes are initially silent and can progress silently until a low trauma fracture occurs [3]. At any given age, bone mass results from the amount of bone acquired during growth. The attainment of a higher peak bone density in growing years has an important role in the prevention of osteoporosis later in life [4]. Etiologically, osteoporosis can be classified into primary and secondary types. Primary osteoporosis is bone loss that occurs either during the normal human aging process due to hormonal changes or due to an unidentifiable cause. The age related changes include decreased absorption of nutrients, hypogonadism and menopause while idiopathic causes could occur in juvenile as well in adult stage. On the other hand secondary osteoporosis could be because of chronic diseases, drug therapies or unhealthy life style [5] [6][7][8].

Bone structure and its maintenance: To maintain its proper functioning, bone must undergo repair through a process of remodeling carried out by bone forming cells, osteoblasts and osteoclasts [9]. Osteoclasts are attracted to the site of micro damage to resorb the bone, and afterwards

osteoblasts are employed to re synthesize the bone. A proper calcium- phosphate level in the body is maintained by parathyroid hormone which is produced in response to hypocalcaemia and is suppressed by hypocalcaemia. The parathyroid hormone acts directly on bone and kidney and indirectly on gastrointestinal tract by stimulating dihydroxyvitamin D3 synthesis. Vitamin D3 for the most part is synthesized from its precursor molecule, 7-dihydrocholesterol in the dermis under U.V. radiations found in the sunlight. The role of vitamin D metabolites is to maintain serum calcium and phosphate levels by directly promoting intestinal absorption of these ions as well as activation of bone resorption. The process of bone formation takes about three to four months. Continuous bone remodeling is a normal process with 1-2 million microscopic areas of bone being repaired at any given time [4].

Bone mineral density is a medical term referring to the amount of mineral matter per square centimeter of bone and is an indirect indicator of osteoporosis. Bone health is important at every age and stage of life. The skeleton is our body's storage bank for calcium – a mineral that is essential for our body to function and is especially important as a building block of bone tissue. Older adults with osteoporosis are most vulnerable to breaks in the wrist, hip and spine which can seriously limit mobility and independence. Our maximum bone size and strength is termed peak bone mass which is an inter play of genetic constitution and lifestyle factors such as diet and exercise that can influence whether full bone mass potential is attained. Childhood, adolescence and early adulthood are the times when we can significantly increase our peak mass through diet and exercise. However, the choices like smoking, poor nutrition, inactivity and excessive alcohol intake can reduce the peak bone mass. Most of the people reach their peak bone mass between 25-30 years of age and by 40 years of age slow loss of bone mass starts. Although the loss of bone mass begins in everyone, people who develop a higher bone mass when young are better protected against osteoporosis and related fractures later in life. During growth, men accumulate a higher peak bone mass compared to women since their bone width and size is greater and women have smaller bones with a thinner cortex and smaller diameter. Though women are more prone to developing osteoporosis, men are equally at a risk after certain age. Puberty is very important time in the development of the skeleton and peak bone mass. Early and late onset of puberty has a direct impact on peak bone mass. Half of body calcium stores in women and two third in men are maintained during puberty. On an average, girls attain puberty at ten years of age and start menstruating at 12 years of age. Regular menarche is very important for bone health since sufficient amount of estrogen helps to improve calcium absorption in intestine and kidney. About 95% of a young woman's peak

bone mass is present by 20 years of age and some overall gain in mass often continue until age 30. The average boy has his fastest growth in height between age 13 and 14 years and stops growing between age 17 and 18 years. Peak bone mass occurs nine to twelve months after the peak rate in height growth. The early and late onset of puberty directly affects peak bone mass. Boys with late puberty generally have less bone mass for life than those who start puberty at typical time around eleven and a half years. Obesity is reported to delay the onset of puberty in boys and could have a negative effect on peak bone mass, while, in girls it accelerates the onset of puberty. However, the effect that obesity and early puberty have, on the peak bone mass is variable in girls. Physical exercise during the teen years is essential to reach maximum bone strength. Whereas, young women who exercise excessively can lose enough weight to cause hormonal changes leading to amenorrhea, suspending menstrual periods and loss of estrogen which cause bone loss when they should be adding to their bone mass [10].

Bone and health issues in various populations: Bone health is becoming an increasingly important health issue. Osteoporosis affects about thirty percent of postmenopausal women with more than half of these suffering bone fractures. It is becoming more of a problem for men. The prevalence has been predicted to increase in the next generation and the effect of osteopenia is already being seen more in younger people [11]. Lower bone density was reported to be a factor in predisposing male [12] and female [13] members of US Marine Corps to the development of fractures. In USA, about 45% of postmenopausal women have a low bone density. Lifetime risk of fracture of hip, spine or forearm is 40% in white women and 13% in White men. African-Americans have few fractures than people of other races. Worldwide, the rates of osteoporosis are variable but in every country age is one of the most important risk factors. As more people have longer lives, the number of those with osteoporosis will also increase [14]. The number of fracture per year, are projected to increase by 25% in Australian population [15]. Age and gender-specific studies in Australian population indicated that among those aged 35-55 years, the fracture rate was about double than the rate in women (65 vs. 35 years). The fracture rate was almost seven times higher in women over sixty year verses women less than fifty five years of age and were 3-4 times higher in women than men. With increased longevity of the population, the substantial health burden imposed by age related fractures will continue to escalate [16]. Peak bone mass has been emphasized as a key determinant of skeletal health throughout life [17]. Both genetic and environmental factors play an important role in the maintenance of peak bone mass [18][19]. A comparative study of young (18-35 years) male and female South Indian population with a population of Nigerian ethnicity, residing in South Indian suburban neighborhood, evidenced a significantly low peak bone mass by 28-30%. Peak bone mass in Indian males and females was 0.507 ± 0.1 and 0.479 ± 0.1 g cm² respectively and it was 0.714 ± 0.2 and 0.682 ± 0.2 g cm² with regard to Nigerian male and female population respectively. Indian males and females who were within the age group of 26-30 and ≤ 20 years, resp., represented high bone mass and the same was the situation with respect to Nigerian counterparts who were within the age group of 21-25 years. Indian and Nigerian non-vegetarian population of both the genders demonstrated a high significance value of $p \leq 0.000001$ deciphered by means of unpaired t-test [20]. Bone density and risk factors for osteoporosis in college going young women of United Arab Emirates were estimated. In all 29 (15.7%) of women out of 185 were classified as having osteopenia

and none had osteoporosis and participants with osteopenia were reported to have late onset of menarche, irregular periods, lower body mass index and a positive family history of osteoporosis. However, late menarche and low body weight could independently predictor osteopenia [21]. The attainment of higher peak bone density has an important role in prevention of osteoporosis later in life [22][23][24]. Genetic factors and race/ethnicity have been related to have a strong influence on peak bone density in other studies as well [25][26]. In a study on female navy recruits, 24% cadets of Asian and 32% of Hispanic origin were reported to develop pelvic stress fracture due to shorter-than-average height or due to difference in anthropometric factors such as pelvic bone geometry or body mass index [13]. BMD in younger age group was assessed to display an ethnic difference in college-aged young adults ranging 18-34 years with a higher BMD value in Blacks than Whites and Hispanics and it was referred that osteoporosis is a pediatric disorder that manifests itself in old age [27].

Human beings of all races and ethnicity are prone to osteoporosis and fractures. It has been shown that blacks have greater and Asians have lower bone mass than whites. Although reliable epidemiological data on enhanced bone fragility and susceptibility to fractures are lacking in India but based on available data and clinical experience an estimated 25 million Indians may be affected. After the age of 60 years, there was almost 100% incidence of either osteopenia or osteoporosis. Osteoporosis fractures in India occur commonly in both sexes and may occur at younger ages than in the West. Widespread deficiency of vitamin D across India at all ages and in both sexes particularly in urban areas, poor sunlight exposure and skin pigmentation are some obvious causes. Indians have low bone mass density as compared to the Western Caucasians. This could be attributed to difference in skeletal size however the high prevalence of vitamin deficiency is a major factor in low bone mass density and poor bone health of Indians. Healthy lifestyle i.e. diet, exercise and sunlight exposure can have a major positive effect on bone metabolism and bone health in Indians [1]. In a study on Indian women in age group between 40 and 65 years, the incidence of osteopenia and osteoporosis was 34% and 8%, respectively [28]. Osteoporosis was considered a disease of post-menopausal women, but in India its incidence was found to be in the ratio of 4:6 in men and women as per a report and young people with changing life style like dieting, smoking etc. have made themselves even more vulnerable to it at younger age [29]. A case study of urban Indians showed history of fracture in relatives, weight less than 60 kg and height less than 155 cm as significant risk factors for osteoporosis [30]. Calcium intake, increased body mass index (BMI) and high activity level was revealed to have a significant protective effect on hip fracture in urban North Indian population. On the other hand excessive caffeine intake and decreased agility increases the risk of hip fracture [31]. A significant association between BMD and socio-economic status, nutritional status, type of diet and menopausal status of adult population was reported to be present in population of rural block of Assam [32]. A high prevalence of clinical and biochemical hypovitaminosis D exists in apparently healthy school children from North India. Also children from upper socioeconomic status from Delhi had significantly higher BMD compared to those from low socioeconomic level. Age, nutrition, height, and weight were significantly related with BMD values [33]. A systematic review and meta-analysis suggested that a diet induced weight loss, if practiced for a period of 6, 12 or 24 months in overweight or obese but healthy adults, proved to be harmful to the bone health [34]. It was reported that by 50% of osteoporotic and

98.2% of osteopenic women consumed vegetarian diet [28]. Another study stated that vegetarians tend to have low bone mineral density due to decreased amount of calcium in their diet [35]. Various physiological, environmental and modifiable life style factors like adequate nutrition, body weight, exposure to direct sunlight, exposure to sex hormones at puberty and level of physical activity are not only important for acquisition of maximal bone mass but also for its maintenance throughout life [36][37][26][38][39][40][41].

Bone health and its social ramification: Osteoporosis, a consequence of loss of bone mass results in serious health and economic problems. 20 % of hip fracture patients die within one year and 50% of survivors require some form of assisted living [42]. A report published by International Osteoporosis Foundation (IOF) in collaboration with European Federation of Pharmaceutical Industry Association (EFPIA) illustrated that approximately 22 million women and 5.5 million men in 27 member state of the European Union have osteoporosis and the total burden is expected to increase to 33.9 million, an increase of 23%, by 2025. Health economic costs are enormous and growing. Total annual cost resulting from new and prior fragility fracture is 37 billion euro which is expected to increase by 25% from 2010 to 2025, indicating an immense health burden. By 2025, the population aged 50 years and over will increase by 20% with larger increase in number of elderly. It was emphasized that prevention of fracture is clearly the only way forward [43][44]. Approximately, 60 million people at present have osteoporosis in India. As the life expectancy is increasing even in developing countries, by the year 2035, maximum number of osteoporosis cases in the world will be in India and China [45]. According to Union Health Ministry of India by 2016, an average male female will live till 68.8 and 71.1 years of age respectively. This will increase by another one year for average male by 2021 (69.8 years) and by 1.2 years for an average female (72.1 years) [46]. The projection of longevity sets an alarm for the increasing medical burden on the receding economy. Moreover, the Indian population is already deficient in basic nutritional requirements and the younger generation is prone to fall for the wrong indulgence into fast food and sedentary lifestyle which can further deteriorate the health status of growing children. Inactivity along with wrong eating habits and genetic disposition can lead to the poor state of bone density, a cause of osteoporosis. Let longevity be not a problem for the forthcoming generations and a proper awareness among younger population regarding the healthy lifestyle be generated.

Conclusion:

Projection of data from various populations is indicative of a rising trend of osteoporotic changes. Physical inactivity, passive and sedentary behavior in addition to incorrect eating behavior is proving to be the major contributing factor for this diseased state. There is a need to adapt and implement a fracture prevention strategy by increasing peak bone mass in the growth period rather than facing the debilitating anomalies in later years of life, as healthy population is one of the major contributors in growth propulsion of a country.

References:

- Malhotra N, and Mithal A. Osteoporosis in India. *Indian Med Res* 2008;127:263-8.
- Dawson HB. Effect of calcium and vitamin D supplement on bone density in men and women 65 years of age or older. *N Eng J Med* 1997;337:670-76
- Loud KJ, Gordon CM, Micheli LJ Field AE. Correlates of stress fractures among preadolescent and adolescent girls. *Pediatr* 2005;115:399-400.
- Rizzoli R, Bonjour J-P, Ferrari SL. Osteoporosis, genetics, and hormones. *J Mol Endocrinol* 2001;26:79-94.
- NIH(National Institute of Health). Osteoporosis Prevention, Diagnosis and Therapy. NIH Consensus Statement 2000;17(1):1-36. <https://consensus.nih.gov>2000>
- Cromer B, Harel Z. Adolescent: at an increased risk of osteoporosis? *Clin Pediatr* 2000;39:565-74.
- Fitzpatrick L. Secondary causes of osteoporosis. *Mayo Clin Proc* 2002;77:453-68. www.ncbi.nlm.nih.gov>pubmed
- Conlisk AJ, Galuska DA. Is caffeine associated with bone mineral density in young adult women? *Prev Med* 2001;31: 562-568.
- Shepherd AJ. An overview of osteoporosis. *Integr Med* 2004;3: 33-41.
- AAOS(American Academy of Orthopaedic Surgeons). Healthy bones at every age. Orthoinfo.aaos.org/topic.Topic.a00127.2012.
- Khosla S, Melton LJ 3rd, Dekutoshi MB, Achenbach SJ, Oberg AL and Riggs BL. Incidence of childhood distal forearm fractures over 30 years. A population based study. *J Am Med Assoc* 2003;290: 1479-1485.
- Beck TJ, Ruff CB, Mourtafa FA, Shaffer RA, Maxwell-Williams K, Kao GL, et al. Dual-energy X-Ray absorptiometry derived structural geometry for stress fracture prediction in male US Marine Corps recruits. *J Bone Miner Res* 1996;11: 645-653.
- Kelly EW, Jonson LCDR, Scott R, Cohen ME, Shaffer CDR, Richard. Stress fracture of the pelvis in female navy recruits: an analysis of possible mechanism of injury. *Milit Med* 2000;165:142-146.
- Melton LJ 3rd, Crowson CS, O'Fallon WM. Fracture incidence in Olonsted County, Minnesota: comparison of urban with rural rates and changes in urban rats over time. *Osteoporos Int* 1999; 9: 29-37.
- Sanders KM, Pasco JA, Seeman E, Ugoni AM, Pasco JA, Martin TJ et al. Age - and gender-specific rates of fractures in Australia. A population based study. *Osteoporos Int* 1999a;10: 240-247.
- Sanders KM, Pasco JA, Seeman E, Kotowick MA. Health burden of hip and other fractures in Australia beyond 2000. Projections based on the Geelong osteoporosis study. *Med J Aust* 1999b;170:467-470.
- Lips P. Vitamin D deficiency and secondary hyperparathyroidism in the elderly: consequences for bone loss and fractures and therapeutic implications. *Endocrinol Rev* 2001;22:477-561.
- Heaney RP, Abrans S, Dawson-Hughes B, Looker A, Marcus R, Matkovic V et al. Peak bone mass. *Osteoporos Int* 2000;11:985-1009.
- Saggese G, Baroncelli GI, Bertelloni S. Osteoporosis in children and adolescents: diagnosis, risk factors and prevention. *J Pediatr Endocrinol Metab* 2000;14:833-859.
- Sapthagirivasan V, Anburajan M. Heel bone mass of a young South Indian population with a Nigerian population residing in a South Indian suburban neighbourhood: a comparative study. *Osteoporos Int DOI* 10.1007/s00198-012-1898-9. A Report of International Osteoporosis Foundation and National Osteoporosis Foundation (2012). Published online 14/2/2012.
- Saadi HF, Reed RL, Carter AO, Qazaq HS, AL-Suhaili AR. Bone density estimates and risk factors for osteoporosis in young women. *J Clin Endocrinol Metab* 2001;86:179-185.
- Nordin BE, Polley KJ. Metabolic consequences of the menopause. A cross-sectional, longitudinal and intervention study on 557 normal postmenopausal women. *Calc Tissue Int* 1987;41(Suppl.1):1S-59S.
- Seeman E, Hopper JL, Bach LA, Cooper ME, Parkinson E, McKay J et al. Reduced bone mass in daughters of women with osteoporosis. *N Eng J Med* 1989;320:554-558.
- Hui SI, Slemenda CW, Johnston CC Jr. The contribution of bone loss to postmenopausal osteoporosis. *Osteoporos Int* 1999;1:30-34.
- Slemenda CW, Christian JC, William CJ Norton JA, Johnston CC Jr. Genetic determinants of bone mass in adult women: a reevaluation of the twin model and the potential importance of gene interaction on heritability estimates. *J Bone Mine Res* 1991;6:561-567.
- Rizzoli R, Bonjour J-P, Ferrari SL. Osteoporosis, genetics, and hormones. *J Mol Endocrinol* 2001;26: 79-94.
- Wilkin LD, Jackson MC, Sims TD, Haddock BR. Racial/Ethnic differences in Bone Mineral Density of young adults. *Int J Exerc Sci* 2010;3(4):197-205.
- Gandhi AB, Shukla AKR. Evaluation of bone mass density of women above 40 years of age. *J Obstet Gynecol India* 2005;55:265-267.
- Young Indian susceptibility to osteoporosis. Report 23/02/2004 ABC News Online.
- Keramat A, Mithal A. Risk factors for osteoporosis in urban Asian Indian

- women presenting for a preventive health check up. 2nd Joint Meeting of the European Calcified Tissue Society and the International Bone and Mineral Society, Geneva, 2005; June 25-29.
- 31 Jha RM, Mithal A, Malhotra N, Brown EM. Pilot case control investigation of risk factors for hip fractures in urban Indian population. *J Bone Miner Metab* 2005;23 (Suppl.):81-83.
- 32 Dutta N, Saikia AM, Saikia AM, Das AK (2015): Status of bone mineral density in adult population using calcaneal ultrasound bone densitometer: A study from Assam, India. *Ind J of Basic App Med Res* 2015; 4(3):150-158.
- 33 Marwaha RK, Sripathy G. Vitamin D & bone mineral density of healthy school children in north India. *Ind. J Med Res* 2008;127: 239-244.
- 34 Zibellini J, Sainsbury RV, Lee C MY, Gibson AA, Hsu M SH, Shapses SA et al. (2015): Does Diet-Induced Weight Loss Lead To Bone Loss in Overweight or Obese Adults? A Systematic Review and Meta analysis of Clinical Trials. *Am Soc Bone Mine Res* DOI: 10.1002/jbmr.2564
- 35 Barr SJ, Prior JC, Janelle KC et al. (1998). Spinal bone mineral density in premenopausal vegetarian and non-vegetarian women: cross-sectional and prospective comparison. *J Am Diet Assoc* 1998; 760-765.
- 36 Francis RM, Harrington F, Turner E, Papiha SS, Datta HK. Vitamin D receptor gene polymorphism in men and its effect on bone density and calcium absorption. *Clin Endocrinol* 1997;46:83-86.
- 37 Uusi-Rasi K, Sievanen H, Pasanen M, Oja P, Vuori I. Association of calcium intake and physical activity with bone density and size in premenopausal and postmenopausal women: a peripheral quantitative complex tomography study. *Bone Mine Res* 1999;12: 255-260.
- 38 Carina E, Bengt F. Bone mineral density in relation to body mass index among young women. A prospective cohort study. *Int J Nutr Studies* 2006 ; 43: 663-672.
- 39 Marwaha RK, Puri S, Tandon N, Dhir S, Agarwal N, Bhandra K et al. Effect of sports training and nutrition on bone mineral density in young Indian healthy females. *Ind J Med Res* 2011;134: 307-313.
- 40 Naseem N. Bone mineral density measured by ultrasound among resident doctors of Multan and their correlation with common risk factors. *JSOGP* 2013; 3: 170-174.
- 41 Javed Z, Imam SF, Imam N, Saba K et al. Bone mineral density and diet of teachers of college of home economics at Lahore. *Pak J Med Sci* 2015;31: 970-974. www.pjms.com.pk.
- 42 Miller P and Epstein S. Bone mass measurements: the case for selected screening? *Tr. Endocr. Metab* 1997; 8:160
- 43 Hernlund E, Sevdobom A, Ivergard M, Compston J et al. A report prepared with the International Osteoporosis Foundation (IOF) and European Federation of Pharmaceutical Industry Association (EFPIA). *Arch Osteoporos* 2013;8: 136.
- 44 Svedbom A, Hernlund E, Ivergard M et al. Osteoporosis in the European Union: a compendium of country-specific report. *Arch Osteoporos* 2013;8: 137.
- 45 Krishna U, and Mehta RU. Osteoporosis—incidence and implications. *J Obstet Gynaecol India* 2000; 50: 150-155.
- 46 Average Indian's life span set to rise over next 10 years. Sinha K|TNN|oct3, 2012,03.42 AM IST. m.timesofindia.com/india