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# Nutritional Management of Osteoporosis: It's More Than Calcium

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## ABSTRACT

**Introduction:** Osteoporosis is a bone disorder that comes under the highly preventable disorder as, among all the risk factors of this bone disorder, most of them are modifiable and dependent on a person's behaviour.

**Objective:** To review facts and findings related to the management of osteoporosis with the help of nutrients and behavioural modifications.

**Approach:** Facilitating proper nutrition is a crucial part of a successful rehabilitation program for patients having osteoporotic fractures and studies have constantly shown that recommended intake of calcium, vitamin D and other nutrients like protein, vitamin C, vitamin K, sodium and phosphorus leads to reduce the loss of bone mass and fracture risks. Among all the macro and micronutrients, calcium has been a major focus of nutritional prevention of osteoporosis as Calcium has a profitable effect on BMD at every site for all ages.

**Conclusion:** There is a scarcity of available knowledge and awareness regarding the role of different nutrients in the prevention and management of osteoporosis is generally calcium and vitamin D has been a major concern. Simultaneously collected evidence suggested that other factors like lifestyle, genetic factors and age-related factors may be a matter of concern in the management of osteoporosis.

**Key Words:** Osteoporosis, Bone Mineral Density, Micronutrient, Calcium, Vitamin D, Nutritional management

## INTRODUCTION

Osteoporosis is the most prevalent skeletal disorder affecting both sexes, but most importantly impacts women who experience a faster bone mineral density loss in the early years after menopause.<sup>1</sup> Osteoporosis is a bone disease with reduced density of bone, decreased bone strength, and absence of bone tissue relative to the biological bone quantity. People may not usually be conscious of their illness as osteoporosis is a "silent disorder" until they experience fragility fracture owing to weakening bones following a sudden strain on bones, bumps or falls.<sup>2</sup> Osteoporosis is an extremely preventable disease as most of them are modifiable and dependent on a person's conduct among all the risk variables of this bone disorder. Facilitating proper nutrition for patients with osteoporotic fractures is a crucial factor for the success of the rehabilitation program and studies have consistently shown that adequate intake of calcium, vitamin D and other

nutrients like protein, ascorbic acid, vitamin K, sodium and phosphorus leads to a reduction in the loss of density of the bones and risk of osteoporotic fractures.<sup>3</sup>

Among all the macro and micronutrients, calcium has been a major focus of nutritional prevention of osteoporosis as Calcium has a profitable effect on BMD at every site for all ages.<sup>4</sup> Several factors are responsible for the management of osteoporosis like recommended intake of calcium, regular physical activity, daily exposure with sunlight and consumption of other essential dietary elements (e.g.-vitamin D, vitamin K, sodium, protein) and phytonutrients (e.g.-soy compounds) for their protective properties should be counted for the nutritional management of osteoporosis. So the other components of the diet like minerals and vitamins should be considered for healthy bone in association with calcium and vitamin D.<sup>5</sup> For optimizing healthy bone mass at all sites, there is some potentially important micronutrient like magnesium, potassium,

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vitamin C, vitamin K which should be consumed in the daily diet and these can be easily available by the consumption of a diet enriched with fruits and vegetables (5 servings per day).<sup>6</sup>

### Nutritional Management of Osteoporosis

Osteoporosis is a bone disorder that can be anticipated and managed with the help of accurate and early diagnosis. Unfortunately, it is mostly undiagnosed until a fracture occurs. So a large number of the population should be encouraged to be screened for this disease should be increased. Determination of BMD is a major tool for the diagnosis of Osteoporosis.<sup>7</sup> Modifications in the lifestyle pattern can decrease the risk of osteoporosis and osteoporotic fractures. It involves a balanced diet, active lifestyle, regular exercise, and prevention from fall, sudden strain or bumps.<sup>8</sup> A balanced diet and adequate nutrition play a major part in osteoporosis prevention and therapy. Among all the macro and micronutrients, Nutritional importance of calcium and vitamin D has been a major focus among all the macro and micronutrient for nutritional prevention of osteoporosis.<sup>9</sup> In the last decades, 25% increased utilization of highly processed food and the confectionary product was recorded in the consumer's diet while contradictory data shows that intake of dairy-based food product has reduced by 20%. Dietary supplements, including calcium, are increasingly popular, resulting in infinite consumption of vitamins and minerals, often without medical consultation. This imbalanced intake of nutrients results in body tissue acidification and intensifies Parathyroid activity that encourages a reduction in calcium from bones which may lead to bone-related disorders like osteoporosis.<sup>10</sup>

A calcium-rich diet may not be effective due to the presence of dietary inhibitory factors like fibre and other Anti-Nutritional factors like phytates, oxalate etc which reduces the biological value of calcium and increases the excretion from the body.<sup>11</sup> On the other side, researches show that the vast majority of people had no understanding of the role of vitamin D in keeping good calcium equilibrium in the body as an adequate supply of vitamin D in association with a calcium-rich diet is essential for protection from osteoporosis.<sup>12</sup> Adequate and balanced nutrition for patients with an osteoporotic fracture is a significant element of an impactful rehabilitation program as inadequate nourishment of the patient can result in slow recovery and increase the susceptibility of further fractures.<sup>13</sup>

### Calcium and Bone Mineral Density

Osteoporosis is a disease that can be avoided during skeletal development by attaining maximum bone mass, maintaining bone mass during adulthood, and decreasing bone density loss with advancing age. Adolescents and young adults should therefore be motivated to embrace healthy lifestyle habits for ideal skeletal health by raising the amount of weight-bearing activity, optimal nutritional calcium and vita-

min D consumption, adequate nutrition and ideal body mass index, cessation of smoking, and mild alcohol, caffeine, and sodium consumption.<sup>14</sup> Research shows that the important impact of physical exercise on bone mass during the development period of kids can enhance with appropriate calcium intake in daily diet.<sup>15</sup>

To evaluate the relationship between calcium consumption and bone mineral density, substantial epidemiological information was collected. In a review of 52 calcium intervention research, 50 showed that adequate calcium intakes resulted in decreased bone remodelling, improved calcium retention, decreased bone loss associated with age, and decreased risk of fracture. The study also revealed that out of 86 observer research, 64 reported interactions with decreased danger of fracture, bone loss or enhanced bone mass in favour of enhanced calcium intakes.<sup>16</sup> Calcium supplementation's beneficial impacts were mainly attributed to a decrease in bone remodelling. Calcium supplements, however, may be connected with mild gastrointestinal disorders such as constipation, flatulence, nausea, stomach pain, and diarrhoea. Calcium can also interfere with iron and zinc intestinal absorption.<sup>17</sup> While conflicting data of a systematic review concluded that there was no evidence of an association between lower risk of fracture and high intake of calcium.<sup>18</sup> Calcium and vitamin D supplements are also available which is an inexpensive treatment for people living with osteoporosis and associated complications. Different studies have consistently shown that medication therapy decreases the risk of vertebral fractures by 30% to 70%, non-vertebral fractures by 15% to 20% and hip fractures by up to 40%.<sup>19</sup> Calcium can lower the greater PTH concentrations in big enough doses and decrease the rate of bone remodelling.<sup>20</sup> Calcium supplementation appears to enhance the effectiveness of anti-reabsorption treatment for bone mass, such as hormone replacement therapy (HRT) (Table 1).<sup>21</sup>

**Table 1: Requirement of Calcium in different Age Group for Healthy Bones**

Age Group		Required Amount (mg)
Infancy	0-6 Month	1000
	7-12 Month	1500
1-8 Years		2500
9-18 Years		3000
Adult Years		2500
Older Age		2000

Source: Mahan and Raymond, 2017<sup>83</sup>

### Vitamin D and Bone Mineral Density

Sun exposure is very limited in India due to darker skin pigmentation; recent modernization of India has resulted in working indoors and reduced physical activity. The In-

dian women are less exposed to the sunlight due to their dressing pattern which covers most of their body parts and working indoors most of the time.<sup>22</sup> So this metabolic bone disorder which progresses silently is widely prevalent in India and related fractures are the primary reason for morbidity and mortality among peri and postmenopausal women. Approximately 1.6 million hip fractures happen globally each year, ranging from 4.5 million<sup>23</sup> million to 6.3 million<sup>24</sup> by 2050.

Sensitive exposure to the sun (generally 5-10 min of arms and feet or hands, arms and face exposure, 2-3 times a week) and increased intakes of nutritional and supplementary vitamin D are sensible methods to ensure sufficient vitamin D.<sup>25</sup> Vitamin D is a calcium absorption and bone mineralization secosteroid hormone that is favourably associated with bone mineral density.<sup>26</sup> Human Vitamin D is produced by the body when the skin is subjected to ultraviolet rays of sunlight and 15 minutes of daily sun exposure meets the regular requirement of vitamin D. Fatty fish like salmon, fish oil, egg yolks, fortified milk and some other food products are also a good source of vitamin D.<sup>27</sup>

There have been various vitamin D supplementation epidemiological studies, typically combined with calcium (500 to 1200 mg / d). A study conducted among peri and premenopausal women shows that none of the diets analyzed provided the recommended daily quantities of vitamin D and only 29% of participants consuming vitamin D supplements. The result of the study shows that respondents have inadequate awareness about osteoporosis and its preventive measures.<sup>28</sup> A big body of clinical information shows that a sufficient status of vitamin D as depicted by the concentration of serum 25-hydroxyvitamin D protects against osteoporosis by enhancing bone mineral density and decreasing the potential risk of fracture.<sup>29-30</sup> This research highlights the prospective need for intervention research on the impacts of supplementing vitamin D on peak bone mass achievement.

### Bone Mineral Density and Role of Micronutrient

**Table 2: Role of Micronutrient in Maintenance of Bone Mineral Density**

Micronutrient	Effect on BMD	Mechanism
Calcium	Increase	Insufficient calcium intake from the diet results in reduced serum calcium level, causing series of consequences. Majorly remodeling of bones and releases of their content into the blood occurs due to increased level of parathyroid Hormone which reduces the Bone Mineral Density

**Table 2: (Continued)**

Micronutrient	Effect on BMD	Mechanism
Vitamin D	Increase	Secondary Hyperparathyroidism, increased bone turnover, bone loss and reduced mineral is positively associated with Vitamin D Deficiency.
Phosphorus (Inadequate Intake)	Decrease	A negative balance of phosphorus or insufficient calcium and phosphorus ratio results in reduced osteoblast activity, and thus bone turnover
Vitamin K	Protective Effect	Vitamin K decreased the excretion of urinary calcium and improves protein carboxylation such as osteocalcin which shows a protective effect on Bone Mineral Density
Magnesium	Increase	Deficiency of magnesium results in endothelial dysfunction and associated damage to bone health. Additionally reduced intake of magnesium results in the release of inflammatory cytokines which results in bone remodelling and osteopenia.
Zinc	Increase	Zinc plays a very important structural role in the bone matrix as well as stimulates the formation of osteoblast cells.
Sodium	Decrease	Sodium is the major reason behind increased urinary loss of calcium. Observational studies show that either increased or reduced intake of sodium will result in a shift in calcium equilibrium from positive to negative.
Fluoride	Decrease	A low level of fluoride intake does not affect bone mineral density as fluoride is a key trace element required for the maturation of the skeleton and dentistry while endemic elevated fluoride regions show the high prevalence of hip and bone fractures.
Vitamin C	Increase	Vitamin C works as a cofactor in the formation of Collagen and this will help in the attainment of peak bone mass. Epidemiological studies also support the fact that sufficient intake of vitamin C is positively associated with the reduced rate of fractures.
Vitamin A	Decrease	The recommended intake of vitamin A does not show any marked effect on bone mineral density while higher consumption shows a detrimental effect on bone mineral density

## Phosphorus

The impacts on bone parameters of elevated P consumption were contentious. Many studies report elevated Phosphorus consumption in respondents whose dietary Ca: P ratio is exceptionally small are detrimental to bone health. However, there is powerful proof that elevated intakes of phosphorus in ordinary subjects with adequate intakes of calcium and phosphorus have no adverse effect on the calcium equilibrium.<sup>31</sup> On the other hand, recommended intake of phosphorus is essential during growth and development period for obtaining peak bone mass while low serum level of phosphorus will reduce the bone formation and mineralization.<sup>32</sup> The studies suggest a diet balanced with enrichment of calcium, moderated amount of protein and recommended amount of phosphorus for the attainment of peak bone mass and improved bone mineral density.<sup>33</sup> Studies also revealed that reduced phosphorus consumption or negative phosphorus balance because of phosphorus present in food-bound with the supplemental calcium may result in phosphorus deficiency in the body, which could reduce the functions of osteoblast cells and increase the process of bone re-absorption.<sup>34</sup> The phosphorus-calcium proportion at any point of age is likely more crucial than phosphorus consumption alone (Table 2).

## Sodium

Sodium is the reason behind the increased excretion of renal calcium. The mean urinary calcium loss is 1 mmol per 100 mmol sodium.<sup>35</sup> According to the studies the bone mass will be reduced if the amount of absorbed calcium is lower than the amount required neutralizing these mandatory calcium losses that are associated with sodium intake.<sup>36</sup> In observational study among women, On the other side, salt was liable for a substantial shift in the bone calcium equilibrium, from positive to negative, when eaten as part of the diet with increased calcium intake but with low calcium consumption, the calcium equilibrium of the bone was negative in both elevated and reduced salt diets.<sup>37</sup> Another study has revealed that reduced salt intake would improve the bone mass of Postmenopausal women with more or equal to 3.4g / day intake of sodium (8.5 g salt).<sup>38</sup> Recently, a study<sup>39</sup> observed a major association of sodium with blood pressure and osteoporosis. In the study, the author observed that there was a negative association between increased sodium excretion and bone mineral density of the hip and spine, i.e. the higher the salt intake, the lower the BMD.

## Potassium

The main role of potassium is mainly associated with calcium homeostasis, especially urinary conservation and calcium excretion.<sup>40</sup> There have been some studies related to potassium consumption and bone density of the Net Endogenous Acid Production (NEAP).<sup>41</sup> Additionally, higher

consumption of potassium citrate with high sodium diet was responsible for the increased rate of bone re-modelling.<sup>37</sup> Increased bone mineral density and decreased bone loss were correlated with enhanced potassium consumption through a diet rich in fruits and vegetables.<sup>43</sup> The need to assure a sufficient consumption of potassium from fruits and vegetables is a powerful rationale for the recommendation ' 5 to 10 servings per day'.<sup>44</sup>

## Magnesium

An epidemiological study found a negative association between lower hip and whole-body BMD and lower magnesium intake in post-menopausal women, but these findings of the study do not associate with increased susceptibility to fractures. A slightly higher magnesium consumption than the RDA is correlated with an enhanced risk of fractures of the lower arm and wrist that may be associated with more physical activity and falls.<sup>45</sup> The latest research demonstrates that hypomagnesemia can lead to inflammatory illnesses that have a current bone loss connection. The oral intake of Magnesium supplement may help lower the detrimental effect of Osteoporosis.<sup>45</sup> Only limited controlled magnesium supplementation clinical trials<sup>46</sup> have been conducted that were mainly efficient in magnesium depleted individuals. There is insufficient information available on the need and significance of magnesium in the general population for the prevention of osteoporosis (Table 2). The mechanisms responsible for the mineralization problems observed when magnesium is elevated are less explored. Overall, magnesium homeostasis control and maintenance is a useful intervention to preserve bone integrity.<sup>47</sup>

## Fluoride

Fluoride is a key trace element required for the maturation of the skeleton and dentistry.<sup>48</sup> Epidemiological studies indicate no effect on bone mineral density or fractures connected with mild fluoride levels typically found in drinking water<sup>49</sup>; nevertheless, some endemic elevated fluoride regions showed a greater rate of hip fractures. Fluorosis, a serious disease associated with extra-osseous calcification and brittle bones, starts with the ingestion of surplus fluoride. While some epidemiological studies reported contradictory fluoride therapy impact on bone mineral density and fracture risk as fluoride therapy improves spine and hip BMD, a small fluoride dose (< or = 20 mg/day of fluoride equivalents) was correlated with a significant reduction in fracture danger.<sup>50</sup>

## Vitamin K

Vitamin K operates as a cofactor in bone metabolism-related enzymes (Booth, 1997). It decreased the excretion of urinary calcium and improves protein carboxylation such as osteocalcin (engaged in the formation of bones)<sup>51</sup>. Observational studies indicate a positive association between bone density



and vitamin K intake.<sup>52</sup> Studies have also shown that vitamin K supplementation leads to improvements in bone health.<sup>53</sup> Studies of epidemiology also found that long-term treatment adversely impacts the risk of vertebral BMD and fracture.<sup>54</sup> In addition, a big proportion of undercarboxylated serum osteocalcin as seen with low serum vitamin K may be a predictor of the danger of fracture<sup>55, 56, 57</sup>, although many of these research are confused with poor nutrition in general.

### Vitamin C

Vitamin C plays an important role as a cofactor for collagen production and construction of hydroxyproline and hydroxylysine. Epidemiologic studies reveal a significant association between bone mass and vitamin C; Bone Mineral Density loss is inversely associated with intakes of vitamin C, and another study noticed that the rate of fractures is low with the higher consumption of vitamin C especially in Pre and Post-Menopausal women using concurrent estrogen therapy and calcium supplements.<sup>58-61</sup>

### Vitamin A

Vitamin A is a fat-soluble vitamin required for reabsorption of the bone and is also an essential nutrient for vision, development and infection control. The distinct kinds of vitamin A found in diet and nutritional supplements are retinol and  $\beta$ -carotene (and other carotenoids). According to some research, increased intake of vitamin A is deleterious to bone health and with the intake of more than 1500  $\mu$ g RE associated with a 2-fold increased possibility of hip fracture in the U.S. and Sweden but not in Iceland or various U.S. trials.<sup>62, 63</sup> On the other side, studies indicate that osteoporosis and related fractures are not substantially associated with daily consumption of vitamin A as long as the concentration of serum 25(OH)D is retained at a mild rate of 50–75 nmol / L. Fruit and vegetable vitamin A (carotenoids) is closely related to the mineral density of the bone<sup>64</sup>.

### Other Nutrients

The association between bone health and trace metals is still unidentified. Three studies among post-menopausal women have shown that intake of calcium with the combination of minerals like zinc, manganese, copper was capable to conquer bone loss from the spine.<sup>65</sup> According to studies, there is no recommended intake of Boron for healthy bone but in some studies, it was suggested that 3 mg daily intake of boron have a positive effect on bone health.<sup>66</sup> Copper's severe deficiency has intense impacts on the bone as it is a significant component that many enzymes, including lysyl oxidase, need for collagen cross-linking. There is little confirmation that zinc affects bone mineral density, osteoporosis, and related fractures, but serious zinc deficiency can lead to poor growth and maturation of the bone.

A cohort study among men and premenopausal women revealed that there is a positive relationship between dietary silicon consumption and bone mineral density at the hip.<sup>67</sup> Recent studies among males and females have found that insufficient vitamin B12 consumption was associated with decreased bone mass in males and females, and osteoporosis in older females but not males.<sup>68</sup> Whether organizations like this are an indication of poor nutrition and frailty generally is unidentified. Similarly, bone mineral density is considerably correlated with dietary iron consumption at all locations in another research (Table 2).<sup>69</sup>

### Management of Osteoporosis- Other than Nutrients

**Age and Menopausal Status** In females, age-related bone loss is higher than in males. By the era of 80, the quantity of cortical and trabecular bone lost is about 40% of the premenopausal BMD peak.<sup>70</sup> According to the epidemiological study, there was an adverse correlation between women's age and bone mineral density.<sup>71</sup> Another comparable report among Indian females over the era of 50, in which an age-dependent decrease in BMD was observed, was tested by digital X-ray radiogrammetry.<sup>72</sup> Another research also showed an important correlation between increased age and low bone mineral density.<sup>73</sup> Similarly, women's menopausal status also correlated with bone health as Indian women showed an important statistical association between osteopenia incidence and osteoporosis and menopause achievement.<sup>74</sup> While research also disclosed that the incidence of osteopenia among females over 35 years of age was high, which in subsequent years of life may lead to osteoporosis.<sup>75</sup>

So based on the available literature it is concluded that advanced age and attainment of menopause is significantly associated with the prevalence of osteoporosis and this increases the requirement of awareness programs regarding preventive measures of osteoporosis to reduce the prevalence of low bone mineral density among the younger women which facilitates the development of osteoporosis in aged women especially after menopause.<sup>76</sup>

### Physical Activity

Bone and muscle movement is needed to accelerate the body's calcium absorption. Community studies have revealed that physical activity and fitness reduce the risk of osteoporosis and fractures and associated injuries.<sup>77</sup> Studies have shown that bone mineral density can be preserved or improved with therapeutic exercise in post-menopausal women.<sup>78</sup> Higher leisure time, sports, household chores and fewer hours of daily sitting were considerably correlated with lower risk of osteoporosis and linked fractures.<sup>76</sup>

### Genetic Factors

Studies have shown that osteoporosis has a large genetic component.<sup>77</sup> Genetic variables affecting the acquisition of

maximum bone mass account for a significant percentage of the variation in bone mineral density (BMD), although the extent to which genes also add to bone loss variability is debatable. Parental history of fracture (especially hip fracture) confers and increases the danger of fractures autonomous of bone mineral density. In addition, the family history impact is not a particular but site-specific predisposition to fractures. But the information on the impact of family history on low bone mineral density incidence is still not a well-documented osteoporosis risk factor.

## CONCLUSION

So the other components of the diet like minerals and vitamins should be considered for healthy bone in association with calcium and vitamin D while consideration of other factors like Age, Menopausal Status, Behavioral and Genetic factors is also very important in the effective management of Osteoporosis. For optimizing healthy bone mass at all sites, there is some potentially important micronutrient like magnesium, potassium, vitamin C, vitamin K which should be consumed in the daily diet and these can be easily available by the consumption of a diet rich in fruits and vegetables (5 servings per day). Awareness of the significance of sufficient calcium and vitamin D consumption (easily observed by serum 25(OH) D) for optimal bone health, as well as the prevention from falls and fractures, should be the major concern for the management of osteoporosis. Healthcare professionals and policymakers should also pay attention to create awareness regarding responsible factors for osteoporosis other than nutrients like physical activity, genetic factors and age-related factors like menopausal status.

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### Author's Contribution

- **Pallavi Singh-** All the information related to the Nutritional Management of Osteoporosis was collected and reviewed by the author.

- **Virginia Paul-** Valuable guidance provided by the author. She was also involved in the review and editing process.
- **Aditya Kumar Singh Pundir-** He was actively involved in the review and editing process.

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