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Vegan and vegetarian diet influence on bone health - a short review

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Summary

Introduction and purpose: Vegan and vegetarian diets rise in popularity. Their success can be attributed to growing ecological awareness and trends in culture. Opponents criticise these diets as incompletely nutritional. In this review, we would like to summarise the state of knowledge over effects of vegan and vegetarian diets on skeletal system. Bone Mineral Density is a widely used indicator of likelihood of fracture and development of osteoporosis. Comparing that parameter between vegans and vegetarians and non-vegans can lead to conclusions about bones' health.

A brief description of the state of knowledge: Lower intake of calcium and vitamins (D3, B12) in vegans and vegetarians can lead to lower bone mineral density and higher risk of fracture. Although, with supplementation of those nutrients negative effects are greatly reduced. Higher bone mineral density in non-vegetarian subjects can be result of higher body

mass, gender and other factors. Plant-based diets are less acid-forming than their counterpart, resulting in lower bone resorption and reduced loss of calcium.

Conclusions: Vegan and vegetarian diet can result in lower bone mineral density. However, if applied correctly, with supplementation of lacking nutrients, or enriching the diet with dairy products it may not lead to any negative effects on bones. Substances contained in plants, more frequently eaten by vegans and vegetarians may have positive effects on bone mineral density.

Key words: Veganism; Vegetarianism; Bone Mineral Density; Fractures

Introduction

With growth of ecological knowledge of society, plant-based diets are becoming more and more popular [1,2]. A vegetarian diet is associated with many health benefits because of its higher content of fiber, folic acid, vitamins C and E, potassium, magnesium, phytochemicals and unsaturated fatty acid [3]. Vegans tend to be thinner, have lower serum cholesterol, and lower blood pressure which reduces their risk of heart disease [3]. Accordingly, the number of consumers following a vegetarian or vegan diet has notably increased in many developed countries [2]. Whereas epidemiological studies suggest many profits of plant-based diets, recent reviews indicate that vegans and vegetarians are more susceptible to bone fractures [2]. The risk of fractures is associated with a decreased bone mineral density (BMD) [2]. BMD is the ratio of mass to the area or volume of bone, which is known as areal (g/cm^2) or volumetric (g/cm^3) BMD, depending upon the measurement methodology used [4]. Bone mineral density is a highly multi-factorial phenotype influenced by genes, hormonal characteristics, physical activity and diet also [4]. Many of the nutrients and food components we consume can potentially have a positive or negative impact on bone health [5]. They may influence bone by various mechanisms, including alteration of bone structure, the rate of bone metabolism, the endocrine or paracrine system and homeostasis of calcium [5]. In order to maintain healthy skeletal system, the diet should be high in calcium, magnesium, potassium, vitamins: D, B12, K, protein, n-3 (ω -3) fatty acids [6]. However, it remained unclear whether these associations were due to dietary habits (i.e., potentially lower intakes of calcium, vitamin D, proteins among vegetarians and vegans), or rather due to participant characteristics, particularly anthropometric parameters because people following plant-based diets have a lower BMI compared to nonvegetarians [7]. What's more, recent studies on the large-scale population-based UK Biobank cohort suggest that, in addition to total body mass and fat mass, lean mass is also lower among vegans and vegetarians than among meat eaters [8]. Conversely, higher total body mass is related to higher BMD among adults because greater mechanical loading and muscle-induced strain enhance bone mineralization [8,9].

Vegan and vegetarian diet- are bones in danger?

Studies using data from the population based study NHANES confirmed earlier observations of lower BMD values among vegetarians than among nonvegetarians [10]. However, it is difficult to determine the significance of the differences due to the lack of adjustment of the anthropometric parameters [10]. Vegetarians tend to be of female gender more often, resulting in less frequent smoking and lower alcohol consumption, and had lower BMI and waist circumference values [10]. BMD after adjustment for anthropometric factors suggests that differences in BMD between vegetarians and nonvegetarians may largely depend on BMI and waist circumference [10]. The recently described lower fracture rates among nonvegetarians may be an example of the "obesity paradox" - better health outcome among people with higher BMI [11]. Another factor that may explain the lower BMD among vegetarians is lower vitamin D levels, which is due to less animal food consumption, not less sun exposure [12]. Vitamin D predominantly is obtained from the diet as cholecalciferol (vitamin D₃) from animal sources [6]. Most vegetarian diets contain very little vitamin D, mainly in form of ergocalciferol (vitamin D₂) [6]. Vitamin D₃ is also synthesized cutaneously from 7-dehydrocholesterol with sunlight (UVB) exposure [6]. However, synthesis is low in the winter season in upper latitudes, which may result in its deficiency increasing the risk of osteoporosis [6]. Study in postmenopausal women group found that vitamin D intakes >600 IU (15 µg) compared with <200 IU (5 µg) were associated with 27% lower risk of osteoporosis [13]. In the NHANES III follow-up in elderly adults, serum 25(OH)D concentrations >24 ng/mL (60 nmol/L) compared with lower concentrations were associated with a 36% lower risk of hip fracture [14]. Although vitamin D status is clearly important, the role of dietary intake has been less clear, given the availability of sun exposure to make vitamin D [6]. Since large proportions of the population showing low vitamin D status, and vegetarians at greater risk of low vitamin D, it is important to focus on adequate intake, for example considering supplementation [6]. Nowadays many soy products as well as orange juice are enriched with vitamin D, and these may offer protection against deficiency [6]. Lactoovovegetarians may obtain vitamin D from milk and egg yolk [6]. Excluding foods such as milk and yogurt from the diet deprives vegetarians of the main sources of calcium known as the "bone nutrient" because nearly 99% of the calcium in the adult human body is contained in bones as hydroxyapatite [6]. Studies of dietary calcium intake support its importance for bone status and fracture prevention and suggest that calcium supplementation may not be sufficient to prevent fracture risk [15]. The NHANES III analysis showed a 2-fold risk of fractures among women ≥ 50 years of age who remembered low milk consumption in childhood and adolescens [16]. Intervention studies with food have shown benefit [17]. When dairy foods were added to the diets of postmenopausal women to raise calcium intake from 900 to 1500 mg per day, the intervention group had significantly lower bone loss relative to controls [17]. Calcium in dairy food may be used more effectively than supplements because it comes packaged with other important nutrients such as vitamin D, protein, potassium, magnesium that work together [6]. Although several vegetables contain calcium, including leafy green vegetables and legumes, the calcium from these sources is not very bioavailable [6]. Vegan populations may obtain calcium from tofu or fortified soy products [6]. Vegetarians are particularly at risk of vitamin B₁₂ deficiency because it is available almost from animal products [6]. It is also important in maintaining bone health [6]. In NHANES III participants, BMD was lower and osteoporosis significantly more likely with increasing serum methylmalonic acid (MMA), a functional indicator of vitamin B-12 inadequacy [6]. Moreover, osteoporosis was twice as likely to occur among participants with serum vitamin B₁₂ levels below the 25th percentile than among participants with serum vitamin B₁₂ levels

above this cut-off [18]. In the Netherlands, the incidence of osteoporosis was almost 7 times higher in women with serum vitamin B12 levels below normal [19]. Study in USA showed a significantly greater decline in total hip BMD with vitamin B12 concentrations ≤ 280 pg/mL (206 pmol/L) compared with higher concentrations [20]. One study among vegetarians showed that low vitamin B-12 concentration was associated with greater bone remodeling, which may accelerate bone loss [21]. In addition to the direct impact of vitamin B12 deficiency, it also leads to an increase in homocysteine levels [22]. Increased homocysteine levels is a risk factor for bone fractures, possibly by weakening collagen cross-linking [22]. Research shows an increase in the risk of bone fractures in people with excessive homocysteine levels, about twice as high for women and four times as high for men [22]. The NHANES III study also found that individuals with serum homocysteine ≥ 20 $\mu\text{mol/L}$ had significantly lower BMD than did subjects with serum homocysteine < 10 $\mu\text{mol/L}$ [18].

Can vegan and vegetarian diet strenghten bones?

Bone health depends on more than just protein, calcium or vitamin D intakes. Studies have shown that bone health is also influenced by nutrients such as vitamin K, potassium or magnesium [3]. Vegan diets do well in providing a number of those important substances and guarantee an acid-base balance that is important for bone health. [3]. A decrease in extracellular pH stimulates bone resorption because bone calcium is used to buffer the decrease in pH [23]. Therefore, a non-vegan diet, being more acidic-forming, increases the excretion of calcium in the urine [24]. A diet rich in fruit and vegetables has a positive effect on the calcium economy and markers of bone metabolism in men and women [25]. The high level of potassium and magnesium content of vegan diet provides an alkaline ash, which inhibits bone resorption [26]. Research confirms that higher intakes of potassium are associated with greater BMD of the femoral neck and lumbar spine of premenopausal women [27]. Results from 2 large, prospective cohort studies support an association between vitamin K intake and risk of hip fracture [28]. Daily consumption of green vegetables (the main source of vitamin K) reduced the risk of hip fracture by 45% compared to the group consuming green vegetables once a week [28]. Studies also suggests the positive effects of soy isoflavones in vegan diet [29,30]. Soy isoflavones showed a significant benefit to spine BMD of menopausal women because of inhibiton of bone resorption and bone formation stimulation [29,30]. In a randomized clinical trial involving osteopenic postmenopausal women, increases in BMD of both lumbar spine and femoral neck were substantially greater with the soy isoflavone, genistein, than with placebo [31].

Conclusions

Vegan and vegetarian diet can theoretically increase the risk of osteoporotic fractures. Their lower intake of calcium and D3 and B12 vitamins may result in lowered BMD. However, they can supplement those nutrients or eat enriched in them functional food. What is more, lower BMD in vegans and vegetarians can be a result of lower body mass and other factors. Other aspects of vegetarian diet may even increase BMD. Non-vegetarian diets tend to be more

acid-forming, increasing the bone resorption and weakening the skeleton. Isoflavones that are eaten in large quantities inhibit the bone resorption. As long as the calcium and vitamin D intake of vegans is adequate, their bone health is probably not at risk because their diet is rich in substances that contribute to bone health. However, more research is needed to provide more definitive data on the bone health of vegan, which will be a valuable resource for balancing a healthy vegan diet.

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