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Review Article

The Role of Diet in Osteoporotic Fracture Risk

Giulia Naldini¹, Roberto Fabiani² and Manuela Chiavarini^{3*}

¹School of Specialization in Hygiene and Preventive Medicine, Department of Experimental Medicine, University of Perugia, Italy

²Department of Chemistry, Biology and Biotechnology, University of Perugia, Perugia, Italy

³Department of Experimental Medicine, Section of Public Health, University of Perugia, Italy

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ABSTRACT

Introduction: Osteoporosis-related fractures constitute a considerable public health burden and nutrition is an important modifiable factor influencing bone health. Numerous micronutrients, macronutrients, and dietary components influence bone health, as well as dietary patterns. This short review describes the role of diet on osteoporosis fracture risk, investigating those dietary factors which improve bone health.

Materials and Methods: Searching Pubmed and Web of Science, we performed a review of current literature.

Results: This review reported the beneficial effects of micronutrients (e.g. calcium, vitamin D, potassium, magnesium, vitamin K, and vitamin B12), macronutrients (e.g. protein and carbohydrates), and foods (e.g. fish and seafood, fruits and vegetables) on osteoporotic fracture risk. A healthy diet, such as the Mediterranean diet, is important for decreasing osteoporotic fracture risk. A potential benefit on fracture risk is attributed to the “Healthy” and “Milk/dairy” dietary patterns which emphasise the intake of fruit, vegetables, whole grains, poultry and fish, nuts and legumes, and low-fat dairy products. By contrast, the unhealthy “Meat/Western” dietary pattern, characterised by high consumption of soft drinks, fried foods, meat and processed products, sweets and desserts, and refined grains, increased osteoporosis fracture risk.

Conclusions: Diet plays an important role in bone health. A healthy diet prevents osteoporosis and reduces osteoporotic fracture risk.

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Introduction

Osteoporosis is a systemic skeletal disorder, characterised by low bone mineral density (BMD) and compromised bone strength [1, 2]. Osteoporosis represents a significant risk factor for bone fractures [1]. Low BMD and osteoporosis-related fractures represent a growing socioeconomic and public health concern [3, 4]. Fragility fractures are associated to increased mortality and can affect considerably the quality of life [3, 5, 6]. The percentage of global burden of deaths attributable to low BMD increased in both sexes from 0.22% in 1990 and to 0.36% in 2010 and percentage of global burden of DALYs (Disability-Adjusted Life Years) almost doubled from 0.12% in 1990 to 0.21% in 2010 [3]. Factors, such as sex, age, physical inactivity, smoking, excessive alcohol

consumption, loss of oestrogen, and nutritional factors mainly related to adequate intakes of calcium and vitamin D, contribute to BMD and osteoporosis [2]. Nutrition has relevant influence on bone health. The aim of this short report is to summarise the influence of diet (micronutrients, macronutrients, food, and dietary pattern) on risk of osteoporosis fracture and identifying pro- and anti-osteogenic nutritional factors.

Materials and Methods

A literature search was carried out on Pubmed and Web of Science. Supplementary sources were obtained from references of articles selected. A review of current literature was performed.

*Correspondence to: Dr. Manuela Chiavarini, Ph.D., Department of Experimental Medicine, Section of Public Health, University of Perugia, Italy; Piazzale Gambuli, n.2 – 06129 Perugia, Italy; Fax:390755858420; Tel:390755858035; E-mail: manuela.chiavarini@unipg.it

Results

I Micronutrients

Phosphorus and calcium are major constituents of bone mineral content. Bone health and normal metabolism require many micronutrients, such as calcium, phosphorus, magnesium, zinc, copper, iron, fluoride, vitamins D, A, C, and K.

i Phosphorus

The recommended dietary daily allowance for phosphorus is 700 mg for men and women aged 51 years and older, but in many Western countries the daily dietary intake is higher than the recommended level [7]. Phosphorus is ubiquitous in foods, especially in high-protein foods in high-fat fast foods and processed snacks [8, 9]. High phosphorus dietary intake interferes with calcium homeostasis with potential adverse effects on bone metabolism and contributes to osteoporosis [8, 10]. High phosphorus dietary intake increases the risk of osteoporotic fractures in both sexes and serum phosphate is positively associated with fracture risk independently of BMD [11, 12].

ii Calcium

The recommended dietary daily calcium intake is 1,000 mg for men aged 51-70 years and 1,200 mg for women aged 51-70 years and older adults [13]. The meta-analysis by Bolland *et al.* showed no significant beneficial effect of dietary calcium on the risk of fractures [14]. The meta-analysis by Wang *et al.* performed on eight prospective cohort studies found no association of high calcium intake with the diet and/or supplementations and hip fracture risk; a continuously high calcium intake for more than eight years, however, significantly reduced relative risk of hip fracture [15]. A positive balance between intake and excretion of calcium plays a crucial role in preserving bone health [16]. The association of high intake of calcium with proteins reduced the risk of fractures [17].

iii Vitamin D

Vitamin D plays an important role for the intestinal absorption of calcium and serum concentrations of 25-hydroxyvitamin D tend to decline with age [18]. The recommended daily dietary intake of vitamin D should be around 400–800 IU [13]. Vitamin D deficiency can result in mineralisation defects, osteoporosis, and fractures [19]. Even though calcium and vitamin-D deficiency is a major risk factor for osteoporosis and the study by Fisher *et al.* describes that adequate calcium and vitamin D supply post-fracture is essential for callus-mineralization, the calcium and vitamin D supplementation showed no significant effect on fracture healing [20, 21].

iv Other Micronutrients

Dietary potassium and magnesium are associated with reduced risk of osteoporotic fracture [22]. Excessive dietary sodium intake represents a risk factor for osteoporosis [23]. High dietary intake of sodium leads to increased urinary calcium excretion, affecting bone remodelling and bone loss [24, 25]. Vitamin B12 deficiency has been associated with low

bone mineral density and low serum concentration of vitamin B12 increased the risk of hip fracture [26, 27]. High dietary vitamin K intake resulted positively associated with better bone mineral density and reduced risk of fractures [28-30].

II Macronutrients

i Proteins

The role of dietary protein in bone metabolism has been controversial. Both low and high dietary intake can influence calcium absorption and affect bone health [31, 32]. Adequate protein intake, however, has been positively associated with bone mineral density and content and with reduced bone resorption markers [33, 34]. Indeed, dietary proteins contribute to collagen formation and stimulate the production of growth factors involved in bone formation [32]. High protein intake has shown a positive association with increased bone mass and bone health [35, 36]. Indeed, the Framingham Osteoporosis Study reported that higher intakes of proteins reduced the risk of hip fracture [37]. On the other hand, the meta-analysis by Shams-White *et al.* found no significant association between dietary protein intake and fracture risk [34]. Other nutrients in the diet could contribute to the complex role of protein in bone health [38].

ii Other Macronutrients

A diet rich in carbohydrates reduces the risk of osteoporotic fractures [39]. While a high-fat diet influences negatively bone remineralisation and the absorption of dietary calcium [40]. Accordingly, high intake of lipids increases fracture risk in postmenopausal women [39].

III Foods

i Fish and Seafood

Fish and seafood are rich in polyunsaturated fatty acids, especially n-3 (ω -3) fatty acids, which have an anti-inflammatory effect that benefits bone health [41]. Moreover, fish with dark flesh is rich in vitamin D and fish consumption has been associated with reduced risk of hip fracture [42].

ii Beverages

The consumption of cola has negative effect on bone mineral density and resulted associated with the risk of fracture in older women [43, 44]. Dietary compounds not usually categorised as nutrients, such as alcohol, can affect bone health. High alcohol consumption increases the risk of hip fractures and osteoporotic fractures [45, 46]. The meta-analysis by Sheng *et al.* found that coffee consumption had no significant effect on the risk of hip fracture, while a nonlinear association between tea consumption and the risk of hip fractures has been observed [47]. However, a previous meta-analysis by Liu *et al.* showed a positive association of coffee intake with fracture risk in women [48]. Caffeine at high doses can increase urinary calcium excretion and contribute to the risk of fractures [49].

iii Fruits and Vegetables

Fruits and vegetables contain important micronutrients, such as potassium and magnesium, which have been associated with increased bone mineral density [50].

IV Vegetarian and Vegan Diet

Vegetarian diet can place individuals at risk of inadequate intakes for several nutrients important to bone health [51]. The recent meta-analysis by Iguacel *et al.* reported that the risk of low bone mineral density and of fracture was higher in vegetarians and vegans than in omnivores [52]. Moreover, vegans showed a higher risk of low bone mineral density and of fracture than vegetarians [52].

V Dietary Patterns

Nutritional epidemiology has recently applied dietary patterns to investigate the relation between diet and chronic diseases rather than focusing on individual foods and nutrients [53,54]. Dietary patterns provide a closer representation of the actual conditions in which foods and nutrients are consumed and permit to estimate the effect of overall dietary habits. Dietary patterns are defined by *a priori* or by *a posteriori* methods. Dietary patterns defined by *a priori* approach consist in dietary indices and scores (i.e. glycaemic index, Mediterranean score) based on current nutritional knowledge of the healthy or unhealthy effects of various dietary constituents and identify a desirable pattern, the adherence to which could maximise health benefit. Dietary patterns defined by *a posteriori* approach identify dietary patterns (e.g. Western, healthy, and dairy patterns) on the basis of available dietary data directly obtained from the studied population [53].

i A priori

a Inflammatory Index

Higher dietary inflammatory index has been demonstrated to increase the risk of osteoporosis and incident fractures in women, while no significant effect resulted in men after adjusting for potential confounders [55, 56].

b Glycaemic Index

A recent trial conducted in 870 subjects aged 55-80 years at high cardiovascular disease risk has demonstrated that high dietary glycaemic index and the dietary glycaemic load increase the risk of osteoporotic fracture [57].

c Mediterranean Diet

The recent meta-analysis by Malmir *et al.* has reported that adherence to Mediterranean diet reduced the risk of osteoporosis fracture and was positively associated with a higher BMD [58]. Mediterranean diet is characterised by alkali-forming food groups (fruits and vegetables) and acid forming food groups (cereals, nuts and dairy product). Greater consumption of such dietary pattern can affect the inflammation process

and might change the acid–base balance and influencing bone density [59-63].

ii A posteriori

a “Meat/Western” Dietary Pattern

The “Meat/Western” pattern is a dietary pattern characterised by a high loading of red meat, processed meat, animal fat, eggs, and sweets. The strong adherence to the “Western” diet involves a high dietary intake of lipids, protein, refined carbohydrates, sodium, and phosphorus. The “Meat/Western” pattern increased the risk of low bone mineral density of 22% and the risk of osteoporotic fractures of 11% [64].

b “Healthy” Dietary Pattern

The “Healthy” pattern is a dietary pattern characterised by a high loading of vegetables and fruits, poultry, fish, and whole grains. The high consumption of fruit and vegetables observed in this dietary pattern is related to high intake of important micronutrients, such as potassium, magnesium, vitamin C, vitamin K, folate, and carotenoids [65]. Adherence to “Healthy” pattern reduced the risk of low bone mineral density of 18% and the risk of osteoporotic fractures of 21% [64].

c “Milk/Dairy” Dietary Pattern

The “Milk/dairy” pattern is a dietary pattern characterised by a high loading of milk and dairy products, which are rich in calcium and magnesium and represent a relevant source of proteins, vitamin D, vitamin B-12, riboflavin, zinc, and potassium [66]. The strong adherence reduced the risk of low bone mineral density of 41%, while it showed no significant effect on fracture risk [64].

VI Malnutrition

A poor nutritional state has been associated with the increased risk of osteoporotic fractures and with mortality in older adults with hip fracture [67, 68].

Conclusions

This review reported the beneficial effects of micronutrients (e.g. calcium, vitamin D, potassium, magnesium, vitamin K, and vitamin B12), macronutrients (e.g. protein and carbohydrates), and foods (e.g. fish and seafood, fruits and vegetables) on osteoporotic fracture risk. A healthy diet, such as the Mediterranean diet, is important for decreasing osteoporotic fracture risk. A potential benefit on fracture risk is attributed to the “Healthy” and “Milk/dairy” dietary patterns which emphasise the intake of fruit, vegetables, whole grains, poultry and fish, nuts and legumes, and low-fat dairy products. By contrast, the unhealthy “Meat/Western” dietary pattern, characterised by high consumption of soft drinks, fried foods, meat and processed products, sweets and desserts, and refined grains, increased osteoporosis fracture risk. The high content of phosphorus in Western diet can affect bone health and contribute to osteoporosis. Nutrition is a relevant modifiable factor influencing bone health. Public health efforts are needed to provide

guidance for nutritional intervention and approaches directed to prevent osteoporosis and osteoporotic fractures.

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Conflicts of Interest

None.

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