

Healthy diet and bone health



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Osteoporosis is a **multifactorial disease** characterised by a decrease in mineral density and an alteration in the microarchitecture of bones, which can lead to fractures. After the age of 50, **osteoporotic fractures** affect **one woman in two** and **one man in five**. As a result, every year, almost **9 million fractures** are reported worldwide due to osteoporosis. This issue of the Global Fruit & Veg Newsletter reports on the links between **diet and bone health**.

Faced with the burden of osteoporosis, number of studies have focused on the effects of diet on bone health, both on the growth process and, more importantly, on limiting bone loss. This edition highlights this subject through 3 recent articles.

These publications reflect a paradigm shift with progress in knowledge and methodologies. Previously focused on the effect of individual nutrients and foods, research is now considering **lifelong dietary habits and lifestyle** and shifting the scale to include the effect of **food systems rather than just foods or nutrients**. This recognition of the complexity of life allows for better dietary management of bone health, as described in the three articles cited here.

- The first article, written by one of the top teams in the field (Rizzoli et al.) and summarized by **Jean-Michel Lecerf**, reiterated that the major role of **calcium, vitamin D and protein** fully justifies the consumption of dairy products from a very young age. The authors point out the osteoprotective effects of other nutrients contained in **fruit and vegetables**, associated with their **alkalising, antioxidant, prebiotic** and even **mineralising** (vitamin K) properties. Therefore, of all the diets studied, the Mediterranean diet is the most favourable.
- The second article written by **Lauren Coheley** corroborates the importance of a **healthy diet** (rich in fruit, vegetables, whole-grain cereals, nuts, fish, and low-fat milk products) during **childhood and especially adolescence** since dietary choices at this stage of life predict 20-40% of adult bone mass.
- The third article written by **Bolaji Lilian Ilesanmi-Oyelere** deals with **postmenopausal osteoporosis**. It draws attention to the negative effects of high intakes of ultra-processed foods or a pro-inflammatory diet on bones and confirms the importance of a healthy and balanced diet or a Mediterranean diet.

Nutrient intakes and bone health: a review stresses the importance of a healthy, varied diet

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Osteoporosis is a multifactorial disease that affects over 20% of women aged 50 and over in Europe (Borgström, 2020). In addition to genetic and hormonal factors and obviously age, there are many lifestyle-related factors that come into play, namely physical activity and nutrition (Rizzoli, 2010). A recent literature review conducted by one of the foremost teams in the area of bone health and nutrition (Rizzoli, 2021) provides a comprehensive overview of this issue. It points out the importance of adequate protein, calcium, vitamin D, fruit and vegetable intakes.

The authors examined the role of nutrients, food and certain diets (in the broad sense), using a rigorous nutritional and scientific approach.

Dairy products: a positive effect on bone mineral density and fracture risk

Dairy products rank first in terms of evidence. Not consuming them is associated with an increased risk of osteoporosis and fractures, regardless of age (Opatowsky, 2003; Goulding, 2004; Konstantinowicz, 2007). Observational studies have shown that high intakes are associated with increased bone mineral density and bone strength and reduced fracture risk (Matkovic, 2004). The clearest benefit is observed for fermented dairy products (Ong, 2020). This is not due to calcium alone but rather to a food matrix effect, because for the same intake of calcium, taking calcium supplements is less effective in terms of bone mineral density than eating cheese (Cheng, 2005). Indeed, high calcium intakes increase bone mineral density in children and adolescents in particular, although no reduction in fracture risk has been demonstrated (Winzenberg, 2006).

Vitamin D also plays a key role in bone metabolism. Vitamin D and calcium supplementation reduces fracture risk in at-risk and elderly subjects (Yao, 2019).

The role of protein has been established in prospective epidemiological studies showing that high intakes are associated with reduced fracture risk, especially for milk protein. Calcium-protein and calcium-vitamin D-protein interactions seem favourable.

Fruit and vegetables: regular consumption reduces fracture risk by 8%

Eating fruit and vegetables is also beneficial for bone mineral density. Observational studies have shown an 8% reduction in fracture risk when fruit and vegetables are consumed on a regular basis (Brondani, 2019). Several mechanisms of action are described as explaining this protective effect:

- the alkalisating action of fruit and vegetables, altering the acid-base balance of the body,
- an antioxidant effect, associated with the presence of vitamin D, beta-carotene and vitamin K in fruit and vegetables,
- a prebiotic effect on the microbiota, likely to increase calcium absorption.

In fact, studies underline that the benefits associated with vitamin A depend on the source, because only beta-carotene has been shown to be inversely associated with fracture risk (Charkos, 2020). Playing a role in collagen synthesis by osteoblasts, and inhibiting osteoclastic activity via its antioxidant effect, vitamin C was associated with a sharp reduction in the risk of femoral neck fracture in interventional studies (Zeng, 2020). Vitamin K is also a candidate but its effect, if there is one, is only modest.

The Mediterranean diet: favourable for bone health.

Lastly, the effects of several diets on the risk of osteoporosis have been studied. Vegetarian and especially vegan diets have an extremely harmful effect, mitigated by high calcium intakes (Ho-Pham, 2009). Weight-loss diets also have a harmful effect, mitigated by protein, calcium and vitamin D supplementation and physical activity (Zibellini, 2015; Paccou, 2021). The Mediterranean diet is the most favourable when it comes to bone health.

In addition to the widely established beneficial role of calcium and vitamin D, this work once again emphasised the importance of a healthy, varied diet rich in fruit and vegetables for the prevention of osteoporosis.

KEY MESSAGES

To prevent osteoporosis, the authors recommend a diet supplying:

- 0.8 g of protein/kg/day (up to 1.3 g for the elderly);
- 800 mg to 1 g of calcium/day;
- 800 to 1000 IU of vitamin D;
- Five servings of fruit and vegetables, and a small amount of salt (≤ 2.5 g/day).

They also recommend a Mediterranean diet.

METHODOLOGY

- Databases used: Embase and MEDLINE, from their creation to March 2021.
- Articles not written in English were excluded.
- Most of the results came from observational studies.



References:

- Borgström F, et al. Arch Osteoporos. 2020; 15(1):59.
- Rizzoli R, et al. Bone 2010; 46: 294–305.
- Opatowsky AR, Bilezikian JP. J Bone Miner Res 2003; 18: 1978–88.
- Goulding A, et al. J Am Diet Assoc 2004; 104: 250–53.
- Konstantynowicz J, et al. Osteoporosis Int 2007; 18: 1601–07.
- Matkovic V, et al. J Nutr 2004; 134: 701S–05S.
- Ong AM, et al. Adv Nutr 2020; 11: 251–65.
- Cheng S, et al. Am J Clin Nutr 2005; 82: 1115–26.
- Winzenberg T, et al. BMJ 2006; 333: 775–78.
- Ebeling PR, et al. Eur J Endocrinol 2018;179: R239–59.
- Yao P, et al. JAMA Netw Open 2019; 2: e1917789.
- Brondani JE, et al. PLoS One 2019; 14: e0217223.
- Charkos TG, et al. BMC Musculoskelet Disord 2020; 21: 711.
- Zeng LF, et al. Front Endocrinol (Lausanne) 2020; 10: 844.
- Ho-Pham LT, et al. Am J Clin Nutr 2009; 90: 943–50.
- Zibellini J, et al. J Bone Miner Res 2015; 30: 2168–78.
- Paccou J, et al. Calcif Tissue Int 2021.

Do Dietary Patterns Influence Bone Strength in Children?

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Research into dietary factors that influence pediatric bone have focused primarily on the role of individual micronutrients (e.g., vitamin D and calcium). Given nutrients are not consumed independently, but rather, consumed together, dietary pattern analysis has emerged as an alternative and complementary approach to examine the overall effects of the diet on bone health. Dietary patterns represent a broader picture of food and nutrient consumption and may therefore, be more robust in producing positive or negative impacts on bone health (Hu, 2002). To date, many studies investigating the role of dietary patterns on pediatric bone are primarily cross-sectional in nature and target adult populations, with little focus on pediatric and adolescent bone. Given, establishing healthy bones during childhood serves as a blueprint for adult bone, it is important to better understand the role of dietary patterns on pediatric bone.

Thus, the following review aims to determine the association between dietary patterns and pediatric bone health.

Pediatric bone development, a blueprint for skeletal health in adulthood

Low bone mass is a key determinant of osteoporotic risk in adulthood and may be attributed to a failure to achieve optimal peak bone mass during childhood or the inability to slow bone loss in adulthood (Ferrari, 1998). Adolescents is a critical period of bone development with approximately 90% of adult bone mass being achieved by the age of 18 (Hansen, 1991). This rapid period of growth is important given bone mineral density tracts through childhood into adulthood (Kalkwarf, 2010). Thus, establishing healthy bones during childhood is imperative for skeletal health in adulthood. Moreover, given lifestyle choices during youth influence 20-40% of adult bone mass, optimizing factors known to influence peak bone mass and strength serve as important strategies to reduce osteoporosis or low bone mass later in life

(Weaver, 2016).

Healthy dietary patterns may decrease the risk of low bone mineral density in children and adolescents

A recent systematic review found that a healthy or prudent dietary pattern, emphasizing the intake of fruit, vegetables, whole grains, low-fat dairy products, fish, nuts and legumes may lower the risk of low total body bone mineral density among children and adolescents (Movassagh, 2017).

Only 2 studies investigated the role of the “a priori” dietary patterns and bone health. One study found that a Mediterranean dietary pattern, associated with high intakes of fresh fruits, vegetables, whole grains, beans, seeds, nuts, and healthy fats, increased radius bone mineral density in adolescents (mean age: 13 years old), but the trend was non-significant (Monjardino, 2014). Moreover, another study demonstrated that adherence to a Mediterranean-based dietary pattern in adolescents (11-14 years old) increased the bone resorption biomarker, urine deoxypyridinoline and improved calcium absorption (Seiquer, 2007).

The association between a vegetarian dietary pattern and bone health in adolescents and young adults

A prospective study showed that the consumption of a vegetarian dietary pattern characterized by increased intakes of fruits (and 100% fruit juice), dark green vegetables, legumes, nuts and seeds, eggs, and low-fat milk during adolescence increased total bone mineral content and density. Participants with higher adherence to the vegetarian-style diet during adolescents, also had higher total body bone mineral content and density, as well as, femoral neck bone mineral density and content, during young adulthood, an average of 15 years later (Movassagh, 2018).

KEY MESSAGES

- Results from both « a posteriori » and « a priori » dietary patterns approaches in children suggests that diets rich in fruit and vegetables might be beneficial for pediatric bone.



METHODOLOGY

- Two main methods exist to describe dietary patterns:
 - « A posteriori » approach uses statistical methods such as factor analysis, cluster analysis, and reduced rank regression to derive dietary patterns from collected data
 - « A priori » approach uses dietary indexes created based on existing nutritional knowledge, and typically assesses compliance with dietary guidelines and recommendations.
- This paper focused on data from « a posteriori » and « a priori » dietary patterns, Mediterranean diet, Dietary Approaches to Stop Hypertension (DASH) diet, Healthy Eating Index (HEI), and Western diet.

Based on: Coheley LM and Lewis RD. Dietary Patterns and Pediatric Bone. *Current Osteoporosis Reports* (2021) 19:107–114.

References:

- Hu FB. *Curr Opin Lipidol*. 2002;13(1):3–9.
- Ferrari S, et al. *J Clin Endocrinol Metab*. 1998;83(2):358–61.
- Hansen MA, et al. *BMJ*. 1991;303(6808):961–4.
- Movassagh EZ, Vatanparast H. *Advances in Nutrition* 2017;8(1):1–16.
- Monjardino T, et al. *Public Health Nutr*. 2014;17(1):195–205.
- Seiquer I, et al. *J Am Coll Nutr*. 2008;27(4):454–62.
- Movassagh EZ, et al. *Nutr J*. 2018;17(1):36.
- Kalkwarf HJ, et al. *J Clin Endocrinol Metab* 2010;95(4):1690-8.
- Weaver CM, et al. *Osteoporos Int*. 2016 Apr;27(4):1281-1386.

Nutrient and dietary patterns to prevent postmenopausal osteoporosis

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Postmenopausal osteoporosis is characterized by an increased low-grade inflammation which contributes to low bone mass and degradation of bone mineral content resulting in bone loss and/or fractures (Brown, 2007; Brown, 2011). Osteoporosis is a multifactorial condition, but its key drivers include oestrogen deficiency, poor dietary habits, chronic inflammation, smoking, excessive alcohol consumption and sedentary lifestyle. Therefore, nutrition and lifestyle improvements could be essential to prevent osteoporosis (David, 2014). Several key nutrients, occurring together in foods and dietary patterns, are known to affect bone mineral content and bone mineral density such as calcium and vitamin D, but also potassium, zinc magnesium, iron, copper, vitamin C and K found in fruit and vegetables.

The aim of the present review was to report the current evidence and status of knowledge about the relationship between nutrient and dietary patterns and bone health in postmenopausal women.

Nutrient patterns and postmenopausal osteoporosis: heterogeneous results with no conclusive nutrient pattern

To date, only two studies have explored the relationship between nutrient patterns and bone health exclusively in postmenopausal women.

The first study (Karamati, 2014) showed that a dietary pattern associated with high in nutrients found mainly in fruit and vegetables (folate, fiber, vitamin B6, potassium, vitamin A, beta-carotene, magnesium, copper, and manganese) was positively associated with lumbar spine bone mineral density. However, no significant correlation was found between well-known nutrients for their benefits for bone health in the pattern high in protein, calcium, phosphorus, zinc, vitamin D, vitamin B2, and vitamin B12 and low in vitamin E. This is mainly because the influence of

protein intakes generally depends on a balanced whole diet in terms of acid-producing potential.

A positive association was found in the second study (Ilesanmi-Oyelere, 2019) between nutrient pattern characterized by high phosphorus, calcium, potassium, magnesium, vitamin B2, vitamin B6, carbohydrates, and sugars and lumbar spine, femoral neck, and whole-body bone mineral density. These nutrients are particularly found in eggs, lean meats, milk and milk products, and some fruit and vegetables. Meanwhile, nutrient pattern high in alpha and beta carotene, vitamin E, and dietary fats was negatively associated with bone mineral density.

Dietary pattern analysis and score/index and bone health in postmenopausal osteoporosis

Due to interaction of various nutrient and foods, it is important to generate dietary pattern with correlated foods.

Some studies examined the association between traditional Western diets characterized by processed foods high in salt, fats, and sugars and bone health status. They evidenced a positive association with osteoporosis (Fairweather, 2011; Sugiura, 2011; Karamati, 2012; Chen, 2015; de França, 2016). In addition, the Dietary Inflammatory Index (DII) assessing diet's inflammatory potential was inversely associated with bone mineral density, which indicates a relationship between inflammation and bone degeneration (Hamidi, 2011; Haring, 2016).

On the other hand, "healthy" and/or "prudent" dietary patterns including foods such as fruit, vegetables, milk, low-fat dairy, and nutrient dense foods have been associated with high bone mineral density. In general, the Mediterranean diet score that indicated compliance with Mediterranean diet, was directly associated with bone mineral density and inversely associated with fracture risk (Feart, 2013; Rivas, 2013).

KEY MESSAGES

- A « healthy » diet rich in fruit, vegetables and milk or a Mediterranean-style diet may be beneficial for bone health compared to Western dietary patterns.
- Policies to increase consumption of vegetables, fruits, whole grains, and low-fat milk is necessary for bone health from childhood to adulthood.

METHODOLOGY

In this narrative review were reported all articles from 2001 to May 2020 in Web of Science, Cinahl and Scopus that have researched a relationship between nutrient and/or dietary patterns and postmenopausal osteoporosis.



Based on: Ilesanmi-Oyelere BL, Kruger MC. Nutrient and Dietary Patterns in Relation to the Pathogenesis of Postmenopausal Osteoporosis—A Literature Review. *Life*. 2020; 10(10):220.

References:

- Brown P et al. University of Auckland/Uniservices: Auckland, New Zealand, 2007.
- Brown P et al. *Health Policy* 2011, 9, 111–123.
- David LA et al. *Nature* 2014, 505, 559–563.
- Karamati M et al. *Calcif. Tissue Int.* 2014, 94, 648–658.
- Ilesanmi-Oyelere BL et al. *Nutrients* 2019, 11, 1262.
- Fairweather-Tait SJ et al. *Am. J. Clin. Nutr.* 2011, 94, 1371–1375.
- Sugiura M et al. *Osteoporos. Int.* 2011, 22, 143–152.
- Karamati M et al. *Calcif. Tissue Int.* 2012, 91, 40–49.
- Chen Y et al. *PLoS ONE* 2015, 10, e0137097.
- De França N et al. *Eur. J. Clin. Nutr.* 2016, 70, 85–90.
- Hamidi M et al. *Am. J. Clin. Nutr.* 2011, 94, 199–208.
- Haring B et al. *JAMA Intern. Med.* 2016, 176, 645–652.
- Feart C et al. *Osteoporos. Int.* 2013, 24, 3031–3041.
- Rivas A et al. *Int. J. Food Sci. Nutr.* 2013, 64, 155–161.

Evidence Update on the Relationship between Diet and the Most Common Cancers from the European Prospective Investigation into Cancer and Nutrition (EPIC) Study: A Systematic Review



With more than 18 million cases and 10 million deaths worldwide in 2020, cancer is one of the most important public health problems. Therefore, identifying the risk and protective factors for this disease is of major importance. A review of 110 articles examined the results of the EPIC study on the relationship between diet and mortality from the four most common cancers in Europe (colorectal, breast, lung, and prostate). Fruit and vegetables consumption was found to be protective against colorectal, breast and lung cancer, while only fruit consumption was found to protect against prostate cancer. The Mediterranean diet is also identified as a preventive factor against colorectal and breast cancer. These results are in line with the latest data on cancer prevention.

Ubago-Guisado E. *Nutrients*. 2021 Oct 13;13(10):3582.

Read for Nutrition' programme improves preschool children's liking and consumption of target vegetable



The American programme « Read for Nutrition » seeks to improve children's liking and consumption of vegetables through reading. In this study, 16 teachers were trained and then asked to read the book « Monsters Don't Eat Broccoli » to children (n=69; 3-5 years old) repeatedly over a 3-week period. Following this intervention, the average consumption of broccoli increased by 35% in all children. A better appreciation of broccoli was also observed. The proportion of children who rated broccoli as « Yummy » increased from 44% to 61% after the intervention. Conversely, the proportion of children who rated it as 'Just OK' or 'Yucky' decreased. The teachers found the programme acceptable, practical and enjoyable to children and to themselves.

Elrakaiby M, et al. *Public Health Nutr*. 2021 ;1-9.

Physical Education and Its Importance to Physical Activity, Vegetable Consumption and Thriving in High School Students in Norway



A Norwegian study assessed the association between students' physical education grades, their vegetable consumption and their level of well-being using the 5C indicators: competence, confidence, character, caring, and connection. Participants (220 students, 17-year-old) self-reported their current academic grade in physical education on a scale of 1 to 6, with grade 1 representing minimal knowledge and investment during physical education sessions. A high physical education grade was positively associated with four of the five indicators. Moreover, a unit increase in the physical education grade increased the likelihood of engaging in physical activity by 94% and vegetable consumption by 68%. These significant results highlight the need for policies and programmes to support physical education classes.

Wium N. *Nutrients*. 2021;13(12):4432.

Cruciferous vegetable and isothiocyanate intake and multiple health outcomes



Isothiocyanates, bioactive compounds found in cruciferous vegetables, are known for their chemopreventive activity. A literature review analyzed over 410 articles to clarify the health benefits of cruciferous vegetables and isothiocyanates. According to this work, cruciferous vegetables consumption reduces the risk of all-cause mortality, cancer and depression. A 10 % risk of all-cause mortality was observed for a 100 g increased daily consumption of cruciferous vegetables. Finally, the authors warn that warfarin resistance may be caused by broccoli due to its high vitamin K content and point out the existence of allergy/hypersensitivity to crucifers.

Li N, et al. *Food Chem*. 2022;375:131816.

Recommendations for Integrating Evidence-Based, Sustainable Diet Information into Nutrition Education



Sustainable diet is an increasingly studied field of research, with knowledge evolving rapidly. Nutrition educators are important relays for informing consumers on this issue. However, to date, no evidence-based recommendations exist for these professionals. This American review summarizes the most recent scientific data and identifies five recommendations: 1/ Shift towards a plant-based diet; 2/ Mitigate food waste; 3/ Limit consumption of ultra-processed foods; 4/ Engage in local food systems; 5/ Choose sustainable seafood. The authors provide examples for each of these recommendations to facilitate their implementation in the United States.

Bastian GE, et al. 2021 Nov 21;13(11):4170.