

# Healthy Nutrient Intakes that Support Skeletal Health during Adulthood

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## REVIEW

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## INTRODUCTION

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Experimental support of the optimal diet for maintaining bone health through adulthood into the late decades of life has not been fully established, but several guiding reports on this important aspect of the prevention of skeletal fractures have been published in recent years. An important caveat, however, in determining such a relationship is that diet alone is only one of many lifestyle factors that contribute to healthy bone tissue.

Although this review focuses on the benefits of healthy eating habits for maintaining optimal bone status, other healthy behaviors, especially having regular physical activity and not smoking, also have beneficial effects on the functions of the skeleton. A decline in physical activity by adults has been established to lead to greater losses on bone mass and bone density [1]. Healthy eating practices is the focus of this review rather than of nutritional supplements, such as of calcium and vitamin D, which have only a limited role in the prevention of fractures, as they are

not needed when a diet of high nutrient quality is consumed [2]. Our opinion is that nutrient supplements should only be taken when a physician prescribes them for an established clinical deficiency.

### Healthy Eating Patterns and Diet Quality

Healthy eating patterns are based mainly on the consumption of many servings of plant foods every day that supply many nutrients and phytochemicals. Animal foods provide other essential nutrients, including several including a few in amounts greater than in plant foods. Dairy foods are especially beneficial to bone health when consumed in moderation. Both dairy foods and animal sources are rich in protein. Fresh fruits and vegetables and additional food items with only limited processing are recommended. Concerns about consuming too much processed food relate primarily to the increased amounts of sodium from salt, too much sugar, too much saturated fat, and excessive intake of calories (energy). Sweetened fruit juices should only be consumed in minimal amounts. Sugar-sweetened beverages and desserts have become major sources of high caloric intakes that contribute to the high rates of overweight and obesity, and they are therefore not recommended. Obesity remains an important risk factor for lowering bone quality and reducing bone function, especially in older adults [3].

A high-quality diet, then, provides a variety of foods and snacks every day and it assures adequate amounts of dietary fiber and other plant molecules or phytochemicals that remain after minimal processing of plant foods, or none [4]. In the U.S.A., not enough servings of plant foods—way below recommended amounts—are consumed by adults of both genders. Two well established types of high-quality diets, the Mediterranean way of eating [5] and the dietary approaches to stop hypertension (DASH)



diet [6]. These two diets are highly recommended for bone health as well as for the prevention of chronic diseases, such as cardiovascular conditions and type 2 diabetes, because they provide a wide variety of healthy foods with sufficient amounts of all the essential nutrients and phytochemicals (Table 1). These diets, and likely other ways of healthy eating, promote good bone health in contrast to the typical western diet that emphasizes upon, high saturated fat, fast foods, highly processed foods, and sugar-sweetened beverages and other food items [7]. Sugar-sweetened beverages, i.e., colas or soft drinks, have been found to have negative effects on bone mass and bone density [8, 9].

**Table 1.** Two Types of Healthy Dietary Patterns Recommended for Bone Health: Mediterranean and Dietary Approaches to Stop Hypertension (DASH). [5, 6]

<b>Mediterranean Diet</b>	<b>DASH Diet</b>
Fish, other seafood	Fish, poultry
Vegetables, legumes	Vegetables
Fruits	Fruits
Whole grains	Whole grains
Nuts, seeds	Nuts
Olives, olive oil	Canola oil
Dairy, low-fat	Dairy, low-fat
Salt, moderate	Salt, low

As part of a healthy diet, choosing modest portion sizes at meals is important, as are other aspects, such as consuming adequate amounts of water, for the support of bone health and the prevention of osteoporotic fractures [10]. Good eating behaviors may need to be re-learned by those at high risk of fracture in order to develop healthy eating patterns for the promotion of bone health.

## Macronutrients and Calories

The macronutrients, i.e., carbohydrate, fat, and protein, need to be consumed each day. Carbohydrates and fats provide the calories (energy) components—starches, sugars, and fatty acids—that have other roles besides being energy sources metabolized by our cells. Proteins contain twenty or so amino acids that are used in building other structural or functions proteins of our cells and tissues.

Recommendations for the three macronutrients are sufficient to support body functions. Excessive amounts, however, are not needed and following absorption of the digested molecules, the extra components are converted to storage molecules, especially fat molecules known as triglycerides. The storage depots of fat are enriched in triglycerides to the extent that about 50 % to 75 % of the adult U.S. population is either overweight or obese according to measurements. Excessive caloric intakes over years has an adverse effect on bone mass and bone density that places people at high risk of fracture and at increasing risk of falls. For general health, plant sources of fats with more mono- and polyunsaturated fatty acids are advised rather than saturated fatty acids, which are derived more from animal products.

Sufficient protein from both plant and animal food sources is needed to support bone health, but intakes greater than the recommended intake of 0.8 g per kg may not be helpful. Older adults with low protein intakes may improve their bone mass and density by increasing protein from animal sources [11, 12]. Plant foods rich in protein, such as whole grains and soy, are recommended for the bulk of protein needed, but dairy foods, eggs, and meat, fish, and poultry contain good sources of protein as well. Fish is a good source of both protein and polyunsaturated fatty acids, both of which may benefit bone [13]. Most of the protein in bones is collagen which has a structural role within the organic matrix, but small quantities of numerous other protein molecules with diverse functions also operate in bone cells. In general, reasonable protein intakes are recommended for the support of bone and other tissues unless a specific medical condition warrants greater dietary amounts from dietary sources or protein supplements.

## Micronutrients

Many micronutrients, i.e., vitamins and minerals, are required in smaller quantities each day than are macronutrients. All micronutrients are required by bone tissue for survival; a few, such as calcium and phosphorus, are needed in larger amounts than the other micronutrients in order to support the mineral phase of bones. One

vitamin, vitamin D, has a special role in maintaining bone health, but all the vitamins have important roles in bone cells. For example, vitamin C has been found to be associated with lower loss of bone mass and density [14].

Recommended dietary allowances (RDAs) of calcium and vitamin D are listed in Table 2 because they are the two micronutrients of most concern regarding potential deficiency and increasing the risk of skeletal fractures [15]. As a general rule, consumption of calcium and vitamin D at the adult RDA level, i.e., approximately 80% of it should be sufficient because each RDA has a built-in safety factor to assure adequacy.

The diverse vitamins and minerals have critical functions in bone tissue, but these roles are beyond this report except to state that they need to be consumed via a variety of plant and animal foods.

**Table 2.** Recommended Dietary Allowances (RDAs) of Calcium and Vitamin D for Men (M) and Women (W). [15]

Adult Age Range	Calcium RDA	Vitamin D RDA
19 – 30	1000 mg/d	15 microg or 600 IU/d
31 – 50	1000 mg/d	15 microg or 600 IU/d
51 – 70	1000 mg/d(M)/1200 mg (F)	15 microg or 600 IU/d
< 70	1200 mg/d	20 microg or 800 IU/d

**Abbreviations:** mg/d = milligrams per day; IU/d = international Units per day.

### Phytochemicals or Plant Molecules

Many different types of phytochemicals, also referred to as bio actives, are made only by plant cells, but they can have roles in animal tissues, including humans, after being consumed and absorbed. These plant molecules are not classified as essential nutrients, but they do play important roles as part of a healthy diet containing numerous plant sources. Some phytochemicals, such as phytoestrogens in soy beans, may have modest skeletal effects, but a two-year clinical study did not find conclusive

evidence of benefits at common fracture sites [16]. Table 3 list a variety of phytochemicals and their roles.

**Table 3.** Examples of Phytochemicals with Positive Roles in Bone Tissue.

Phytochemical	Food Sources	Metabolic Role
Phytoestrogens	Soy beans, other legumes	Maintain Bone Mass & Density
Polyphenols	Green Tea	Bone Microarchitecture

Dietary fiber represents a group of plant molecule, but it is not considered an essential nutrient. Even though a RDA is established for fiber, they have no specific functional requirements beyond their gut-associated benefits of fiber molecules [17]. Fiber molecules help reduce the absorption of fatty acids, lower the absorption of dietary cholesterol, and slow the flow of ingested food components in the in the lower gastrointestinal tract, especially the large bowel. Plant fiber molecules are typically modified by gut bacterial enzymes, but they are not absorbed into the blood circulation, as are nutrients and many of the phytochemicals.

### Research Studies Demonstrating Dietary Benefits on Bone Mass and Bone Density

A few recent reports on the positive effects of a healthy diet, i.e., having an emphasis on several daily servings of plant foods, on bone are offered to demonstrate the maintenance, or possibly the gain, of both bone mass, measured as bone mineral content (BMC), and bone mineral density (BMD). Dual energy x-radiography (DXA) is the type of machine now commonly used to assess BMC and BMD of the whole body or of site-specific bones, such as the hip and lumbar vertebrae, which are most at-risk of fracture in older adults. These reports are summarized in Table 4.

A four-year study of the association between diet quality and risk of hip fracture in postmenopausal U.S. women, but not men of similar age, demonstrated a

statistically significant reduction of fracture risk with a high score. Those subjects with a high Mediterranean diet score were especially significant, but those with a high DASH diet score just missed being significant [18]. A report of the association between a Mediterranean-type diet and risk of hip fracture in 90,000 participants in the Women's Health Initiative came to a similar conclusion: fracture risk declines when a healthy plant-based diet is consumed [19]. In another report, healthy plant-based diets have been associated with a lower risk of death from chronic diseases in an analysis of U.S. adults in a representative sample of subjects in the NHANES III data [20]. This finding supports the contention that not only deaths associated with osteoporotic hip fractures diminish when a healthy plant-based diet is regularly consumed, but so are deaths from heart disease, diabetes, cancer, and other causes lowered.

**Table 4.** Reports on the Association of Healthy Plant-Based Diet and Risk of Bone Fractures.

Report	Study Population	Major Findings
Fung et al., 2018	Postmenopausal W and M over 50, (Cohorts: Nurses; Professional Men) but not M	Lower risk hip fracture W
Haring et al., 2016	Women's Health Initiative	Lower risk hip fracture W
Mazidi et al., 2017	NHANES 2005-2010	Lower risk hip fracture W/M
Orchard et al., 2018	Women's Health Initiative	Lower risk hip fracture W
Kontogianni et al., 2009	Convenience sample of Greek W	Lower risk hip fracture W
Byberg et al., 2016	2 Central Sweden Cohorts	Lower risk hip fracture W/M
Benetou et al., 2018	5 Cohorts: Greece, Sweden, USA	Lower risk hip fracture W/M

**Abbreviations:** W = women, M = men; NHANES = National Health and Examination Survey (USA).

Several other reports have specifically addressed the association between the long-term consumption of a healthy diet and a reduced risk of fracture, especially of the hip, investigating populations in the U.S.A. and other countries. A few examples are illustrative. A pro-inflammatory diet, which is rich in red meats and butter, is

associated with low BMD and increased risk of fracture in a NHANES sample of U.S. adults [21]. Results in women younger than 63 years were reported for participants in the Women's Health Initiative. Although the precise mechanism linking the inflammation to increasing bone loss by osteoclasts has not been established, the published reports are consistent in their findings for both older men and women. A study of women living in Greece revealed that adherence to a Mediterranean dietary consumption pattern, i.e., high intakes of fish and olive oil, was associated with greater bone mass and bone density of women [22]. Lastly, two reports from Sweden showed that the risk of hip fracture was reduced in both men and women by a Mediterranean pattern of food consumption [23, 24].

These impressive prospective investigations based on large population samples from several nations strongly support the benefits of a plant-based dietary pattern on bone health. The same general conclusion was offered in a review by investigators from Canada [25], but they also included findings from a few older publications that did not show a positive relationship between diet and bone measurements. These authors concluded the following in their review: "A dietary pattern that emphasized the intake of fruits, vegetables, whole grains, poultry and fish, nuts and legumes, and low-fat dairy products and de-emphasized the intake of soft drinks, fried foods, meat and processed products, sweets and desserts, and refined grains was implicated as being beneficial for bone health." The more recent data findings reported here, however, have been consistent in showing even more powerfully statistical skeletal benefits, especially in postmenopausal women but not always in similarly aged male adults. Further long-term prospective studies are needed to confirm and strengthen the current understanding of this important diet-bone relationship.

## Conclusions

A healthy diet of high quality can make a world of difference in the maintenance of bone mass and density of older adults. The Mediterranean way of eating and the DASH diet are two of the better ones to follow for

supporting a healthy skeleton. In addition, those who practice healthy eating behaviors are also likely to remain physically fit in the adult years, which makes it difficult to be assured that only dietary practices are the more significant in conserving bone mass and density in the later years of life.

Recommended intakes of the nutrients for optimal bone health by men and women during the adult years typically focus only on a few nutrients, especially calcium and vitamin D, but all the nutrients are important and need to be consumed in sufficient amounts. Calcium and vitamin D, however, are commonly low or deficient in the diets of adults, so that an overemphasis on these two nutrients has likely been made by well-meaning organizations and pharmaceutical companies to assure safety. The most important message from this review of diet quality and bone health is that every adult diet should emphasize a diet rich in plant foods but not to the exclusion of animal foods, only lesser numbers of servings each day.

## PEER REVIEW

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