Nutrition for Bone Health
Beyond Classic Nutrients, Calcium and Vitamin D

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Summary: The key for a strong and healthy skeletal system across life cycle is healthy eating habits by consuming a balanced diet every day. The IOF (International Osteoporosis Foundation) recommends that at every stage of life a nutritious, balanced diet promotes strong, healthy bones. A good diet includes sufficient calories and adequate protein, fat and carbohydrates, as well as vitamins and minerals - particularly vitamin D and the mineral calcium. In childhood and adolescence, good nutrition helps to build peak bone mass (maximum bone density, attained in the 20's) thereby reducing vulnerability to osteoporosis later in life. In younger and older adults, a nutritious diet helps preserve bone mass and strength. And in those who have had a fracture, it speeds and aids recovery and reduces the risk of having another fracture. Varied and enjoyable eating habits, including calcium-rich foods, are a recipe for a lifetime of strong bones and the high quality of life that comes with them.

NUTRITION AND BONE
Adequate nutrition is essential for the development and maintenance of the skeleton (bone health). Roughly 80–90% of bone mineral content is comprised of calcium and phosphorus. Protein is another crucial nutrient and is incorporated into the organic matrix of bone for collagen formation, upon which mineralization occurs. Besides this, protein seems to be involved in regulation of calcium absorption. Although calcium has been studied most extensively, other minerals such as magnesium, fluoride, zinc, copper, iron, selenium and vitamins D, A, C, K and folate are required for normal bone metabolism.

We cannot control our genes, and we cannot easily control our environments, but we can control what we eat- Robert P. Heaney, M.D. John A. Creighton University Professor

MACRONUTRIENTS:

Energy:
Adequate energy intake is required to maintain healthy body weight. Very low body weight is associated with lower peak bone mass development in the young and increased bone loss and risk of fractures in older persons

Protein:
Adequate dietary protein intake is essential for bone health. Protein being one of the major structural components of bone makes up roughly 50 percent of the volume of bone and about one-third of its mass. Insufficient protein intake is detrimental, both for acquisition of bone mass during childhood and adolescence and for the preservation of bone loss with aging (IOF 2007). Protein is essential for intestinal absorption of calcium.

Dietary protein intake below 0.8g/ kg bodyweight is associated with a probable reduction in intestinal calcium absorption sufficient to cause secondary hyperparathyroidism. The long term effect of the low protein diet induced changes on mineral metabolism is not known, but such a diet could be detrimental to skeletal health. Of concern are several recent epidemiological studies that demonstrate reduced bone density and increased rates of bone loss in individuals habitually consuming a low protein diet.

Essential fatty acids (EFA):
EFA’s have also been found to increase calcium deposition in bone, as bone calcification must take place in the presence of...
phospholipids. It is also been indicated that essential fatty acids appear to improve bone strength, possibly by generating collagen synthesis (International Osteoporosis Foundation – IOF 2011).

**VITAMINS:**

**Vitamin A (Retinol)**

Vitamin A plays an essential role in the development of osteoblasts, the bone-building cells that laydown new bone. A deficiency in vitamin A also limits calcium absorption and metabolism, which results in poor bone growth. Beta carotene is the pro-vitamin A found in plant foods.

**Vitamin D**

Vitamin D’s key function is the absorption of calcium. Dietary sources of vitamin D are limited to very few foods - such as salmon, tuna fish, and sardines. Most of the vitamin D required is produced by the body upon exposure to adequate sunlight. A normal diet alone (without exposure to sunlight) cannot supply the recommended daily vitamin D intake.

**Vitamin K**

Vitamin K is an essential micronutrient for bone health. Its role in post-translational modification of several matrix proteins, including osteocalcin, is now well established. Osteocalcin, a bone-specific protein made by osteoblasts, requires vitamin K for its posttranslational carboxylation, that is, maturation.

**Vitamin C**

Vitamin C is necessary for healthy bones; it is involved in the formation of collagen, the main protein in bone.

**Vitamin B6**

Vitamin B6 plays an important but indirect role in bone metabolism. Vitamin B6 is necessary for hydrochloric acid (HCl) production by the stomach, and HCl in turn is necessary for calcium absorption. Deficiency of vitamin B6, vitamin B12 and folic acid lead to Hyperhomocysteinemia which has been linked to increased risk for cerebrovascular disease and also found to have adverse effects on bone health. Vitamin B12 is not found in plants, but is abundant in animal protein. Vegetarians are therefore strongly advised to ensure adequate B12 intake.

**Minerals:**

**Calcium**

Calcium is one of the three major nutrients (calcium and vitamin D and protein) necessary for bone health. Calcium is the major structural component of bone tissue. Ninety nine percent of the calcium in the body is stored in the bone which therefore also acts as reservoir of calcium for maintaining calcium levels in the blood at about 10mg/dl.

Besides the amount of calcium in the diet, the absorption of dietary calcium from the food is also a critical factor in determining the bioavailability of calcium for bone development and maintenance.

The amount of calcium consumed regulates the efficiency of intestinal calcium absorption. Calcium absorption efficiency is increased when calcium intake is low and decreases when calcium intake is high. Thus calcium is a unique nutrient for which intestinal absorption is auto regulated in a homeostatic mechanism. Calcium deficiency leads to bone diseases like osteoporosis and osteopenia.

**Magnesium**

More than 50% of the magnesium in the body is found in bone tissue. It is necessary for the conversion of vitamin D into its active form. Magnesium is involved in calcium absorption metabolism and homeostasis and as well as in the formation of hydroxyapatite.
Note: It’s often overlooked that magnesium and calcium function together, so deficiency of one markedly affects the metabolism of the other. In fact, increasing calcium supplementation without magnesium supplementation can actually increase magnesium loss.

**Phosphorus**
Phosphorus combines with calcium to form a mineral crystal that gives strength and structure to bones and teeth. It is important to maintain the ideal ratio of these minerals in the diet that is one part calcium to one part phosphorus.

**Potassium**
Potassium is also known as the hidden bone guardian of bone health; this protective role relates mainly to neutralizing the bone-depleting acids that are produced during every day normal metabolic processes.

**Sodium**
High sodium intakes, particularly in association with a low calcium intake, can contribute to osteoporosis because they result in increased calcium excretion.

**Trace Minerals**
Trace Minerals, especially fluoride, iron, zinc, copper, manganese, and boron, function in bone metabolism, but in general their roles in preventing bone loss are not well established.

**Boron**
Boron appears to be utilized by osteoblasts for bone formation, as demonstrated in both rodent and human studies but whether boron is absolutely required for human bone formation has not been determined.

**Chromium**
Chromium helps to keep insulin activity in the body efficient, an effect that may be bone-protective in the following ways: i) by promoting the production of collagen ii) by moderating bone breakdown iii) and lowering calcium excretion.

**Copper**
Copper is needed for the cross-linking of collagen and elastin molecules, and it may have roles in other enzymes of bone cells. Like manganese, copper is an essential trace mineral that has only recently been found to play an important role in bone health maintenance. This role is still not fully understood, but it is known that by virtue of a copper-containing enzyme called *lysyl oxidase*, copper aids in the formation of collagen for bone and connective tissue and contributes to the mechanical strength of bone collagen fibrils — the long thin strands of proteins that cross-link to one another in the spaces around cells. Copper also helps inhibit bone resorption through a copper- and zinc-containing antioxidant called *superoxide dismutase*. This antioxidant neutralizes superoxide radicals produced by the bone breakdown cells called *osteoclasts* during bone resorption.

**Fluoride:** Fluoride enters the hydroxyapatite crystals of bone and within narrow limits, increases the hardness of bone minerals without any adverse effects. At intakes of 2 ppm or greater fluoride is considered to produce bone that is subject to increased micro fractures because of the change in the properties of the hydroxyapatite crystals.

**Iron:** Iron serves as a catalytic cofactor for the vitamin C – dependent hydroxylations of praline and lysine in collagen maturation. Iron also has other roles in osteoblasts and osteoclasts related to mitochondrial oxidative phosphorylation as well as in other enzymes, similar to the needs of other cells in the body.

**Manganese:** Manganese is required for the biosynthesis of mucopolysaccharides in bone matrix formation, and it acts as a cofactor in energy-generating reactions. In recent decades research has uncovered the special role manganese plays as a co-factor in the formation of bone cartilage and bone collagen, as well as in bone mineralization.
**NUTRITION AND BONE HEALTH**

**Zinc:** Zinc is essential for enzymes in osteoblasts that are responsible for collagen synthesis. In addition, an important enzyme in osteoblasts, alkaline phosphatase, requires zinc for its activity. Proper calcium absorption also depends on zinc, and a deficiency prevents full absorption of calcium. It’s essential for bone healing, and increased amounts are found at the sites of bone repair. Zinc is a constituent of the hydroxyapatite mineral crystals of bone, and plays a role in the regulation of bone turnover. Zinc is also needed for the correct functioning of alkaline phosphatase, which is required for bone mineralization.

**Silicon:** Recent research recognizes silicon as an essential mineral for bone formation.

**Non-nutrients that influence bone health:**

**Dietary Fiber:** Excessive dietary fiber intake may interfere with calcium absorption.

**Isoflavones:** The isoflavones in soybeans, as well as chick peas function both as estrogen agonists and antioxidants in bone cells, may result in the inhibition of bone resorption.

**Conclusion:** Maintaining optimal bone health is a life-enhancing strategy. Overall diet patterns are likely as important as or more important to growing bone than adequacy of individual nutrients. The whole diet needs to be considered to determine if nutrients needs are being met. The whole diet should contain constituents that can enhance or inhibit nutrient absorption, influence their excretion, or influence bone turnover. The nutrients that are essential for bone health do not function in isolation and all work together to keep one’s bones standing strong all his/her lifelong.

**Nutrients Found in the Foods**

**Grains (cereals)-** good source of B vitamins (except B12), vitamin E, magnesium, iron, silica and fiber. (Ragi is a rich source of calcium, iron and manganese)

**Vegetables** – good source of fiber, folate, potassium, β-carotene (provitamin A), vitamin C and other antioxidants. Green leafy vegetables also contain calcium and other minerals and vitamin K.

**Fruits** – good source of β-carotene (provitamin A), vitamin C, folate, potassium and antioxidants

**Milk and Dairy** – good source of calcium, vitamin D, protein, phosphorus, zinc, vitamin A, vitamin B12, potassium and essential fatty acids.

**Meats** – good source of protein*, zinc, iron, vitamin B12, vitamin B6 and Niacin.

**Eggs** - good source of protein, riboflavin, vitamin B12, phosphorus and selenium.

**Fish and Shellfish** - good source of protein, iodine, iron, zinc, niacin and omega-3 fatty acids.

Oily fish (salmon, mackerel, lake trout, herring, sardines, and albacore tuna) contain naturally occurring vitamin D.

**Legumes, Nuts and Seeds:**

Legumes, (whole grams, dried beans) are a good source of protein, calcium, iron and fiber.

Nuts are a good source of protein, calcium, phosphorus, magnesium, potassium.

Seeds are a good source of protein, calcium and iron.

Mehti seeds (fenugreek) are a good source of soluble fiber.

Flax seeds are also good source of ALA (15 g meets the RDA for Omega-3 Fatty acids -3g/day)

Choosing variety of foods under each category will ensure variation and nutritional adequacy.

**References**