Publication on

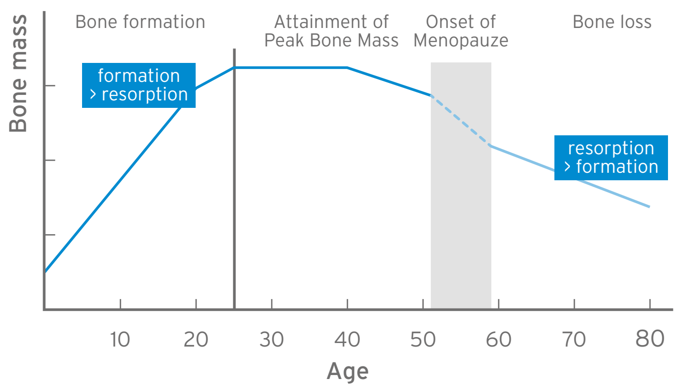
Dairy and bone maintenance

Heredity is the most important factor for strong bones. Genes determine the variation in peak bone mass, the maximum bone density, for 60-80%. Nutrition and exercise also play important roles in the development of the bones while growing (children) and in the maintenance phase of the bone tissues in adults and elderly.

Bone mass

Bones consist of a protein matrix, which is filled with calcium phosphate and other minerals, such as sodium, magnesium, potassium and zinc. During life, bone tissue is constantly broken down (resorption) and built up again (formation) for recovery after minor 'damage' and for adjustment of the strength to the load exerted on a bone. From birth up to the age of about 30 years, the formation of bone exceeds the bone resorption and so the bone density increases, resulting in a peak bone mass (PBM). In the period between birth and the age of 2 years bones are growing fast. A second period of fast bone growth is seen during adolescence. (International Osteoporosis Foundation, 2001 en 2013) The peak bone mass decreases as from the age of 50, more with women (figure 1) than with men. The higher the peak bone mass, the stronger the bones at a later age. (Dawson-Hughes *et al.*, 2013; Huth *et al.*, 2006; Rizzoli *et al.*, 2012) It is important to pay attention to the build-up of bones already from a young age. A 10% increase of the peak bone mass of children reduces the risk of a fracture at a later age by 50%. (International Osteoporosis Foundation, 2001 en 2013)

FIGURE 1 Course of the bone mass during life with women

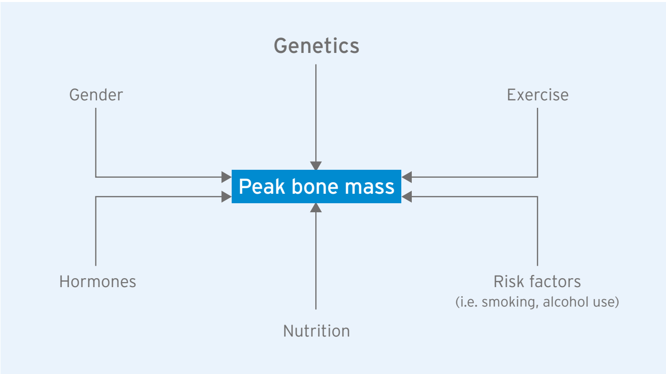


Source: Dawson-Hughes *et al.*, 2013

Factors determining the bone mass

Genetic factors determine the variation in peak bone mass for 60 to 80%. Besides, sufficient (weight-bearing) physical exercise and a diet with sufficient calcium, vitamin D and protein play important roles. Hormones (sex and growth hormones), ethnicity, gender, use of medicines, BMI, smoking and use of alcohol are decisive for the bone mass as well. (International Osteoporosis Foundation, 2011; Rizzoli *et al.*, 2012)

FIGURE 2 Factors influencing the peak bone mass



Source: Rizzoli *et al.*, 2012

Good nutrition and a healthy lifestyle are essential for healthy, strong bones during the entire life. At an older age, strong bones and well-developed muscles are important to remain mobile and independent for a longer time. (International Osteoporosis Foundation, 2011)

Nutrients related to bone mass

The most important nutrients that are required for the growth and development of bones with children are calcium, vitamin D and protein. These nutrients contribute to the maintenance of bones in adult life. Next to that phosphorus, magnesum and zinc play a role in the maintenance of normal bones. (EFSA 2009 en 2010). Therefore it is important to get a sufficient amount of these nutrients (FAO, 2013; International Osteoporosis Foundation, 2011). The composition and structure of the bone tissue is mainly determined by calcium, phosphorus and protein (Bonjour *et al.*, 2013).

Calcium

Calcium is necessary for the maintenance of bones and teeth. As 99% of the calcium in the body is stored in the bones the bone tissue plays a crucial role in calcium metabolism. Calcium is absorbed both actively and passively in the intestine. The active process chiefly takes place in the first part of the small intestine and depends on calcitriol (1,25-dihydroxyvitamin D), which is obtained through a stepwise activation of vitamin D by the liver and the kidneys. Active calcium absorption also depends on vitamins D2 and D3, obtained from the food or through 7-dehydrocholesterol activation by sunlight in the skin (previtamin-D3). The passive absorption takes place by means of diffusion in virtually all parts of the small intestine and a minor part in the large intestine. The active absorption is particularly relevant in case of a low calcium intake. A low solubility of calcium in the lumen of the intestine, for example as a result of complex formation with phytate from grains or oxalate from spinach, reduces the availability for absorption. A high calcium density in food provides more available calcium through the passive transport along the intestinal wall. (ILSI, 1999) The physiological aspects, such as calcium intake in the past, age (absorption decreases when getting older), pregnancy, breastfeeding (higher calcium absorption) and the vitamin D status, are decisive for the availability of the consumed calcium (FAO, 2013; International Osteoporosis Foundation, 2011).

In general, foods such as milk, milk products and cheese are considered to be good natural sources of calcium because of their high calcium density and good fractional absorption (under normal conditions about one third of the available calcium is absorbed). (Weaver and Heaney, 2006). A glass (150 ml) of semi-skimmed milk contains 183 mg calcium. Vegetables that contain calcium and are low in oxalate are broccoli, sweet potato, kale and bok choy (FAO, 2013). Their calcium content per serving ranges from 35 to 79 mg. Calcium and dairy intake recommendations differ per age category and per region in the world.

TABLE 1 Bioavailability of calcium

Product	mg Ca/100 g product	Absorption efficiency (%)	mg Ca available for the body/ 100 g	g product needed to meet the available Ca in 200 ml of milk
Broccoli (cooked)	33	61,3	20,2	387
Spinach (cooked)	84	5,1	4,3	1828
Milk (semi skimmed)	122	32,2	39,3	200

Source: Miller *et al.*, 2007

Vitamin D

Vitamin D is most efficiently absorbed from the intestine when fat is present. In the intestinal cells it is packaged in the chylomicrons, together with cholesterol, triglycerides and lipoproteins, and it reaches the bloodstream through the lymph system. The liver hydroxylates vitamin D into 25-hydroxyvitamin D (25OH-D) and the kidneys take care of the production of the hormone calcitriol, the biologically active vitamin D. Calcitriol stimulates the absorption of calcium and phosphate from the intestine, which is required for mineralising the bone tissue. Together with the parathyroid hormone (PTH) from the parathyroid glands (parathyroids), calcitriol also controls the release of calcium from the bone and the retention of calcium by the kidneys, depending on how much calcium the body needs. A third hormone, calcitonin produced by the thyroid reacts to too high calcium values in the blood serum by limiting the bone resorption. Vitamin D also has a direct effect on the production and differentiation of osteoclasts (bone resorption cells). (Heaney, 2009; IOM, 2011; Bonjour *et al.*, 2013; FAO, 2013; International Osteoporosis Foundation, 2011)

25-hydroxyvitamin D is generally considered to be a robust and reliable parameter of the vitamin D status. An intensive discussion is going on about which threshold values are to be used for this indicator with respect to specific target groups within the population or health areas. (Cashman and Kiely, 2013). Fat fish types, such as herring, salmon and mackerel, contain vitamin D.

Protein

Protein is a building block for muscles and bones. This macronutrient plays a role in the growth and preservation of the muscle mass and the maintenance of the bone mass (EFSA 2010 en 2011). Dairy products, eggs, fish, meats, tofu and legumes are good sources of protein.

Protein in food increases the production of IGF-1 (Insulin-like Growth Factor) by the liver. As IGF-1 stimulates the calcitriol

production in the kidneys, the systemic availability of calcium and phosphorus increases as well (Bonjour *et al.,* 2013). A higher protein intake may lead to a higher acidity of the blood and so a higher calcium level in the urine (Fenton *et al.,* 2008). It was demonstrated that this does not have any effect on the calcium balance in the body, which is the difference between the calcium intake through food and the excretion through urine and faeces. In case of a higher protein intake, the body actually also absorbs more calcium from food. (Calvez *et al.*, 2012; Kerstetter *et al.,* 2011)

Phosphorus

Phosphorus makes a contribution to the maintenance of the bone mass (EFSA, 2009). Phosphorus is particularly found in dairy products, wholemeal products, cheese, meat, fish and legumes. 85% of the total amount of phosphorus present in the body is stored in the bones.

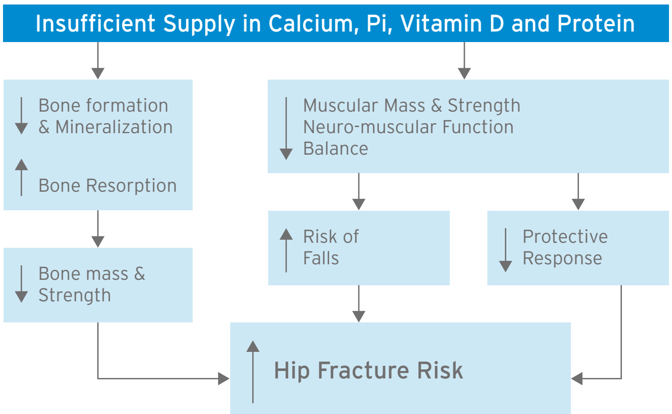
Inorganic phosphate passes the intestine through both active and passive transport. The serum values for phosphate are largely determined by the consumed amount, calcitriol (absorption from intestine and bone) and PTH (resorption from bone, increase of excretion by kidneys). Apart from this osteocytes in the bone tissue produce the hormone FGF-23 (fibroblast growth factor 23). FGF-23 decreases the absorption of phosphate from the intestine and increases the excretion by the kidneys. The osteocytes are involved in the mineralisation process in the bone and seem to play a regulating role in the functioning of both osteoblasts (formation) and osteoclasts (resorption). (Penido and Alon, 2012)

The phosphorus requirement is closely related to the calcium requirement. A recent meta-analysis of calcium balance studies in relation with the intake of phosphate supplements showed that a higher phosphate intake lowers the excretion of calcium in the urine and slightly raises the calcium retention, independent of the calcium intake. (Fenton *et al.,* 2011)

Bone strength

A high peak mass at a young age and the decrease of bone loss at a later age are two ways to reduce osteoporosis risk (Weaver, 2013). The nutrients calcium, vitamin D and protein, as well as the interaction between these nutrients, play a role in the maintenance of bones (Bonjour *et al.,* 2013). An inadequate intake of protein may also reduce muscle mass, which increases the risk of a fracture caused by a fall.

FIGURE 3 Schematic view of the effects of an inadequate intake of calcium, vitamin D, protein and phosphorus related to the risk of a hip fracture.



Source: Bonjour *et al.*, 2013

Scientific discussion

A recently published study demonstrated that a higher milk consumption during the teenage years is related to an increased chance of a hip fracture with men at a more advanced age (Feskanich *et al.,* 2013). This effect was not shown in connection with women. The authors give the growth in length resulting from the milk consumption as a possible explanation for this. In the study of Feskanich (2013) the participants were asked to describe their milk consumption during their teens. This intake was compared with the milk consumption in the period in which the respondents suffered from a fracture. This was many years later. In the same scientific journal Weaver (2013) brings the rightfulness of the conclusions of the study up for discussion. She particularly criticises the research methods. Weaver (2013) emphasises that other studies show that milk consumption during childhood reduces the chance of a bone fracture at the adult age. Also research among milk drinkers and non-milk drinkers (including persons with a lactose intolerance) shows that the non-milk drinkers have a higher fracture prevalence than milk drinkers (Goulding *et al.*, 2004; Honkanen *et al.*, 1997)

Milk, milk products and cheese

A glass (150 ml) of semi-skimmed milk contains about 23% of the daily reference intake (DRI) for calcium, 22% of the daily reference intake for phosphorus and 5.1 g of protein. Apart from the above-mentioned nutrients, 100 grams of cheese also provide almost half of the daily reference intake for zinc (9% per slice of 20 g). Because of the contribution that milk, milk products and cheese make to the intake of nutrients that support our bones, these are globally recommended by food authorities (FAO, 2013).

Although calcium supplements can be used as a complement when the nutrition does not provide sufficient calcium, calcium through food is more recommended than the use of calcium supplements (Bauer, 2013). Besides, a calcium supplement is not a replacement for foodstuffs such as milk, milk products and cheese, as these products do not only contain calcium but other nutrients as well, which together play a role for our bones.

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