Osteoporosis & Calcium Metabolism and Absorption

Whether milk is good or bad for calcium intake is a question that you will often have to answer in clinical practice. Many people think that the consumption of milk and dairy products will prevent osteoporosis—a belief that is being promoted in the media and through advertising campaigns but is also deeply rooted in our cultural heritage. Is there any medical consensus regarding this controversial issue? What have recent studies found out? How can physicians develop a well-founded stance on the subject without falling back on fatalistic platitudes? And most importantly: How can you as a medical practitioner adequately advise your patients on osteoporosis prevention while simultaneously dispelling any unfounded myths?

Osteoporosis: Etiology and Symptoms

Osteoporosis refers to a decrease in bone mass and density leading to an increased number of falls and fractures in old age. Concerning etiology, there are two different forms of osteoporosis:

The most common type is **primary osteoporosis**. It mostly affects women (90 %) and usually stems from hormonal changes (estrogen deficiency) during menopause (postmenopausal osteoporosis, type I osteoporosis). Another subclass of primary
Osteoporosis is senile osteoporosis (type II osteoporosis), which affects both women and men equally and refers to a bone loss related to aging. Risk factors that favor the development of primary osteoporosis are a lack of physical exercise, vitamin D deficiency and alcohol and nicotine abuse.

### Risk factors are:

<table>
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<th>Nonmodifiable</th>
<th>Modifiable</th>
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<tr>
<td>- Age</td>
<td>- Premature menopause (&lt; 45 years) or hypogonadism</td>
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<td>- Caucasian or Asian ethnicity</td>
<td>- Current tobacco use</td>
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<tr>
<td>- Female sex</td>
<td>- Heavy alcohol use</td>
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<tr>
<td>- Thin body habitus (&lt; 127 lbs)</td>
<td>- Sedentary lifestyle</td>
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<td>- Positive family history</td>
<td>- Dietary deficiencies (calcium, vitamin D)</td>
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The causes of the less common secondary osteoporosis are immobilization, endocrine disorders (e.g., Cushing syndrome, hyperthyroidism, primary hyperparathyroidism) and/or long-term treatment with medication that induces osteoporosis (e.g., glucocorticoids, anticonvulsants, glitazone, antiandrogens).

**Note:** Medication-induced osteoporosis is an often tested subject in exams. Next to glucocorticoids and the above-mentioned drugs, the long-term administration of heparin can also result in osteoporosis.

Early symptoms of osteoporosis often include diffuse back pain. With a progressive course of the disease, patients may develop angular kyphosis (a.k.a. gibbus) or experience a loss in height due to vertebral compression fractures. Other pathological fractures may affect the long bones (femur, humerus).

Diagnosis of osteoporosis is made based on history, imaging of the spine (x-ray on two planes) and the measurement of bone mineral density (DXA). Laboratory studies should include the determination of calcium and bone metabolism (Ca, PO, ALP) as well as other parameters that might be altered in connection to secondary osteoporosis (CBC, ESR/CRP, creatinine, TSH, vitamin D, PTH).

**Note:** Osteoporosis is diagnosed when the T-score is < -2.5 on the DXA.

If the osteoporosis has not manifested yet, a progressive course can be prevented by prophylactic intake of calcium and vitamin D as well as regular physical exercise (possibly physical therapy). Clinically manifested osteoporosis is treated with medication, for instance, with bisphosphonates.

Which foods are good sources of calcium and how does the body absorb it?

### Calcium content of selected foods

As a physician, you should always strive to establish a doctor-patient relationship based on mutual trust. This implies not having an exclusively pathogenetic perspective but also contributing to overall health maintenance. This can be done by providing guidance on a health-promoting lifestyle, including nutrition counseling. Use your status and knowledge to do away with fallacious beliefs regarding, e.g., the physiology of nutrition!

The following table gives you an overview of the calcium content of selected foods. While the calcium content of dairy products is indeed higher than in other foods, this should not lead to hasty conclusions as the absorption of calcium from these food sources is influenced by the combination of other food products (see below):

<table>
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<tr>
<th>Portion</th>
<th>Food Source</th>
<th>Calcium content in mg per 100 g of food</th>
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To view the table correctly, please refer to the PDF version.
Calcium Metabolism and Absorption: Promoting and Inhibiting Factors

Without going into molecular biology detail, you should know about the basic facts of the calcium metabolism—which might require revisiting some old pre-med study material. The following substances are involved in the hormonal control of calcium balance:

- Parathyroid hormone (PTH)
- Calcitriol, the active form of vitamin D (1,25-dihydroxycholecalciferol; 1,25-(OH)2-D3)
- Calcitonin

Calcitriol enhances the absorption of calcium (by increasing the enteric calcium resorption and reducing the renal calcium excretion), which then becomes incorporated into bones under the influence of calcitonin (inhibition of osteoclasts). Parathyroid hormone, on the other hand, extracts calcium from the bones (demineralization of the bones through activation of osteoclasts).

The ratio between intake and excretion of calcium is referred to as calcium balance, which is dependent on age. The maximum bone mineral density (BMD) is reached around the age of 30; from then onward, it continuously decreases by 1 % per year, even more so in women due to the changed estrogen status after menopause. With advanced age, the activity of the osteoclasts becomes predominant, and the calcium balance consequently rises.

Also, a lack of sunlight exposure leads to vitamin D deficiency (diminishing the endogenous formation of calcitriol). This, in turn, results in a decrease in enteric calcium resorption and in an increase in renal calcium excretion: more calcium is being excreted than absorbed. The calcium balance becomes negative.

Independent of the hormonal regulation of the calcium metabolism, there are some foods and substances which influence the enteric calcium resorption (based on data taken from “DocMedicus Vitalstofflexikon“):

The following factors inhibit calcium resorption through, e.g., complexation:

- Oxalic acid: in rhubarb, spinach, star fruit, cocoa and others.
- Phytic acid: in cereal bran and others.
- **Phosphoric acid**: in processed meats, cheese spread, soft drinks and more; a calcium-phosphate ratio of 1 : 1.0 - 1.2 in your diet is considered optimal.
- Tannic acid: in coffee, black tea, and some herbal teas.
- Dietary fibers rich in uronic acid: whole-grain products, fruits, and vegetables, etc.
- Sugars and sugar substitutes which are not at all, or are not well, resorbed; e.g., sorbitol contained in mustard, mayonnaise, etc.
- (Long-chain, saturated) fatty acids such as stearic acid contained in animal and vegetable fat.

**These factors enhance calcium resorption:**

- Various single doses of calcium spread throughout the day.
- 1,25-dihydroxycholecalciferol (1,25-(OH)2-D3): stimulates the intracellular synthesis of calbindins.
- Easily resorbed sugars such as lactose (milk sugar).
- Lactic acid.
- Citric acid.
- Amino acid
- Casein phosphopeptides.

Non-resorbable carbohydrates, such as inulin, fructooligosaccharides and lactulose, which become fermented to short-chain fatty acids through bacterial processes in the ileum (final section of the small intestine) and colon (large intestine). The consequent decrease of the pH level in the intestinal lumen leads to an increased release of bound calcium so that more free calcium is available for passive resorption.

According to a study by the Human Resource Council conducted in 2014, only 1.5 % of U.S. citizens identify themselves as vegetarian and 0.5 % as vegan (sample n = 11,399). The most common and conventional dietary style in the Western world still includes dairy as well as meat products. **Phosphates are one of the main reasons why the calcium in milk cannot be absorbed** and is excreted through complexation. Phosphates are mostly found in industrially processed foods containing flavor enhancers and preservatives.

This means that a classic bacon and eggs breakfast with café au lait or a breakfast sandwich do not provide a sufficient amount of calcium for the average omnivore consumer.

Vegans, on the other hand, while they do not consume products as rich in calcium as dairy products are, neither do they take in the phosphates contained in meat and dairy.
A study by the Australian Garvan Institute of Medical Research, published in 2009 in *Osteoporosis International*, compared the bone density of vegan women (strictly vegan Buddhist nuns) with those of non-vegetarian women. The recommended daily calcium intake is 1,000 mg. The vegan nuns only ingested an average of 370 mg/d but had the same post-menopausal bone density as the non-vegetarian women.

In 2014, the *British Medical Journal* published a Swedish cohort study on the question of whether high milk consumption influences the risk of bone fractures at old age. The study comprised of one male and one female cohort of about 50,000 participants, who were administered food frequency questionnaires over a time span of 20 years.

The study showed an association of higher milk intake with increased mortality in both men and women and with a higher fracture incidence in women. The authors cautiously attributed these result to a chronically higher exposure to D-galactose, which causes permanent oxidative stress and inflammatory processes (as observed by biomarkers 8-iso-PGF2α and serum interleukin 6). In contrast to milk intake, they considered cheese and fermented dairy products (e.g., soured milk) as less of a risk factor due to their lower lactose and galactose content.

**Summary**

The three main pillars of bone health are **physical activity, vitamin D and calcium**.

Focusing exclusively on calcium-rich foods without regular weight-bearing exercise will not be of much use to your patients. In turn, dairy products are not essential as a calcium source; some studies even suggest the opposite.

As of yet, scientific studies have not reached a final consensus on the role of milk for bone health, and there might come about a change of dietary guidelines, especially regarding the best way of calcium intake and food sources. Whether the consumption of milk should be discouraged (lactose intolerance, diseases associated with insulin-like growth factors ...), is yet to be conclusively determined and will require comprehensive studies on possible long-term consequences.
References


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