Skeletal benefits of vitamin D supplementation in healthy adults are uncertain. The IOM recommends 600 IU for women aged between 50 and 70 years and 800 IU daily for those aged older than 70 years, stating that these intakes were sufficient to achieve serum 25-OHD levels of at least 20 ng/mL in most postmenopausal women. Meta-analyses of the effects of calcium and/or vitamin D on fracture risk provide inconsistent conclusions, with most reporting no benefit on fracture risk.[82,83] In the bone health substudy in the Vitamin D and Omega-3 Trial, the bone density effects of 2,000 IU of cholecalciferol (vitamin D_3) daily were evaluated over 24 months in healthy women (average age, 63 y) with baseline serum 25-OHD levels of 27.6 ng/mL.[84] No effect was observed in the entire study group or in the subgroup with baseline serum 25-OHD levels less than 30 ng/mL. The inability to demonstrate effectiveness may be related to calcium and vitamin D being threshold nutrients; severe deficiencies may be harmful, but intakes more than the threshold to avoid deficiency does not provide additional benefit. Salutary effects of vitamin D with calcium on fracture risk have been observed most often in institutionalized or vitamin D-deficient older adults.[85] Most studies evaluating the effects of calcium or vitamin D have not restricted the study population to deficient participants. The US Preventive Services Task Force (USPSTF) concluded that there was insufficient evidence to assess the balance of the benefits and harms of daily supplementation with vitamin D 400 IU or more and calcium 1,000 mg or more daily for the primary prevention of fractures in community-dwelling, postmenopausal women.[86] They also recommended against the use of vitamin D supplements to prevent falls.[87]

Women with osteoporosis do not require more calcium than women with normal BMD, and there is no convincing evidence that taking calcium and vitamin D supplements improves the effectiveness of osteoporosis drugs.[88] Adequate intakes of calcium and vitamin D are recommended when taking osteoporosis drugs to reduce the risk of treatment-induced hypocalcemia.[5]

Protein intake

Studies of relationships between protein intake and BMD or fracture risk have been inconsistent. In fall-prone older adults who were losing weight, higher protein intake was associated with reduced fall frequency.[89]

Probiotics

The gut microbiota can influence several aspects of bone health, including the absorption of calcium and vitamin D and immune response. In animal models, probiotics may prevent bone loss associated with estrogen deficiency, and preliminary studies in humans suggest that probiotics could have a role in preventing bone loss.[90]

Other supplements

Strontium is a heavier divalent cation than calcium and increases BMD by being deposited in the skeleton. *Strontium ranelate*, a proprietary strontium salt, reduced the risk of vertebral and nonvertebral fractures in postmenopausal women with osteoporosis.[91] This drug was never approved in the United States or Canada, and it is no longer available in the rest of the world because of concerns about increased cardiovascular risk. Other strontium salts (citrate, chloride) are promoted to support bone health in the United States, but there is no evidence for their effectiveness or safety.

Meta-analysis found no meaningful relationship between *magnesium* intake and skeletal health.[92] Routine magnesium supplementation is not recommended in healthy adults with normal diets.

Various *vitamin K* supplements have been promoted to improve bone health. A recent meta-analysis found no evidence that vitamin K affects bone density or vertebral fracture risk in postmenopausal women and that the evidence was insufficient to confirm a reduction in clinical fractures.[93]

Phytoestrogens, including isoflavones, are plant-derived compounds with weak estrogenic activity. In a systematic review, some isoflavones (aglycone form) had a moderately beneficial effect against estrogen-deficiency bone loss.[94] Isoflavones are not recommended as effective strategies to prevent or treat postmenopausal osteoporosis.[95]

There is also no compelling evidence for a beneficial effect of boron, zinc, black cohosh, berberine, or dehydroepiandrosterone on BMD or fracture risk in postmenopausal women.

Avoiding harmful lifestyle factors

Cessation of smoking and limiting alcohol intake are important general health measures. The AEs of smoking on bone health appear to reverse when smoking is stopped.[96]

Physical activity and exercise

Skeletal mass is strongly influenced by mechanical loading. During growth in children, impact-loading exercise programs induce small gains in BMD, whereas diseases causing immobilization are associated with low bone mass. A *Cochrane* review and several meta-analyses found relatively small, statistically significant effects of exercise on BMD compared with control groups in postmenopausal women.[97-99]

The perception that exercise can reverse osteoporosis in postmenopausal women by inducing new bone formation is unfounded. Programs of regular exercise for general health can be recommended, especially those that increase muscle strength and improve balance, leading to fewer falls. Women with osteoporosis, especially those with vertebral fractures, should avoid activities that involve lifting or pulling with forward spine flexion or rotation and may benefit from an exercise program to stretch and strengthen the extensor muscles of the spine.[100]

Fall prevention

At least one-third of women aged 65 years and older experience one or more falls each year, and the risk of falling and of fracture increases with advancing age.[101] Because most fractures occur as a result of a fall, attempts to reduce the