Osteoporosis and Lifestyle

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Summary Skeletal tissue is formed during the first two decades of life; then a constant bone mass is maintained until 40 y of age. In the case of women, the bone mass is rapidly reduced at menopause at around 50 y of age. After that, bone mass slowly decreases in both men and women who have passed the 70-y-old mark. The National Institute of Health Consensus Conference adopted the definition of osteoporosis as a skeletal disorder that is characterized by compromised bone strength leading to a predisposition for and an increased risk of fracture. Since osteoporotic fractures are the third-highest cause for becoming bedridden, the maintenance of healthy bones is an important factor in extending a person’s healthy lifespan. Bone mass is influenced by many factors, such as nutrition, physical activity, smoking and alcohol intake, as well as by genetic factors. Thus, a healthy diet providing balanced nutrients including calcium, vitamin D, vitamin K and protein, regular physical activity, and not smoking help maintain bone health and delay or prevent osteoporosis. Some functional foods containing soy isoflavones, milk basic protein and n-3 fatty acid may help promote bone health.

Key Words osteoporosis, bone, nutrition, physical activity, lifestyle

Since the incidence of osteoporosis is increasing each year, and fractures are the third-highest cause for becoming bedridden, the maintenance of healthy bones is an important factor in extending a person’s healthy lifespan. Skeletal tissue is formed during the first two decades of life; then a constant bone mass is maintained until 40 y of age. In the case of women, the bone mass is rapidly reduced at menopause at around 50 y of age. After that, bone mass slowly decreases in both men and women who have passed the 70-y-old mark (Fig. 1).

In the postmenopausal bone tissue, high bone turnover is observed because the bone resorption rate is higher than the bone formation rate, thereby causing a decrease in bone mass. This phenomenon is mainly attributable to estrogen deficiency, which protects osteoclast activity involving bone resorption (1).

Bone mass is influenced by many factors, such as nutrition, physical activity, smoking and alcohol intake as well as by genetic factors. The nutritional requirement for maintaining bone health is the most important factor for prevention of osteoporosis. Adequate intake of calcium, vitamin D, vitamin K and protein is essential for preserve healthy bone. Furthermore, recently some functional food components such as isoflavones, milk basic protein (MBP) and omega-3 fatty acid have come to be considered as potentially effective ingredients for bone health.

Definition of Osteoporosis

The National Institute of Health (NIH) Consensus Conference adopted the definition of osteoporosis as a skeletal disorder that is characterized by compromised bone strength leading to a predisposition for and an increased risk of fracture (2). Seventy percent of bone strength is determined by bone mineral density and 30% by bone quality factors such as matrix protein, bone turnover rate, micro-structure, micro-fractures and calcification.

Effects of Diets/Nutrients on Bone Mass

Calcium and vitamin D

Skeletal tissue consists of bone matrix proteins (e.g., collagen) and minerals (e.g., calcium and phosphorus). Therefore, it is obvious that protein and minerals, especially calcium, are important nutrients for the prevention of osteoporosis. More than 99% of the body’s calcium is found in the skeletal tissue and in the teeth. The recommended daily allowance (RDA) of calcium, based on the estimated average requirement in the Dietary Reference Intakes (DRIs) for Japanese (2015), is 650 mg/d for adult men and women (30–49 y old) (3).

Vitamin D stimulates calcium absorption in the intestine and induces calcium re-absorption in the distal tubules of the kidneys. Vitamin D promotes bone formation indirectly via calcium in normocalcemic conditions. On the other hand, when the dietary calcium is low, serum calcium will decrease and the hormonal form of vitamin D, 1,25(OH)2D, is needed to mobilize calcium from bone promptly. Thus, bone resorption is the direct action on bone of vitamin D. 1,25(OH)2D also increases calcium absorption in the intestine as well as the kidneys, and normalizes calcium balance. The adequate intake (AI) of vitamin D in the DRIs for Japanese (2015) is 5.5 μg/d for adult men and women (3).
Vitamin K

Vitamin K plays an important role in bone formation through osteocalcin activation.

There are 2 major forms of dietary vitamin K: phylloquinone (PK) and menaquinone (MK). PK is present in vegetables, whereas MK is either produced by bacteria or is present in animal tissues. However, there is evidence that MK-4 is synthesized from dietary PK and seems to act as an active form of MK (4). Previous studies have reported that treatment of a high dose of MK-4 (45-mg) prevents osteoporotic fractures and postmenopausal bone loss (5). Therefore, in Japan, this dose is prescribed for the treatment of patients with osteoporosis. According to DRIs for Japanese (2015), the AI of vitamin K for Japanese men and women aged over 18 y was set at 150 mg/d in terms of maintaining blood coagulation (3). However, a previous study suggested that the amount of vitamin K required for maintaining bone health is higher than the amount required for blood coagulation (6). Indeed, in our previous study, the serum concentrations of undercarboxylated OC (ucOC) in healthy postmenopausal Japanese women with around 250 mg/d of vitamin K intake were nearly at fracture-inducing levels of ucOC. In the study, MK-4 supplementation at 1.5 mg/d accelerated the rate of osteocalcin (OC) γ-carboxylation (7). MK-4 supplementation at 1.5 mg/d also prevented bone loss in the forearms of postmenopausal Japanese women (7). In epidemiological studies, it has been also reported that higher concentrations of serum vitamin K are required to prevent osteoporosis in elderly people (8).

On the other hand, it has been reported that a single nucleotide polymorphism (SNP) in the gamma-glutamyl carboxylase (GGCX) gene is associated with the BMD. Tsugawa et al. investigated the effect of GGCX polymorphism on the correlations among the vitamin K intake, level of serum vitamin K, and ratio of ucOC to intact OC in healthy young Japanese subjects. According the results, dietary vitamin K intake from vegetables was significantly correlated with the level of serum PK, and vitamin K intake from fermented beans (natto), was also significantly correlated with the level of serum MK-7.

Adequate vitamin and mineral intake should be considered for the preservation of bone health. The recommended intake values of nutrients related to bone metabolism, as reported by the Japan Osteoporosis Society, are shown in Table 1 (9). Protein also plays an important role in preserving bone quality. Excessive intake of sodium, phosphorus, caffeine, alcohol, and smoking are detrimental to bone health and should be avoided.

**Effects of Functional Food Components on Bone Health**

**Soybean isoflavones**

Soybean isoflavones (daidzein, genistein, and glycitein) are commonly referred to as phytoestrogens because they preferentially bind to and transactivate estrogen receptor. This suggests that isoflavones may exhibit estrogenic or anti-estrogenic actions in various tissues. Isoflavones have received considerable attention because of their potential to preserve bone mass in postmenopausal women, as well as osteoporosis animal models (10). Epidemiological studies in Asia have shown that higher intakes of soy and soy products are associated with lower prevalence of osteoporosis and menopausal syndrome (11). Recent meta-analyses have shown beneficial effects of isoflavone on postmenopausal bone metabolism in Asian women, although there have been several randomized controlled trials that demonstrate no relationship between isoflavone intake and bone mass in Caucasian women with high calcium and vitamin D intake (12). Isoflavones reduced urinary deoxy-pyridinoline, which is one of the bone resorption markers, in postmenopausal Japanese women.

**Milk basic protein (MBP)**

It is well known that milk has beneficial effects on bone health. MBP, a basic protein fraction of milk whey protein, plays a functional role in bone remodeling. MBP consists of several active substances that promote bone formation and suppress bone resorption. It has been shown that whey protein and MBP enhances bone strength of the femur in osteorotic animal models. In

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**Table 1. Assessment and Recommendation of Calcium and Vitamins from Guideline for Prevention and Treatment of Osteoporosis 2011 (22).**

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Intake</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>700–800 mg/d</td>
<td>Dairy products, Soy, Fish etc.</td>
</tr>
<tr>
<td></td>
<td>400–800 Unit/d</td>
<td>Fish</td>
</tr>
<tr>
<td>Vitamin D</td>
<td>(10–20 μg/d)</td>
<td>Mushroom</td>
</tr>
<tr>
<td>Vitamin K</td>
<td>250–300 μg/d</td>
<td>Natto</td>
</tr>
<tr>
<td>Protein (reference)</td>
<td>Female: 50 g</td>
<td>Vegetables</td>
</tr>
<tr>
<td></td>
<td>Male: 60 g</td>
<td>Meat, Fish, Egg, Bean</td>
</tr>
</tbody>
</table>

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**Fig. 1. Relationship between aging and bone mass.**
addition, human studies with healthy adults and young women clearly showed that MBP improved the balance of bone metabolism and increased bone mineral density (13).

The Consumer Affairs Agency of the Japanese government approves functional food ingredients as Foods for Specified Health Uses (FOSHU). Soybean isoflavones, MBP and vitamin K have been approved as principle ingredients on the list of FOSHU as targeted to "individuals concerned about bone health".

**Omega 3 fatty acids**

Substantial evidence has accumulated over the past year that dietary long chain polyunsaturated fatty acids (LCPUEAs) with a chain length longer than 18C are beneficial for bone health. Recent studies have suggested that PUFAs of the n-3 series, as well as the n-6 fatty acid gamma linolenic acid (GLA), may prove beneficial to bone health when consumed in appropriate amounts (14). In addition, it has been shown that a reduction of the n-6/n-3 PUFA ratio could result in increased bone strength in animals and in humans.

**Effect of Physical Activity on Bone Mass**

Physical activity helps maintain bone mass, muscle mass and body balance. Several metaanalyses have shown that the bone fracture risk decreases with an increase in physical activity (15). Appropriate physical activity during the growing stages is very important for prevention of osteoporosis because this results in a higher peak bone mass. In addition, it has been reported that mechanical stress acts to oppose bone loss in postmenopausal women (16). This evidence shows that mechanical stress is an important factor in maintaining bone mass.

Conversely, it has been reported that excessive exercise may lower estrogen levels, which, in turn, can lead to low mineral densities in young female athletes (17). Because stopping exercise also terminates its benefits on bone mass, it is desirable to continue regular exercise routines for as long as possible.

**REFERENCES**


