HEALTHY NUTRITION, HEALTHY BONES

HOW NUTRITIONAL FACTORS AFFECT MUSCULOSKELETAL HEALTH THROUGHOUT LIFE

Key Messages
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Relevant Australian information inserted in blue.

Overview

- Genetics plays a significant role in determining skeletal growth, decisions made by parents and their children regarding nutrition and exercise, can have a profound effect upon fracture risk later in life.
- A clear consensus exists on the amount of dietary calcium that we should consume, which is shared by leading organisations across the world.
- Numerous reports from all regions of the world indicate that calcium intake is often below recommendations of national guidelines.
- Being at either extreme of body mass distribution – whether underweight or overweight – is bad for bones.
- Vitamin D deficiency is a problem.
- Dietary factors that can adversely affect bone include excessive consumption of alcohol and caffeinated beverages.
- Nutrition plays an important role for our seniors.

Changing Nutritional needs throughout life

- Throughout our lives the size of our skeleton and the amount of bone contained within it changes significantly.
- During the first 10-12 years of life bone mass increases steadily. At puberty the rate accelerates, resulting in peak bone mass by mid-twenties. Thereafter a gradual decline occurs into old age with an accelerated period of bone loss for several years in women after menopause.
- Primary objectives for good bone health at stages of life are:
  - Children & adolescents: achieve genetic potential for peak bone mass
  - Adults: avoid premature bone loss and maintain a healthy skeleton
  - Seniors: prevent and treat osteoporosis.
- The most important nutrients for bone health are calcium, vitamin D and protein.
- Calcium
  - calcium is a major building block of our skeleton
  - calcium also plays an important role in nerve and muscle functioning
  - calcium is important for bone health throughout the life-course, particularly during the teenage years.
- Vitamin D
  - plays 2 key roles – assists with calcium absorption from food and ensures correct renewal and mineralisation of bone
  - vitamin D is made in the skin when exposed to UV-B rays in sunlight and can also be obtained in small quantities from certain foods.
- Protein
  - Dietary protein provides the body with a source of amino acids to support building the bone matrix.
  - In older adults, low protein intake is associated with loss of bone mineral density.
Maternal Nutrition

- The majority of bone development in the human foetus occurs during the third trimester.
- Intestinal absorption of calcium increases in the mother during pregnancy.
- Vitamin D insufficiency is common during pregnancy.
  A large study is currently underway in the UK, testing whether offspring of mothers supplemented with vitamin D in pregnancy have higher bone mass at birth than mothers not supplemented.
- Internationally, strategies to improve calcium and vitamin D intake have included encouraging consumption of dairy and calcium-rich foods and consumption of fortified foods (note: several countries overseas have a broader range of vitamin D fortified products than Australia).

Recommended dietary intake (RDI) of calcium during pregnancy in Australia
- 14-18 years: 1,300 mg/day
- 19-50 years: 1,000 mg/day

Bone Building in Childhood & Adolescence

- While genetics contributes up to 80% of the variance of Bone Mineral Density observed within the population, a number of modifiable factors impact on the skeletal growth for an individual child. Modifiable factors include:

  Nutrition
  In children and adolescents the nutrients most important to optimise bone health are calcium, vitamin D and protein.
  - Calcium
    - Breast milk from the mother (or infant formula) is the primary source of nutrition for infants in first year.
    - Milk and other dairy products are the source of up to 80% of dietary calcium intake for children from the second years onwards.
    - Studies based on data collected in developed countries have evaluated milk consumption around children and adolescents over recent decades. A body of evidence suggest that a decrease in milk consumption is accompanied by increased consumption of sweetened beverages.

  Recommended dietary intake (RDI) of calcium for children in Australia
  - 1-3 years: 500 mg/day
  - 4-8 years: 700 mg/day
  - 9-18 years: 1000mg/day
  - 12-18 years: 1,300 mg/day
  - Vitamin D
    - Sunshine is the main source of vitamin D.
    - Only a small group of foods are naturally rich in vitamin D which includes oily fish (eg: salmon, mackerel, sardines) and liver. Some countries have selected foods fortified with vitamin D.

  Recommended Adequate Intake (AI) for vitamin D in Australia
  - 1-3 years: 600 IU/day
  - 4-8 years: 600 IU/day
  - 9-18 years: 600 IU/day
  - Protein
    - Dietary protein is a source of amino acids which are needed to build the bone matrix. (note: milk is a source of high-quality proteins which contain growth promoting elements).

  Recommended dietary intake (RDI) of protein for children in Australia
  - 1-3 years: 14 g/day
  - 4-8 years: 20 g/day
Exercise and Lifestyle

Osteoporosis Australia published *Building Healthy Bones Throughout Life* (2013), this review recognised childhood and adolescence may be the pivotal period in the life-course for exercise to most significantly impact on bone health in the long-term. The primary recommendation relating to exercise needs in children and adolescents was to encourage schools to incorporate a diverse range of weight-bearing activities and sports into physical education programs. Short bursts of daily moderate to high-impact exercises (jumping, skipping, hopping) was also encouraged.

Body weight and composition

A healthy body weight during childhood and adolescence is required for optimal bone health. A body mass index at either end of the spectrum can pose a threat to development of the skeleton.

Anorexia nervosa has been shown to have a profound negative impact on BMD in adolescent girls and boys. Obese children have low bone mass and area for their weight.

Hormones

During the growth of the skeleton hormonal factors impact on cortical bone size, particularly in boys. Hormonal balance during puberty is important for the development of peak bone mass.

Maintaining Bone Mass in Adulthood

- Bones are in a perpetual state of turnover throughout life, the entire skeleton is replaced every decade. This process is known as bone remodelling cycle. Osteoclast cells are recruited to sites of microdamage to remove old bone (known as bone resorption) and when the task is completed osteoblast cells deposit new bone to fill the gap (known as bone formation)
- For the total amount of bone to remain constant the rate of bone resorption needs to be equivalent to the rate of bone formation.
  - During adolescents the rate of bone formation exceeds the rate of absorption
  - During adulthood a period of balance between formation and resorption maintains bone mass
  - After menopause, women undergo a period of rapid bone loss
  - After the age of 70 bone loss in men tends to accelerate
- A well balanced diet rich in calcium, vitamin D and protein, with adequate intake of other micronutrients is essential to maintain a healthy skeleton during adulthood. Regular weight bearing exercise also plays an important part in ensuring good adult bone health.
- Key components of a ‘bone healthy’ diet in adults
  **Calcium**
  Calcium is absorbed in the intestine and plays important roles in mineralising the skeleton and supporting nerve and muscle function. Inadequate calcium intake can result in lower levels of calcium in the blood. When this occurs a highly effective compensation mechanism is initiated which draws calcium from the bones and other areas. So adequate calcium intake is important.

Sources of calcium in the diet

Calcium content in food varies. Milk and other dairy foods are the most readily available sources of calcium. Other good sources include certain green vegetables (eg: broccoli, curly kale, bok choy), whole canned fish with edible bones, nuts (almonds, Brazil nuts) and firm tofu set with calcium.
Recommended dietary intake (RDI) of calcium for adults in Australia
Women: 19-50 years 1,000 mg/day (increasing to 1,300 mg/day over 50)
Men: 19-70 years 1,000 mg/day (increasing to 1,300 mg/day over 70)

Calcium supplements
Supplements should only be used as needed to bring total calcium intake to the recommended level in healthy adults. There is ongoing debate in the scientific community about the role of supplementation.

Vitamin D
Vitamin D assists with
- the absorption of calcium from food in the intestine
- ensuring correct renewal and mineralisation of bone
- stimulating muscle tissue and so reducing falls
- regulating PTH (so reducing PTH induced bone loss)

Sources of vitamin D
- sun exposure
- Few foods contain vitamin D but some good sources include oily fish (salmon, herring, mackerel) sardines, egg yolk, shiitake mushrooms (fresh and dried)

Recommended adequate intake of vitamin D for adults in Australia
19-70 years 600 IU/day (IU = International Units)

Inadequate vitamin D levels
Adults at risk of having inadequate levels of vitamin D include
- Latitudes with lower exposure to sunlight
- Individuals who are obese
- Individuals with darker skin tone
- Individuals who do not expose their skin for cultural or medical reasons
- Individuals with diseases that impact vitamin D

Note: Measuring vitamin D in only needed for high risk individuals to help assess any need for supplementation and dose.

Protein
Protein is a source of amino acids which are needed to maintain bone structure.
Protein rich foods include dairy products, meat, fish, poultry, lentils, beans and nuts.

Recommended dietary intake (RDI) of protein for adults in Australia
Women: 19-70 years 46 g/day
Men: 19-70 years 64 g/day

Other Vitamins in the bone story
Vitamin K
Vitamin K is required to make osteocalcin, the second most abundant protein in bone after collagen. Good food sources of vitamin K include leafy green vegetables (lettuce, spinach, cabbage, kale) liver and fermented cheeses and nato.
Magnesium

Approximately half of total body magnesium is stored in the skeleton. Magnesium plays an important role in bone formation by stimulating proliferation of osteoblasts (bone forming cells). Good sources of magnesium include green vegetables, legumes, nuts, seeds, unrefined grains, fish and dried fruit (apricots, prunes, raisins). Magnesium absorption decreases with age.

Zinc

Zinc plays a role in bone tissue renewal and mineralisation. Zinc deficiency is associated with calorie and protein malnutrition. Good sources of zinc include lean red meat, poultry, whole grain cereals, pulses, legumes and dried fruit (peaches, prunes, apricots).

**Nutritional Needs of Seniors**

A number of expert groups in different countries have published guidance on nutrients important to bone health in the elderly. A common theme across these guidelines is evident - adequate intake of calcium, vitamin D and protein is an essential component of effective bone care for older people.

**Recommended calcium, vitamin D and protein intake for seniors in Australia**

<table>
<thead>
<tr>
<th>Sex</th>
<th>Age</th>
<th>Calcium mg/day</th>
<th>Vitamin D (IU/day)</th>
<th>Protein (g/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Women:</td>
<td>51-70 years</td>
<td>1,300 mg/day</td>
<td>600 IU/day</td>
<td>46 g/day</td>
</tr>
<tr>
<td></td>
<td>over 70 years</td>
<td>1,300 mg/day</td>
<td>800 IU/day</td>
<td>57 g/day</td>
</tr>
<tr>
<td>Men:</td>
<td>51-70 years</td>
<td>1,000 mg/day</td>
<td>600 IU/day</td>
<td>64 g/day</td>
</tr>
<tr>
<td></td>
<td>over 70 years</td>
<td>1,300 mg/day</td>
<td>800 IU/day</td>
<td>81 g/day</td>
</tr>
</tbody>
</table>

**Malnutrition in the elderly**

Malnutrition is highly prevalent in the elderly. A number of factors can contribute to inadequate availability of these key nutrients for bone health:

**Calcium**
- Decreased overall dietary energy intake including calcium
- Decreased intestinal absorption of calcium, exacerbated by low vitamin D status
- Decreased capacity of intestinal cells to adapt to low calcium intake
- Decreased retention of calcium by the kidneys

**Vitamin D**
- Less frequent exposure to sunlight for the housebound
- Decreased capacity of the skin to synthesise vitamin D
- Decreased renal capacity to convert vitamin D to its active form

**Protein**
- Decreased anabolic response to ingested protein
- Increased need for protein to offset inflammatory and catabolic conditions

**Impact of nutrition on muscle in seniors**

As people age there is also loss of muscle mass and strength known as sarcopenia (commonly referred to as age-related muscle wasting). Preventing muscle wasting is important because it lowers the risk of falls – and the associated injuries from falls including fractures. The IOF Nutrition Working Group published a position paper in 2013 on the impact of nutrition on muscle mass, strength and performance in older adults. It acknowledged protein plays an important role in muscle health and a review of scientific literature identified a moderate relationship between vitamin D and muscle
strength. Furthermore, the authors concluded the acid-base balance of the diet plays an important role in maintaining muscle mass.

### Treatment of Osteoporosis

A persistent osteoporosis care gap is evident among people who have suffered fractures in the past (from a minor incident). Major efforts are ongoing throughout the world to eliminate this care gap with Fracture Liaison Services to ensure patients with a fracture have their bone health properly investigated and are treated to prevent further fractures.

As health systems take steps to eliminate the secondary fracture care gap, the advent of absolute fracture risk calculators provide health professionals with an opportunity to deliver primary fracture prevention in a systematic way.

In Australia only 20% of people who come to medical attention due a fracture (from a minimal trauma) are investigated for poor bone health and treated to prevent further fractures. The healthcare system is repairing the fracture but missing the underlying cause.

### Diseases and Disorders that affect Nutritional Status

#### Inflammatory Bowel Disease

This refers to a number of diseases which are characterised by inflammation of the bowel, the most common being Crohn’s Disease and ulcerative colitis. A number of factors predispose sufferers to be at increased risk of bone loss:

- Poor nutritional status
- Poor absorption of nutrients by damaged intestine
- Surgery to remove parts of intestine
- Treatment with glucocorticoid medications to reduce inflammation
- Hormonal modifications induced by the disease

Osteoporosis prevention measures need to be included in the overall care strategy for patients with these disorders.

#### Coeliac Disease

Coeliac disease is a genetically mediated autoimmune disease characterised by intolerance to gluten (a protein group) found in wheat, rye and barley. Patients affected suffer damage to the villi lining, the surface of the intestine that are involved in the absorption of nutrients from food. The disorder has to be controlled by strict adherence to a gluten-free diet. Patients may be at increased risk of osteoporosis if the disorder goes undiagnosed or is poorly controlled.

#### Lactose maldigestion and intolerance

When people are unable to digest all the lactose they have eaten they have maldigestion. This results from a deficiency in the enzyme lactase (produced in the small intestine) which is responsible for breaking down lactose (the principal sugar found in milk) into simpler sugars which are then absorbed into the body. The term ‘lactose intolerance’ refers to the abdominal symptoms (eg cramps, bloating) resulting from the inability to digest lactose. The prevalence varies significantly between races and as a function of age. People who are lactose intolerant should consult their doctors to discuss the best way of ensuring adequate calcium intake, either through diet or if needed through the use of supplements.


Cover image: ©International Osteoporosis Foundation