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Invest in your bones

Bone Appétit

The role of food and nutrition in building and maintaining strong bones

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IOF is an international non-governmental organization which represents a global alliance of patient, medical and research societies, scientists, health care professionals and the health industry. IOF works in partnership with its members and other organizations around the world to increase awareness and improve prevention, early diagnosis and treatment of osteoporosis. Although osteoporosis affects millions of people everywhere, awareness about the disease is still low, doctors often fail to diagnose it, diagnostic equipment is often scarce, or not used to its full potential, and treatment is not always accessible to those who need it to prevent the first fracture. IOF's growing membership has more than doubled since 1999, reflecting the increasing international concern about this serious health problem. There are 173 member societies in more than 80 locations worldwide (June 2006).

For more information about IOF and to contact an IOF member society in your country visit: www.osteofound.org

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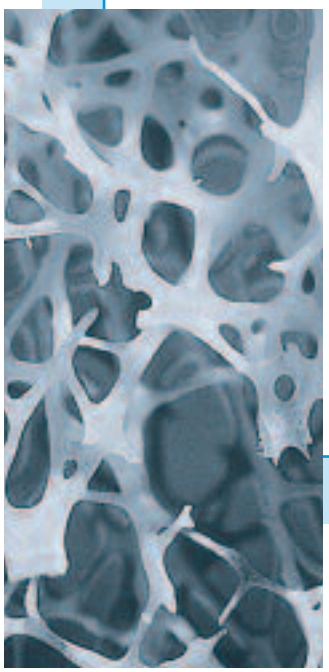
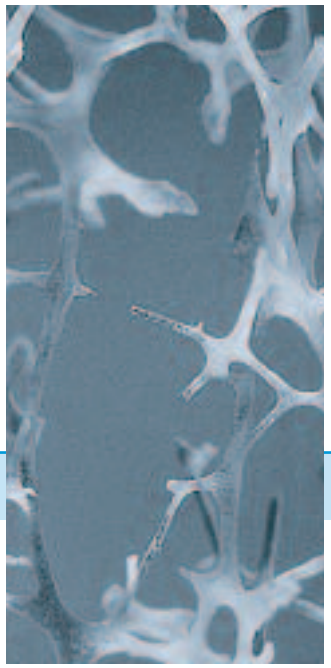
What is osteoporosis?

Osteoporosis is a disease in which the density and quality of bone are reduced, leading to weakness of the skeleton and increased risk of fracture, particularly of the spine, hip and wrist. Osteoporosis is a global public health problem; the disease and its associated fractures are an important cause of morbidity and mortality affecting millions of people worldwide. The loss of bone occurs progressively over many years and doesn't have any symptoms, and often the first sign of having osteoporosis is a fracture. For this reason, osteoporosis is often referred to as the "silent epidemic".

- Osteoporosis currently affects approximately one in three women and one in five men over the age of 50 years, and is increasing in significance as the population of the world grows in size and is living longer
- The number of hip fractures occurring worldwide each year is expected to rise from the current figure of over 1.5 million to over 6 million by the year 2050, with the steepest increases expected throughout Asia and Latin America[1]
- Having a spine fracture substantially increases the risk for sustaining additional spine fractures within one year[2]
- Every 30 seconds, someone in the European Union has an osteoporotic fracture[3]
- For the elderly who survive a hip fracture, only one in three returns to their previous level of independence[4]



Normal bone



Osteoporotic bone

Foreword

World Osteoporosis Day this year, 2006, celebrates the theme of food and nutrition, which marks the middle year of the IOF's global, 3-year 'lifestyle' campaign. I use the word 'celebrates' with good reason – food is not just 'fuel' for the body, but is one of the joys of life, for all its associated tastes, textures, sights and scents, and for the pleasures it brings in allowing shared time with family and friends. Last year's theme was exercise-oriented, with the admonishment to 'Move it or Lose it', and next year we will cover the whole gamut of osteoporosis risk factors under the theme 'Beat the Break – know and reduce your risks'. However, for this year, we offer a respite from all the cautions, and invite you to do more of something pleasurable – include more calcium-, vitamin D- and protein-rich foods and drinks in your diet, and give your bones the boost they need to last you a lifetime.

A healthy, nutritious diet is one of the cornerstones of ensuring strong, healthy bones at every stage in life. Certainly, during childhood and adolescence, good nutrition will help to ensure attainment of maximal peak bone mass, and thereby reduce vulnerability to osteoporosis later in life. However, the phrase 'never too late' is highly appropriate for bones – a healthy diet is also extremely important for preserving bone mass and strength both in younger and older adults, even in those who have already had a fracture – good nutrition speeds and aids recovery, and helps prevent further fractures. This review, for which I would like to acknowledge the co-authorship of Dr Jo Cadogan at the IOF, covers the scientific basis for many of the claims made regarding nutrition and bone health, and also covers some of the 'negative' dietary factors and practices.

Good nutrition alone will neither prevent nor cure osteoporosis, but in the context of measures to ensure a bone-friendly lifestyle – including avoiding smoking and excess alcohol, and taking exercise – it is perhaps the least onerous task on the list. *Bone Appétit!*

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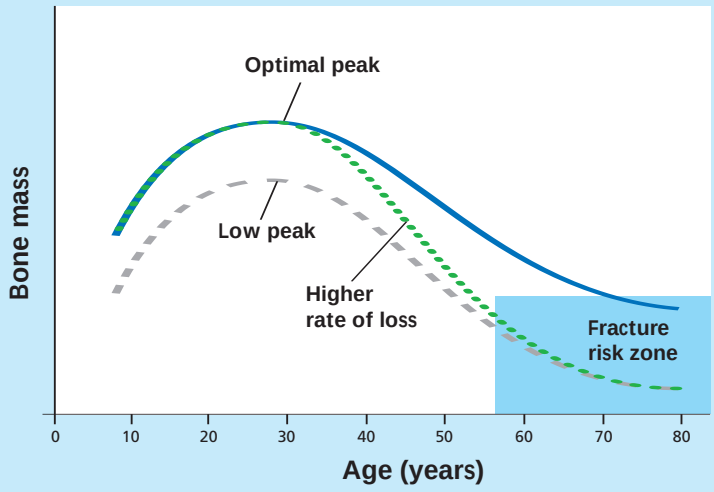
Introduction

Bone is a living, dynamic, metabolically active tissue – throughout the whole of life. Bone is made up of two major types: cortical bone, which forms the hard, smooth outer shell of the bones, and trabecular bone, which is inside the bones and has a honeycomb-like structure. Bone undergoes a process of constant renewal throughout life, through a process called *bone turnover* in which cells called osteoclasts remove old or damaged bone, and cells called osteoblasts make new bone to replace it. Bones can also adapt their 'architecture' to the demands of different activities, such as a new type of exercise. Bone is a specialized connective tissue, composed of a collagen (protein) framework permeated with mineral salts composed of mostly calcium and phosphate, together with trace amounts of other minerals and ions. Just like the muscles, the heart and any other organ in the body, the skeleton needs a constant supply of energy and nutrients. A healthy, balanced diet containing both macronutrients (protein, fat and carbohydrate) and micronutrients (vitamins and minerals), plus sufficient calories, is vital for both the normal development and on-going maintenance of the skeleton.

The critical years for building bone mass are during childhood and adolescence. This is when new bone is formed more quickly than old bone is removed, causing bones to become larger and denser. This pace continues until around the mid 20's when 'peak bone mass' is normally reached (maximum bone density). Bone tissue loss generally begins after the age of about 40 years, when we are no longer able to replace bone tissue as quickly as we lose it. In women, the rate of bone tissue loss increases quite substantially in the few years immediately after menopause, when estrogen production stops and bones no longer benefit from its protective effect. Men also suffer from loss of bone tissue after age 50 years, but the rate of loss is slower than in women. At this stage in life, taking preventive measures – including ensuring a balanced, healthy diet – will help to slow the rate of bone tissue thinning and reduce the risk of having osteoporosis-related fractures, for both men and women.

The mineral calcium is one of the major building blocks for the skeleton, and is essential for bone health throughout life. Vitamin D is also essential for the development and maintenance of bone, both for its role in assisting calcium absorption from the diet, and for ensuring the proper renewal and mineralization of bone tissue. Protein is also a key constituent of bone tissue and therefore an adequate dietary supply is essential. By investing in the 'bone bank' during youth and early adulthood, through good nutrition and lifestyle, the bones become stronger and less vulnerable to osteoporosis later in life. Short-term studies in children and teenagers suggest that a higher calcium or dairy intake is associated with enhanced bone mineral gain. If the higher intakes were to be maintained into young adulthood, it is likely that this would have a positive impact on peak bone mass.

Good nutrition, especially protein, calcium and vitamin D, is also important for preserving bone mass and strength in



Bone mass changes throughout life, showing effect of low peak bone mass, or higher rate of bone loss

This hypothetical graph is a representation of bone mass changes throughout life. The critical years for building bone mass are during childhood and adolescence. 'Peak bone mass' is achieved in the mid-20's, then bone mass remains stable during young adulthood. Bone loss begins after the age of about 40 in both genders.

The graph also shows two hypothetical situations, one in which a low peak bone mass is attained (gray, dashed), and one in which bone loss is faster than it should be (green, dotted). In both situations, this would place a person at risk of fracture at an earlier age in life, i.e. they would enter the shaded 'fracture risk zone' sooner. Healthy lifestyle habits, including good nutrition and exercise, can help to ensure that individuals attain their maximum peak bone mass, and also help to slow bone loss, ensuring they stay on the optimum (blue, solid) line in life.

adults and the elderly. In addition, attention to nutrition is an important component of a successful rehabilitation program in patients who have had an osteoporotic fracture. In frail, elderly patients who have sustained hip fractures this is crucially important, as poor nutritional status can slow recovery, and increase susceptibility to further fractures.

Comparisons between parents and their children, or between twins, suggest that genetics accounts for 60 to 80% of the variability in bone mineral density (BMD) between individuals. However, although genetic factors are very important in determining whether an individual is at heightened risk of osteoporosis, lifestyle factors such as good nutrition and exercise play a key role in building bone during youth, maintaining bone mass in younger adults, and helping to slow down bone loss in adults and the elderly. The importance of these lifestyle factors is that they are amenable to change (unlike your genes) – individuals can take positive steps to strengthen their bones and reduce their risk of osteoporosis.

Good nutritional habits, which begin early in life, will help to promote bone health over the whole lifetime.

Nutritional factors and bone health

Calcium and vitamin D

The two key nutrients to consider for bone health are the mineral calcium, and vitamin D. Calcium is a major structural component of bone tissue. It is deposited in bone in the form of a mineral complex called hydroxyapatite, which confers strength to the skeleton. Ninety-nine percent of the calcium in the body is stored in the skeleton, which therefore also acts as a 'reservoir' of calcium for maintaining calcium levels in the blood. Blood calcium levels have to be tightly maintained at a constant level, for calcium's other roles such as in nerve and muscle functioning. Recommended daily calcium intakes for populations vary between countries, often as a result of differing use and interpretation of the available scientific data. The FAO/WHO[5] recommendations, based on data from several countries, are shown in Table 1.

Calcium is absorbed in the small intestine both by passive diffusion, and by an active mechanism which requires vitamin D. An inadequate intake of calcium results in a reduced amount of calcium being absorbed, which in turn leads to a lower blood level of calcium. As a result our bodies produce a hormone, called parathyroid hormone (PTH) that causes calcium to be released from the bone 'reservoir' into the blood stream, because as stated above it is vital that blood calcium levels are kept constant at all times. It is thought that if calcium intake is habitually low on an ongoing basis (over years), then the small but sustained increase in the PTH level over time could cause a gradual loss of calcium from the bones, making them thinner and weaker.

Calcium requirements are high in the teenage years, during the time of rapid growth of the skeleton, and during this time, calcium absorption efficiency increases. The efficiency of calcium absorption, however, declines with age. This means that over time we need to consume higher amounts of calcium, which is why higher intakes are usually recommended for people over 65 years. We must also ensure that we have enough vitamin D (via sunlight exposure or dietary intake), to help with the process of calcium absorption. Diet composition, season and race also influence calcium absorption efficiency.

Milk and other dairy foods are the most readily available sources of calcium in the diet. Dairy foods have the additional advantage of being good sources of protein and other micronutrients (besides calcium) that are important for bone and general health. Other good food sources of calcium include certain green vegetables (e.g. broccoli, curly kale, bok choy); whole canned fish with soft, edible bones such as sardines or pilchards; nuts (almonds and Brazil nuts in particular); and tofu set with calcium.

Although some other plant foods also contain appreciable amounts of calcium, some contain substances that bind to the calcium and prevent it being absorbed, e.g. compounds called oxalates in spinach and rhubarb, and phytates in dried beans, cereal husks and seeds[6]. However, oxalates and phytates only bind the calcium in the foods they are in – they don't interfere with calcium absorption from other foods or drinks. Calcium-fortified foods and drinks, including breads, cereals, orange juice and soy beverages are also available in some countries, as are various commercial brands of mineral waters which can contain significant amounts of calcium. Soy beverages are sometimes called 'soy milk', but it is important to look for ones that are fortified with calcium, because soy drinks don't naturally contain calcium. Some examples of the approximate calcium levels in foods[7] are shown in Table 2.

Vitamin D is also essential for the development and maintenance of bone, both for its role in assisting calcium absorption from food in the intestine, and for ensuring the correct renewal and mineralization of bone tissue. Vitamin D is made in the skin when it is exposed to sunlight (ultraviolet B rays); in children and adults exposure of the hands, face and arms to the sun for as little as 10 to 15 minutes per day is usually sufficient for most individuals. Vitamin D can also be obtained from food, and dietary supplements. Food sources of vitamin D are rather limited, and include oily fish such as salmon, sardines and mackerel, eggs, liver, and in some countries fortified foods such as margarine, dairy foods and cereals (Table 3). The version of vitamin D made in the skin is referred to as vitamin D_3 (cholecalciferol), whereas the dietary form can be vitamin D_3 or a closely related molecule of plant origin known as vitamin D_2 (ergocalciferol). The vitamin D compound that is measured in the blood, to test whether a person has adequate vitamin D status, is called 25-hydroxyvitamin D. However, this is not the 'active' form of vitamin D (the form that promotes intes-

Table 1: Recommended calcium allowances* (mg/day)

Infants and children:	
0-6 months	300-400
7-12 months	400
1-3 years	500
4-6 years	600
7-9 years	700
Adolescents:	
10 to 18 years	1300**
Women:	
19 years to menopause	1000
Postmenopause	1300
During pregnancy (last trimester)	1200
Lactation	1000
Men:	
19-65 years	1000
65+ years	1300

*The 'recommended allowance' refers to the amount of calcium that each age group is advised to consume (with daily intake corresponding to an average intake over a period of time), to ensure that calcium consumed compensates for calcium excreted from the body each day (e.g. in the urine), and lost in other ways (e.g. through the skin, hair and nails). The calcium allowance figures for children and adolescents also take account of skeletal growth (net calcium gain), and those for postmenopausal women and the elderly also take account of a lower intestinal calcium absorption efficiency.
**Particularly during the growth spurt.

Figures based on Western European, American and Canadian data. Source: FAO/WHO: Human Vitamin and Mineral Requirements, 2002, reference 5.

Table 2: Approximate calcium levels in foods

Food	Serving size	Calcium (mg)
Milk, whole	236 ml / 8 fl oz	278
Milk, semi-skimmed	236 ml / 8 fl oz	283
Milk, skimmed	236 ml / 8 fl oz	288
Goats milk, pasteurized	236 ml / 8 fl oz	236
Yoghurt, low fat, plain	150 g / 5 oz	243
Yoghurt, low fat, fruit	150 g / 5 oz	210
Yoghurt, Greek style, plain	150 g / 5 oz	189
Fromage frais, fruit	100 g / 3.5 oz	86
Cream, single	15 g / 1 tablespoon	13
Cheese, cheddar type	40 g / medium chunk	296
Cheese, cottage	112 g / 4 oz	142
Cheese, mozzarella	28 g / 1 oz	101
Cheese, Camembert	40 g / average portion	94
Ice cream, dairy, vanilla	75 g / average serving	75
Tofu, soya bean, steamed	100 g / 3.5 oz	510
Soya drink	236 ml / 8 fl oz	31
Soya drink, calcium-enriched	236 ml / 8 fl oz	210
Broccoli, cooked	112 g / 4 oz	45
Curley kale, cooked	112 g / 4 oz	168
Apricots, raw, stone removed	160 g / 4 fruit	117
Orange, peeled	160 g / 1 fruit	75
Figs, ready to eat	220 g / 4 fruit	506
Almonds	26 g / 12 whole	62
Brazil nuts	20 g / 6 whole	34
Sardines, canned in oil	100 g / 4 sardines	500
Pilchards, canned in tomato sauce	110 g / 2 pilchards	275
Whitebait, fried	80g / average portion	688
Bread, white, sliced	30 g / 1 medium slice	53
Bread, wholemeal, sliced	30 g / 1 medium slice	32
Pasta, plain, cooked	230 g / medium portion	85
Rice, white, basmati, boiled	180 g / medium portion	32

Calcium levels from reference 7: Food Standards Agency (2002) McCance and Widdowson's The Composition of Foods, Sixth summary edition. Cambridge: Royal Society of Chemistry.

tinal calcium absorption); the kidney converts 25-hydroxyvitamin D into the active form, which is called 1,25-dihydroxyvitamin D, according to the body's requirements (e.g. if calcium intake is low, more 1,25-dihydroxyvitamin D is produced, to enhance calcium absorption).

Because the sun provides a source of vitamin D in varying amounts for different individuals, dietary recommendations for vitamin D are approximate. Many countries advise a dietary intake of 200 IU/day (5 µg/day) for children and young adults, and 400-600 IU/day (10-15 µg/day) for older persons, to augment that derived via sun exposure. The FAO/WHO[5] dietary intake recommendations are shown in Table 4. These recommendations are derived from calculations of the intakes required to achieve an optimal blood level of vitamin D, together with various other factors. There is as yet no common definition of 'optimum' vitamin D status, although there is emerging evidence and expert opinion that the minimum blood level of 25-hydroxyvitamin D that would be optimal for fracture prevention is 70-80 nmol/l[8]. To achieve this, an average older man or woman would need a vitamin D intake of at least 800-1000 IU/day (20-25 µg/day), which is approximately double the intake recommended in most countries.

Dietary or supplemental vitamin D increases in importance during the winter months for populations in northern latitudes (when no skin synthesis of vitamin D takes place), and for elderly people who do not go outdoors much and in whom the capacity for skin synthesis of vitamin D is reduced. Use of sunscreen creams, and a greater degree of skin pigmentation, also reduces the amount of vitamin D that is made in the skin. An increasing body of evidence suggests that on a global level, vitamin D deficiency is widespread, even in very sunny countries such as in the Middle East and parts of Australasia[9].

Vitamin D is made in the skin on exposure to the sun's ultraviolet B rays. Casual exposure of the face, arms and hands for as little as 10 to 15 minutes per day is usually sufficient for most individuals.

Table 3: Approximate vitamin D levels in foods

Food	µg per serving	IU per serving	% RNI (10 µg/d or 400 IU/d)*
Cod liver oil**, 1 tbsp	23.1	924	231
Salmon, grilled, 100g	7.1	284	71
Mackerel, grilled, 100g	8.8	352	88
Tuna, canned in brine, 100g	3.6	144	36
Sardines, canned in brine, 100g	4.6	184	46
Margarine, fortified, 20g	1.6	62	16
Bran Flakes***, average serving, 30g	1.3	52	13
Egg, hen, average size, 50g	0.9	36	9
Liver, lamb, fried, 100g	0.9	36	9

*The RNI (recommended nutrient intake) for adults, ages 51-65 years. The RNI is defined by the FAO/WHO as "the daily intake which meets the nutrient requirements of almost all (97.5%) apparently healthy individuals in an age- and sex-specific population group". Daily intake corresponds to the average over a period of time.
** Fish liver oils, such as cod liver oil and halibut liver oil, also contain appreciable amounts of vitamin A, which can be toxic if consumed in excess.
***Bran Flakes are given as an example of a vitamin D-fortified breakfast cereal.

From reference 7: Food Standards Agency (2002) McCance and Widdowson's The Composition of Foods, Sixth summary edition. Cambridge: Royal Society of Chemistry.

Table 4: Recommended vitamin D intake
by age group, both as international units (IU) and micrograms (µg) per day

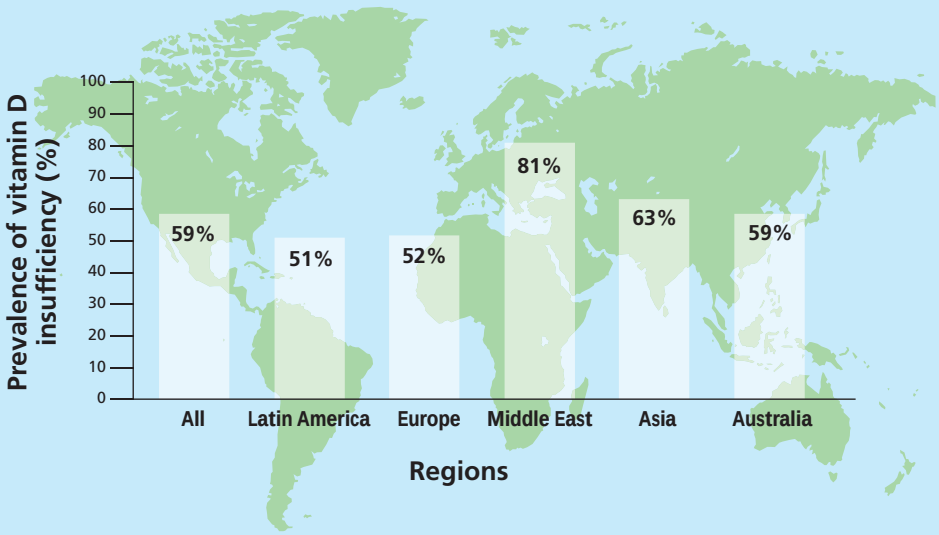
Age group	RNI* (IU/d)	RNI (µg/d)
0-9 years	200	5
10-18 years	200	5
19-50 years	200	5
51-65 years	400	10
65+ years	600	15
Pregnancy	200	5
Lactation	200	5

Figures based on Western European, American and Canadian data. Source: FAO/WHO: Human Vitamin and Mineral Requirements, 2002, reference 5.

* The RNI (Recommended Nutrient Intake) is defined by the FAO/WHO as "the daily intake which meets the nutrient requirements of almost all (97.5%) apparently healthy individuals in an age- and sex-specific population group". Daily intake corresponds to the average over a period of time.

Vitamin D insufficiency is widespread

Increasingly, scientific evidence suggests that on a global level, vitamin D insufficiency is widespread, even in very sunny regions such as the Middle East, Latin American and Asian countries, and Australia. This is clearly demonstrated in this international epidemiological study in postmenopausal women. The prevalence of vitamin D inadequacy was over 50% in all five world regions, and was highest in the Middle East (81%) and Asia (63%).



Global prevalence of low serum 25(OH)D levels (defined as < 30 ng/ml). Cross-sectional observational international study in 1,285 community-dwelling, postmenopausal women with osteoporosis, in 18 countries (from reference 9).

In children, severe vitamin D deficiency results in inadequate mineralization of the bone matrix, leading to growth retardation and bone deformities known as rickets. In adults, the same condition is known as osteomalacia ('softening' of the bones, due to the poor mineralization). In industrialised countries, rickets and osteomalacia are relatively rare conditions. However, milder degrees of vitamin D inadequacy are common, and can predispose to osteoporosis. This is because without a sufficient supply of vitamin D from the skin or diet, the metabolism of calcium is disturbed. For example, lower vitamin D levels result in less efficient calcium absorption from the intestine, which in turns leads to higher PTH levels and greater calcium loss from the bones. Over time this leads to bone loss and eventually osteoporosis. Poor vitamin D status in older adults and the elderly also increases the likelihood of falling (and therefore possibly sustaining a fracture), because vitamin D is also important for the correct functioning of the muscles and nervous system[10]. Maintaining adequate vitamin D status during pregnancy is important, as there is some evidence that mothers deficient in 25-hydroxyvitamin D in pregnancy give birth to children with reduced bone mass, which could in turn be a risk factor for osteoporosis later in life[11].

The best dietary source of vitamin D is oily fish (also called fatty fish). A portion of an oily fish such as salmon, tuna, sardines or mackerel provides a good amount of vitamin D, up to a half or two-thirds of our daily recommended intake.

The effects of calcium, vitamin D and dairy foods on bone density and fracture risk

The importance of nutrition to bone health has been demonstrated in a number of research studies, in human subjects across the age range. Intervention trials carried out over one to three years in children and adolescents have shown that supplementation with either calcium, dairy calcium-enriched foods, liquid milk, or a calcium-enriched milk powder enhances the rate of bone mineral acquisition, compared with un-supplemented (or placebo) control groups[12-15]. In general, these trials increased the usual calcium intake of the supplemented children from about 600-800 mg/day, to around 1000-1300 mg/day. Although these studies were short term, if the higher calcium intakes were maintained into the mid-20's, such an increment would likely have a beneficial impact on peak bone mass. Some retrospective observational studies suggested that adults who consumed milk regularly during childhood had a higher bone mass than those who did not, although such studies are a weaker form of scientific evidence than intervention trials. At the population level, it is estimated that a 10% increase in peak bone mass could reduce the risk of osteoporotic fractures during adult life by 50%[16].

In studies among adults, one three-year intervention study in healthy young women aged 30-42 years showed that supplementing the usual diet with dairy foods prevented bone loss in the spine, compared with control subjects who did not increase their dietary calcium intake[17]. In postmenopausal women and the elderly, several intervention studies have shown that calcium or milk supplementation slows the rate of bone loss[18-27]. In a study carried out in healthy, elderly women living in nursing homes, calcium (1200 mg/day) and vitamin D (800 IU/day) supplementation over 18 months reduced the risk of hip fractures and other non-vertebral fractures[19]. A similar intervention over three years (500 mg/day calcium, 700 IU/day vitamin D) was shown to reduce bone loss and the incidence of non-vertebral fractures in elderly men and women living at home, i.e. not in institutions[18]. In comparative intervention studies, dairy food supplements and calcium supplements were equally effective in preserving hip bone mass in postmenopausal women[24,27], although these studies were not designed to evaluate reductions in fracture rates. Several studies have shown that vitamin D alone and in combination with calcium lowers the risk of falling in older men and women[8].

Explanation of study designs

Throughout this report, several different types of studies investigating effects of nutrition on bone health are described. When evaluating scientific evidence, it is important to take into account the type of study, as some provide 'stronger' evidence than others. Broadly, studies are classified as either an 'intervention trial (study)' or an 'observational study'. Sometimes observational studies are broadly referred to as 'epidemiological studies'.

Intervention trials

Also called clinical trials, these are the 'gold standard' in study design, providing the strongest type of scientific evidence. The best design is the *randomised, double-blind, placebo-controlled intervention trial*. The participants are randomly (like tossing a coin) allocated to two groups, one group being the 'intervention' group who will receive the treatment item to be tested (e.g. a calcium tablet, or a medicine in a drug trial), and the other group being the 'control' (comparison) group, who will receive a placebo (dummy) tablet. 'Double-blind' refers to the fact that neither the investigators nor the subjects know which tablet – treatment or placebo – they are receiving. Therefore, the only difference between the two groups is whether or not they receive the treatment, and the investigators can then see whether it changes bone mineral density (as an example of a 'study outcome') over a period of time. If a food is used as the intervention (e.g. milk), it is not possible for the study to be double-blind or placebo-controlled, so it would be called a 'randomised, controlled, open, intervention trial'.

Observational studies

In observational studies, nothing is given to the study participants. Instead, as the name implies, they are 'observed' in the course of their normal life. A simple example is a *cross-sectional study*, e.g. where you might take a group of people, measure their calcium intake on one occasion with a questionnaire, measure their bone density, and investigate statistically to see if calcium intake correlates (shows a relationship) with bone density. Another, stronger type of observational study is the *prospective cohort study*, in which a large group (cohort) of people is studied over a long period of time, usually years (hence 'prospective'), and investigators can look at how their dietary intake affects measures of disease outcome (e.g. fractures). Usually the investigators divide the cohort into 3, 4 or 5 groups (tertiles, quartiles or quintiles) according to low, medium and high intake of a particular food or nutrient, and compare the bone densities or fracture rates between the groups. Well-known examples of this type of design are the Nurses Health Study and the Framingham study in the USA, which involve thousands of study subjects. It is also possible to look back in time, at people's previous diet or 'exposure', and how it affects their current disease risk. Examples include *retrospective cohort studies, and case-control studies*. The latter compare 'cases' (people who have the disease) with 'controls' (people free of the disease), and looks at whether measures of dietary exposure statistically 'predict' the disease outcome.

The above-described trials demonstrated the effectiveness of calcium and vitamin D supplementation for reducing non-vertebral fracture rates in at-risk populations, such as men and women over 65 years, and elderly living in care homes. Other trials carried out in adults living at home (i.e. not in care homes) have not shown a benefit of calcium and vitamin D supplementation in terms of fracture prevention. One such study is the Women's Health Initiative (WHI) calcium plus vitamin D trial, a large placebo-controlled intervention trial carried out in American women ages 50-79 years, which showed no apparent benefit of calcium with vitamin D supplementation on fracture rates in the supplemented group as a whole over seven years, compared with the placebo group[28]. However, hip fracture rates *were* significantly reduced by 30%, both in women who used only the calcium and vitamin D supplements provided in the study (meaning that they had the lowest habitual calcium and vitamin D intakes, because they weren't already taking their own supplements), and in those who were compliant with the supplements (defined as those who took at least 80% of their calcium and vitamin D). A further explanation for the negative finding in the whole group could be that the dose of vitamin D used (400 IU/day) was not sufficient, since it appears that supplementation of 700 or 800 IU/day is needed to reduce the risk of hip and other fractures[29].

Calcium and vitamin D alone are insufficient to prevent the rapid bone loss that occurs in women around the time of the menopause, or to reduce fracture risk optimally in patients with osteoporosis. Nevertheless, they are an essential component of therapy, in patients diagnosed with osteoporosis. It is recommended that people of all ages ensure adequate intakes in order to keep bones as strong and healthy as possible. Dairy foods provide the most readily available dietary sources of calcium, and also improve the nutritional quality of the diet in other respects because they contain protein and an array of vitamins and minerals[30,31]. It is sometimes stated in the lay press that dairy foods might be detrimental to bone health, based on the observation that the countries with the highest dairy food intakes (and also in consequence, the highest calcium intakes) have the highest rates of osteoporotic fractures. However, this argument is confounded by the fact that these tend to also be the countries with the longest life expectancies, and age is the strongest risk factor for osteoporosis – the longer you live, the more likely you are to have a fracture. In addition, it is highly problematic making comparisons of disease rates between countries, due to variations in other factors such as racial and genetic differences, physical activity levels, total dietary patterns, sun exposure, disease reporting accuracy, and many other population-level differences. Another argument leveled against dairy foods is that they are high in

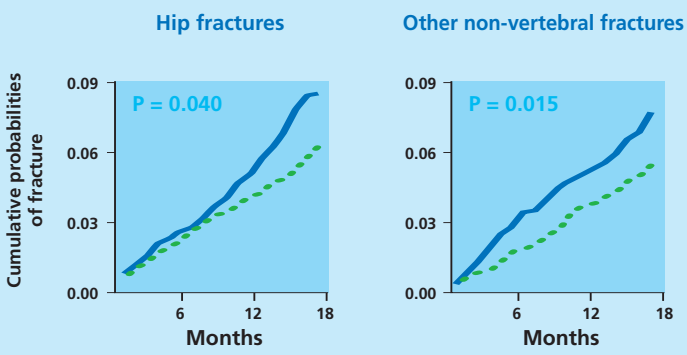
Special considerations for calcium and vitamin D in the elderly

Elderly persons are at increased risk for calcium and vitamin D insufficiency. There are also several alterations in body functions that can contribute to calcium loss from bone, and hence increased risk of osteoporosis.

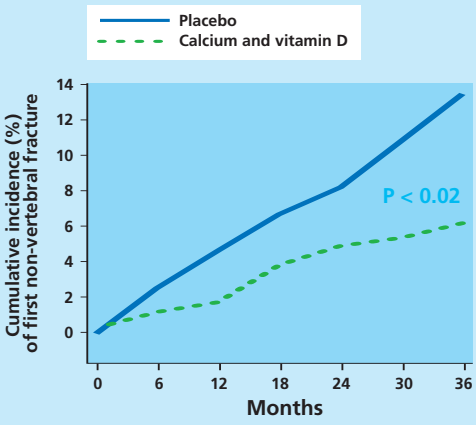
With ageing there is:

- A decrease in dietary calcium intake, usually as a result of decreased overall dietary energy intake (e.g. poorer appetite, intercurrent illnesses, social and economic factors)
- A decrease in the intestinal absorption of calcium (exacerbated if vitamin D status is low)
- A decrease in the capacity of the intestinal cells to adapt to a low calcium intake, and increase their absorptive capacity
- Less frequent exposure to sunlight (e.g. elderly who are housebound, or institutionalized, or have reduced mobility), hence poorer vitamin D status
- A decrease in the capacity of the skin to synthesize vitamin D
- A decrease in the efficiency with which the kidneys can retain calcium, leading to increased calcium loss in the urine
- A decrease in the capacity of the kidneys to convert vitamin D into the most active form, 1,25-dihydroxyvitamin D

Studies showing reduced non-vertebral fracture risk with calcium and vitamin D supplementation



In a study carried out in healthy, elderly women living in care homes, calcium (1200 mg/day) and vitamin D (800 IU/day) supplementation over 18 months significantly reduced the risk of hip fractures and other non-vertebral fractures (reference 19).



In a study carried out in elderly men and women over 65 living independently within the community, calcium (500 mg/day) and vitamin D (700 IU/day) supplementation over 3 years significantly reduced the risk of non-vertebral fractures (reference 18).

cholesterol, but this is not the case. Many countries give guidance that daily cholesterol intake should not exceed 300 mg per day. A 236 ml glass of reduced fat milk (at 1.7% total fat content) contains approximately 15 mg of cholesterol, and a 28 g portion of an average hard cheese contains approximately 28 mg of cholesterol[7].

The typical recommended calcium intake of about 1300 mg/day for older adults may be difficult to achieve through food sources alone, particularly in the frail elderly who may have reduced appetite due to lower physical activity levels or medical conditions. Supplementation might therefore be required where dietary intake is inadequate, as advised by the doctor. In addition, as indicated above, in patients diagnosed with osteoporosis and receiving a drug treatment, calcium and vitamin D supplements are also usually prescribed, to ensure maximum effectiveness of the drug therapy. The calcium from supplements is absorbed equally as well as the calcium from dairy foods and calcium-rich mineral waters.

Elderly persons are at increased risk for calcium and vitamin D insufficiency. Several studies have indicated that supplementation with these nutrients may be beneficial for maintaining bone health.

Emerging evidence – other micronutrients and bone health

Vitamin K

Vitamin K is needed for the production and functioning of a compound called osteocalcin. Osteocalcin is the second most abundant protein in bone after collagen, and it is required for bone mineralization. Some lines of evidence suggest that low dietary intake of vitamin K or low vitamin K status could contribute to low BMD and increased risk of fragility fractures in the elderly, via a reduced functioning of osteocalcin[32,33]. However, the possible mechanisms whereby suboptimal vitamin K intake and status affect bone metabolism are not well understood at present, and there is not yet adequate clinical trial evidence that adding vitamin K would be effective in either preventing or treating osteoporosis. Good food sources of vitamin K include leafy green vegetables such as lettuce, spinach, cabbage and kale, liver, and some fermented foods such as fermented cheeses and *natto* (fermented soybeans).

B vitamins and homocysteine

Recent observational studies suggest that high homocysteine levels in the blood may be associated with lower BMD and increased hip fracture risk in older persons[34,35]. Homocysteine is an amino acid (amino acids are the building blocks of proteins) that has been linked with increased risk of cardiovascular disease. It is thought that it might also have adverse effects on bone, by interfering with the formation of the main protein in bone, collagen. Homocysteine levels in the blood may rise if there is inadequate intake of vitamin B_6, vitamin B_{12} and folic acid, which play a role in the chemical reactions that change homocysteine into other amino acids for use by the body, and therefore help to keep it out of harm's way. No intervention trials have yet been carried out to determine whether supplementation with any or all of these B vitamins reduce fracture risk, so it is not yet known whether deficiencies in these vitamins are potentially modifiable risk factors for osteoporosis.

Vitamin A

The role of vitamin A in osteoporosis risk is controversial. Vitamin A is present 'pre-formed' in foods of animal origin, such as liver and other offal, fish liver oils, dairy foods and egg yolk, as a compound called retinol. Some plant foods contain a precursor of vitamin A, in the form of a group of compounds called carotenoids, for example in green leafy vegetables, and in a variety of red and yellow fruits and vegetables such as carrots, pumpkins, red and yellow peppers, mangoes, papaya and apricots. It is known that consumption of very high amounts of vitamin A (well above the recommended daily intake levels) have adverse effects on bone (plus the liver and skin), but the findings of studies looking at vitamin A intakes in normal diets are conflicting. One population-based observational study in postmenopausal American women found an association between high levels of vitamin A intake and hip fracture risk[36], and a similar population-based study in Swedish men found an association between blood retinol levels (but not blood carotenoid level) and fracture risk[37]. However, another study – in which blood levels of vitamin A compounds were measured in a large cohort of elderly British women – found no indication of increased risk of hip or other fractures with higher vitamin A intakes, either from the diet or fish oil supplements[38]. Further research is clearly needed in this area, although many countries currently caution against taking fish liver oil supplements and a multivitamin supplement concurrently, as this could lead to an excessive intake of vitamin A.

Magnesium

The mineral magnesium is involved in calcium homeostasis, and in the formation of hydroxyapatite (bone mineral). Severe experimental magnesium deficiency results in abnormal bone structure and function[39], but this level of depletion is rarely observed in generally well nourished human populations. Magnesium is fairly widespread in the food chain; particularly good sources include green vegetables, legumes, nuts, seeds, unrefined grains, and fish. The elderly could potentially be at risk of mild magnesium deficiency, as magnesium absorption decreases and renal excretion of magnesium increases with age. Older persons are also more likely to be taking certain medications that can increase magnesium loss in the urine, such as loop and thiazide diuretics, cancer medications or antibiotics. However, there are no studies to date which demonstrate that magnesium supplementation is useful either in preventing bone loss or reducing fracture risk.

Zinc

The mineral zinc is a constituent of the hydroxyapatite mineral crystals of bone, and plays a role in the regulation of bone turnover. Zinc is also needed for the correct functioning of an enzyme called alkaline phosphatase, which is required for bone mineralization (the process by which the hydroxyapatite crystals attach to newly formed bone matrix). Severe zinc deficiency is usually seen in conjunction with calorie and protein malnutrition, which is associated with impaired bone growth in children. However, milder degrees of zinc deficiency have been reported in the elderly and could potentially contribute to poor bone status. An observational study in middle-aged and elderly men showed that men with the lowest blood zinc levels had lower BMD than men with the highest blood zinc levels, and also that dietary zinc intake and blood levels were lower in men with osteoporosis than in men without osteoporosis[40]. Another study in postmenopausal women indicated that the bone-trophic effects of zinc could be mediated, at least in part, via a decrease in the blood levels of insulin-like growth factor-I (IGF-I), a compound that stimulates bone formation[41]. Zinc is most abundant in lean red meat and meat products, with poultry, whole grain cereals, pulses and legumes also being significant sources.

Protein

Adequate dietary protein intake is essential for bone health. Insufficient protein intake is detrimental both for the acquisition of bone mass during childhood and adolescence, and for the preservation of bone mass with ageing. Poor nutritional status, particularly with respect to protein, is common in the elderly, and appears to be more severe in patients with hip fracture than in the general ageing population[42]. As well as adverse effects on skeletal integrity, protein undernutrition also leads to reduced muscle mass and strength which is itself a risk factor for falls.

In the Framingham prospective cohort study, elderly men and women with lower total and animal protein intakes had greater rates of hip and spine bone loss than subjects consuming higher amounts of protein[43]. There is also evidence that increasing protein intake has a favorable effect on BMD in elderly men and women receiving calcium and vitamin D supplements, suggesting synergistic effects of these nutrients in improving skeletal health[44]. Randomized clinical trials in elderly patients with hip fracture have demonstrated the beneficial effects of giving protein supplements on the clinical outcome following surgery to repair the fracture. Protein supplementation resulted in fewer deaths, shorter hospital stays, and a greater likelihood of return to independent living[45-47].

A nutritious, varied diet, containing foods rich in calcium and vitamin D, helps build and maintain strong bones.

One of the mechanisms by which increasing protein intake may have favorable effects on bone is via an increase in the blood levels of IGF-I, which is a key compound involved in promoting bone formation[42]. Serum levels of IGF-I are exquisitely sensitive to fluctuations in dietary protein intake. In studies in which healthy children or adults were given extra servings of milk in their diets, and hence extra protein, significant increases in serum IGF-I were observed compared with control subjects[13,48]. Serum IGF-I also increased in elderly hip fracture patients given pure protein supplements[46]. In addition, recent studies suggest that certain amino acids (building blocks of protein) may promote calcium absorption from food in the intestine[49].

Despite the above research evidence that dietary protein is beneficial for bone health, and for recovering hip fracture patients, there has nevertheless been speculation that a higher dietary protein intake could have *negative* effects on calcium metabolism and possibly induce bone loss. This relates to the hypothesis that the 'acid-base balance' of the diet is a potential risk factor for osteoporosis. As foods are digested, absorbed and metabolized by the body, they produce chemicals which are acidic, neutral or basic. When acid is produced, it needs to be buffered (neutralized) in order to maintain the blood pH at optimum levels for the cells in the body. This buffering occurs by the action of the kidneys (excrete the acid substances) and the lungs (exhale carbon dioxide). Foods can be ranked according to whether they produce acid or base on a scale referred to as their Potential Renal Acid Load, or PRAL[50]. For example cereals, grains, rice, pasta, certain hard cheeses, fish and meat are acid-producing and have a higher PRAL value than fruits and vegetables, which are almost all alkaline, base-producing foods (they contain alkaline salts of potassium, calcium and magnesium). It is sometimes stated that milk is an acidic food that 'leaches' calcium from the skeleton, but this is not the case – milk is in the category of foods that are essentially neutral, neither particularly acidic nor basic[50]. Milk is a rich source of dietary calcium, protein and other nutrients, and supplementing the diets of children or adults with milk has been shown to improve bone mineral density[13,24,27].

It has been theorized that if the diet provides predominantly acidic foods (which includes key protein sources) and does not contain sufficient alkali-rich basic foods, then the alkaline salts of the skeleton may be drawn on in order to help with the buffering process, following which some of the calcium from bone is lost in the urine. The extension of this theory is that over a long period of time, ongoing consumption of a slightly more 'acidic' diet could gradually lead to bone loss[51]. Although there is some evidence from observational studies that a more alkaline-producing dietary pattern may be beneficial for bone health in pre- and postmenopausal women[52], the theory has not been proven in more definitive clinical trials.

As a normal part of ageing, kidney function declines and with it the ability to process and excrete acids, therefore the extra acid load imposed by 'acidic' diets is likely to be of greater concern in the elderly than in younger age groups. However, as described above, higher protein intakes (including animal protein) are associated with *improvements* in BMD and skeletal metabolism in the elderly. Furthermore, many protein-rich foods such as meat and

Adequate dietary protein intake is essential for bone health, at all stages in life.

There are many good sources of protein, of both animal and vegetable origin. Lean red meat, poultry and fish are excellent sources of animal protein, as are eggs and dairy foods. Vegetable sources of protein include pulses, nuts, grains and soya products.

dairy foods are also rich in phosphorus and potassium, both of which have an opposing effect in that they tend to *prevent* urinary calcium loss[53]. Finally, some amino acids promote calcium absorption[49] which would also offset urinary losses, and as long as calcium intake is adequate, higher protein intakes have been shown to improve bone density[44].

In summary, the majority of scientific evidence – including that from clinical trials – supports beneficial effects of protein intake on bone health, and highlights the risks associated with protein insufficiency and malnutrition.

Fruits and vegetables

In population-based observational studies, higher fruit and vegetable consumption has been demonstrated to have beneficial effects on bone mineral density in elderly men and women[54]. As described in the 'Protein' section, this could be related to the fact that fruits and vegetables supply alkaline salts in the diet, which assist in maintaining the acid-base balance of the body by helping to buffer the effects of the more acid-producing foods. However, fruits and vegetables contain a whole array of vitamins and minerals, antioxidants and possibly other types of bioactive compounds, so the exact components which may confer a benefit to bone are still to be clarified.

Evidence for a beneficial effect of fruits and vegetables on bone health was provided by the Dietary Approaches to Stopping Hypertension (DASH) intervention trials, carried out in men and women of ages 23-76 years[55]. Although the DASH studies were designed to investigate how diet could prevent heart disease, one of them investigated whether the total dietary pattern could also influence bone health. In the bone study, half of the subjects were asked to modify their whole dietary pattern, and consume a diet rich in fruits, vegetables and low-fat dairy products and low in sodium (the DASH diet), and the other half continued with their regular diets. Over a period of a few months, the DASH diet improved markers of bone and calcium metabolism (chemicals in the blood), which could potentially result in improved bone density if continued over the long term.

The potential role of phytoestrogens in preventing osteoporosis is a relatively new area of research. Phytoestrogens are compounds in plant foods that act like weak estrogens in the human body, and it is thought that they could therefore have similar bone-protective effects as the estrogen that is naturally produced in the body. One class of phytoestrogens – soy isoflavones – has received much attention. In some epidemiological studies in Asian populations, where soy foods are traditionally consumed, higher isoflavone intake was associated with higher bone mineral density. Among Caucasian populations, a few intervention studies in pre- and postmenopausal women examining the effect of soy isoflavones on bone density have been carried out but the findings are unclear, possibly because they were of short duration, involved relatively few subjects, and used varying sources and amounts of the isoflavones (reviewed in ref. 56). More research is needed in this area, but these early findings are not promising.

Higher fruit and vegetable consumption has been demonstrated to have beneficial effects on bone mineral density in the elderly.

Negative dietary factors and practices

Alcohol

Moderate alcohol intake is not thought to be harmful to bone. In contrast, higher levels of alcohol intake – more than 2 standard units of alcohol daily – were found to produce a significant increase in the risk of hip and other osteoporotic fractures, in a large data analysis conducted in women and men[57]. Excessive alcohol intake is known to have direct detrimental effects on bone-forming cells and on the hormones which regulate calcium metabolism. In addition, chronic, heavy alcohol consumption is associated with reduced food intake (including low calcium, vitamin D and protein intakes) and overall poor nutritional status, which will in turn have adverse effects on skeletal health. Excess alcohol use also increases the risk of falling, thereby increasing the opportunity for fracture.

Weight loss diets and eating disorders

Being underweight is a strong risk factor for osteoporosis. Very low body weight is associated with lower peak bone mass development in the young, and increased bone loss and risk of fragility fractures in older persons. In a large data analysis of 60,000 men and women worldwide[58], the risk of hip fracture almost doubled in people with a body mass index (BMI) of 20 kg/m^2, compared with people with a BMI of 25 kg/m^2. The effect of low body weight on fracture risk is largely due to its effects on BMD.

Weight loss diets could also jeopardize bone health, especially if undertaken repeatedly, given that nutrients such as calcium, vitamin D and protein are necessary to maintain bone and muscle strength. A study in a cohort of almost 7000 older women in the USA showed that weight loss increased the rate of hip bone loss, and almost doubled the risk of hip fracture, regardless of the women's current weight, or intention to lose weight[59]. In elderly men and women, weight loss promoted BMD loss, whereas weight maintenance and also commonly practiced forms of physical activity protected again BMD loss[60]. In overweight adults who are restricting energy (calorie) intake in order to lose weight, prudent measures to prevent bone loss include ensuring sufficient intake of calcium and vitamin D, taking weight bearing physical activity, and avoiding 'fad' diets in which whole foods groups are eliminated.

The eating disorder anorexia nervosa is a chronic psychiatric illness with an onset usually during adolescence – the time of life when maximal bone mass accrual occurs, thereby putting these patients at very high risk for compromising their peak bone mass. The extreme body thinness in female anorexia patients leads to estrogen deficiency and amenorrhea (cessation of menstruation). Estrogen deficiency in younger women contributes to bone loss in much the same way that estrogen deficiency after menopause does[61]. The low body weight and specific nutrient deficiencies are of themselves risk factors for low bone mass, as are the multiple hormonal and metabolic disturbances seen in anorexia patients. Anorexia patients with an average illness duration of about 6 years are found to have an annual fracture rate 7 times greater than that of healthy women of the same age[62]. Even recovery from anorexia nervosa does not confer full establishment of normal bone density, and fracture risk is increased throughout life[63]. Particular attention needs to be paid to the skeletal health of anorexic patients, in order to prevent and/or treat osteoporosis; they need to be identified early, and given appropriate support.

Maintaining a healthy body weight will help to preserve bone density. Young girls and women are particularly at risk of becoming underweight, due to excessive concerns with staying slim.

Lactose maldigestion and intolerance

When people are unable to digest all the lactose they have eaten, they are said to have lactose maldigestion. It 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 by the body. The term lactose intolerance refers to the abdominal symptoms (e.g. cramps, bloating) resulting from the inability to digest lactose. Lactose maldigestion does not necessarily result in lactose intolerance. Most people with lactose maldigestion can still consume at least some lactose-containing foods without experiencing symptoms of lactose intolerance. Lactose intolerance has to be diagnosed by a doctor using special tests, as the abdominal symptoms it causes can be confused with other digestive disorders, such as irritable bowel syndrome. Lactose maldigestion and intolerance are more common among Asians and Africans than among people of northern European descent, although supplementation studies in postmenopausal Chinese women demonstrated that additional milk intake was well tolerated and slowed the rate of bone loss[21,23].

Lactose intolerance is a potential risk factor for bone loss and osteoporosis, due to the avoidance of dairy products and hence possibly lower calcium intakes. People with lactose intolerance need to pay careful attention to diet, to ensure a sufficient calcium intake. Being lactose intolerant does not necessarily preclude all dairy products from the diet; some people with this disorder can still drink small quantities of milk without suffering any symptoms. In some countries lactose-reduced milks are available. Yoghurt with live cultures can often be tolerated, because the bacteria in the cultures produce the enzyme lactase, and some hard cheeses contain only negligible amounts of lactose. Another alternative is to take lactase tablets or drops along with dairy foods. Other foods and drinks can provide good sources of calcium, such as green leafy vegetables, nuts, canned fish with soft, edible bones such as salmon and sardines, calcium-fortified beverages and calcium-rich mineral waters. People who are lactose intolerant should consult with their doctor to discuss the best way of ensuring adequate calcium intake, either through diet, or if necessary, through the use of supplements.

Although there is no firm evidence that carbonated soft drinks themselves adversely affect bone health, these drinks 'displace' milk in the diet of children and teenagers – resulting in lower calcium intake.

Carbonated beverages

Concerns have been raised that consumption of carbonated soft drinks, notably cola drinks, may adversely affect bone health. Although a few observational studies have shown an association between high carbonated beverage consumption and either decreased BMD[64] or increased fracture rates[65] in teenagers, there is no convincing evidence that these drinks adversely affect bone health. It has been suggested that either the phosphorus content or the caffeine content of cola beverages may have a negative impact on calcium metabolism, but this has not been demonstrated in experimental studies[66]. Phosphorus is a key constituent of bone mineral along with calcium, and there is no evidence for detrimental effects of phosphorus intake on bone health or osteoporosis risk in healthy individuals[53]. An alternative explanation proposed was that cola beverages are acidic, but they do not have a high PRAL and are essentially 'neutral' to the kidney[50]. The acid in cola beverages is phosphoric acid, which is a biologically weak organic acid (as is citric acid, found in citrus fruits and fruit juices – these latter items are in fact 'basic' rather than 'acidic', which may seem counterintuitive). If there is any negative effect of carbonated beverages, it is more likely to be due to the fact that these drinks displace milk in the diet, and hence impact on calcium intake.

Finally, it should be noted that the carbonation is not the culprit. Many commercial mineral waters are carbonated, and some are rich in calcium and other minerals. High-calcium mineral waters have been shown to improve parameters of skeletal metabolism in postmenopausal women with a dietary calcium intake less than 700 mg/day[67].

Salt and caffeine

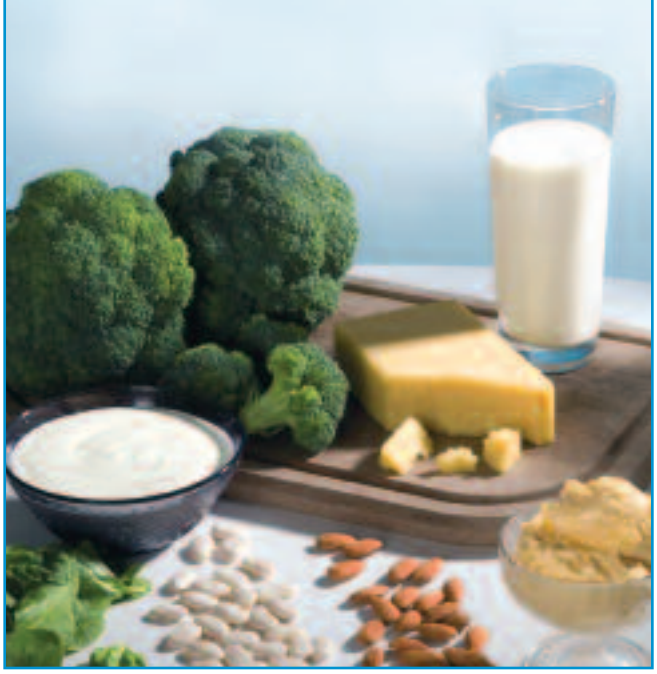
A high sodium (salt) intake promotes urinary calcium excretion, and is therefore considered to be a risk factor for bone loss. The DASH bone study showed that lowering sodium intake was beneficial for bone metabolism, but this was in the context of other dietary changes[55]. Studies in teenage girls have shown that salt loading decreased the amount of calcium taken up by the bones, apparently via a decrease in calcium absorption[68]. One study showed a small association between sodium excretion (a measure of salt intake) and bone loss in postmenopausal women[69]. However, there is no clear evidence that lowering sodium intakes would reduce fracture rates in populations, although there may be other public health benefits from such a strategy, primarily a reduction in population blood pressure levels which in turn could reduce the risk of stroke and cardiovascular diseases.

Caffeine is often implicated in the development of osteoporosis, but again without any convincing evidence that this is the case[70]. Caffeine does produce a small increase in urinary calcium excretion and a very small decease in calcium absorption, but the body appears to balance this out by reducing calcium excretion later in the day, therefore the net effect is negligible[66,70]. Studies examining the effects of caffeine on rates of bone loss in postmenopausal women showed that as long as calcium intake was sufficient (above about 800 mg/day), caffeine intake had no detrimental effects. However, if calcium intake was low, caffeine intake equivalent to about 3 cups of brewed coffee per day was associated with more bone loss[71]. The messages from the protein studies and the caffeine studies appear to be the same – as long as calcium is consumed in sufficient amounts (i.e. at least at the level of the recommended daily allowance), the effects of other single dietary constituents on bone metabolism are probably of little concern.

Ensuring sufficient calcium intake will help to offset potential calcium losses associated with salt and caffeine.

Key messages

- Ensure an adequate calcium intake, which meets the relevant dietary recommendations in the country or region concerned, at all stages of life
- Dairy foods, calcium-set tofu, some green vegetables (e.g. broccoli, kale and bok choy), nuts, and small canned fish with soft bones (e.g. sardines) provide the most readily-available sources of dietary calcium
- Maintain an adequate supply of vitamin D through sufficient exposure to the sun, through diet, or through supplements
- Ensure an adequate protein intake. Protein malnutrition is an important risk factor for hip fracture, and can also contribute to poor recovery in patients who have had a fracture
- Avoid excessive alcohol consumption
- Avoid being underweight, which is a strong risk factor for osteoporosis (body mass index < 18.5 kg/m^2)
- If on a weight-reducing diet, ensure adequate intakes of calcium and vitamin D, and avoid 'fad' diets in which whole food groups are severely restricted or eliminated
- Include plenty of fruits and vegetables in the diet, as these are beneficial for both bone and overall health
- In addition to a nutritious diet, other complementary lifestyle practices such as taking regular exercise and avoiding smoking help to maintain your bone density



Diseases and medications – special issues for nutrition and bone health

Inflammatory bowel disease

Inflammatory bowel disease is a general term referring to any disease characterized by inflammation (redness, irritation and swelling) of the bowel. Two of the most common disorders are *Crohn's disease* and *ulcerative colitis*. Crohn's disease causes ulcers throughout the small and large intestine, and ulcerative colitis usually causes ulcers in the lower part of the large intestine. Symptoms of these disorders tend to occur intermittently, and include diarrhea, abdominal cramps and pains, fever and weight loss. Patients with these disorders are at increased risk for bone loss and osteoporotic fractures, due to a variety of factors including: poor food intake and nutritional status; poor absorption of nutrients by the damaged intestine (including calcium, vitamin D, protein and calories); surgery to remove parts of the intestine; treatment with glucocorticoid medications to reduce the inflammation (see Glucocorticoid section below); hormonal modifications induced by the gastrointestinal disease; and the release of compounds called cytokines (chemical messengers) as part of the inflammatory process, which increase the loss of calcium from bone. Osteoporosis prevention measures need to be included in the overall care strategy for patients with these disorders, including ensuring an adequate calcium and vitamin D intake either through diet or supplements. Other measures to prevent bone loss include avoidance of excessive alcohol intake and smoking, and taking regular weight-bearing exercise. Osteoporosis medications may be recommended for some patients, for example older patients taking long-term glucocorticoid therapy and those with prior fragility fractures, as determined by the doctor.

Celiac disease

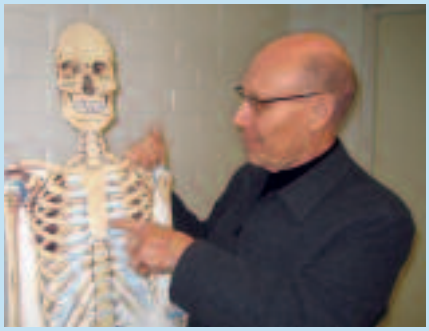
Celiac disease is a genetically mediated autoimmune disease characterized by intolerance to gluten (a protein group) found in wheat, rye and barley. It is also sometimes referred to as celiac sprue, gluten-sensitive enteropathy, or simply gluten intolerance, and is a relatively common disorder thought to affect about 0.5–1% of the population. Those affected suffer damage to the villi, the tiny finger-like protrusions lining the surface of the intestine that are involved in the absorption of nutrients from food. Symptoms include diarrhea, weight loss, anemia, fatigue, muscle cramps and nutritional deficiencies, and the disorder has to be controlled by strict adherence to a gluten-free diet. People with celiac disease may be at increased risk of osteoporosis if the disorder goes undiagnosed or is poorly controlled, due to inadequate nutrient absorption from food (including calcium and vitamin D), sometimes leading to frank malnutrition. Rates of celiac disease are commonly found to be higher among patients with osteoporosis than those without osteoporosis. Sometimes the celiac disease has no symptoms, and is 'discovered' when a patient who is vitamin D-deficient shows no response (i.e. blood levels don't change) to being given a large therapeutic dose of vitamin D. By following a gluten-free diet, the damage to the gut surface is reversed, nutrients can be absorbed properly again, and the symptoms should abate.

Glucocorticoid medications

Glucocorticoids are steroid hormone medications that are used to treat many chronic inflammatory diseases, for example rheumatoid arthritis, chronic obstructive pulmonary disease (COPD), asthma, Crohn's disease, and some skin and liver diseases. Commonly prescribed glucocorticoids include cortisone, hydrocortisone, prednisone and dexamethasone. Glucocorticoid use is an extremely important risk factor for osteoporosis and related fractures, as they can induce substantial bone loss, early in the course of treatment. A rate of bone loss of over 15% per year has been reported in patients receiving doses of prednisone at 30 mg/day. The predominant effect of the glucocorticoids is a reduction in bone formation, due to direct detrimental effects on the cells that make new bone (osteoblasts), although there is also evidence that they increase the activity of the cells that remove bone (osteoclasts). They can also interfere with calcium metabolism, and adversely affect the levels of sex hormones. In addition to the glucocorticoid treatment, the primary disease itself might also predispose to bone loss, through factors such as nutritional deficiencies (e.g. in gastrointestinal diseases) or the increased production of inflammatory cytokines which enhance bone loss (e.g. in rheumatoid arthritis).

Patients taking glucocorticoids long-term (more than 3 months) should be evaluated for osteoporosis risk. The decision to initiate treatment with an osteoporosis medication (often a bisphosphonate) would depend on the glucocorticoid dose, and the patient's other risk factors for fracture[72]. In addition, those initiating long-term glucocorticoid treatment should be counselled on preventive lifestyle changes, such as good nutrition, ensuring adequate calcium and vitamin D intake (supplements are usually required), and weight-bearing exercise.

Case Studies



Jouko Numminen, Finland

"Because one reason for my osteoporosis was celiac disease, I follow a strict gluten-free diet."

"I am 57-years old and was diagnosed with severe osteoporosis only after decades of painful fractures.

As a child I was very active: Always running, jumping and playing outside in the sun. I also drank milk. I continued to lead a physically active lifestyle as an adult.

Then, at the age of 30, I experienced a rib fracture. At the time I thought "that's normal, it can happen". I had another fracture at the age of 40 and subsequently several rib fractures. I questioned whether this was indeed normal, but the doctor didn't take me seriously and reassured me that little accidents can happen. There was also no real explanation for the excruciating back pain. I was told that the vertebral discs had become a little thinner but, not to worry, everyone has degenerative arthritis.

As a result, for many years my life was filled with pain and my quest for a diagnosis included visits to various doctors, X-rays, physiotherapy – a frustrating and expensive odyssey. I even spent a whole year working only two days a week to see whether my health would improve. This turned out to have no effect – in the end it was always painkillers and "on with life" regardless of the pain.

Five years ago, as I leaned over the back of the chair in our kitchen, something snapped in my chest. My wife refused to believe that a broken bone could "just happen" for no reason. Inspired by an advertisement in a newspaper, I made one phone call to a private medical center and made an appointment for a DXA scan. The result of the DXA clearly showed that I had very serious osteoporosis.

I took the DXA-results to the company doctor at work, and after that to the university hospital. A series of examinations revealed the whole picture: how serious my osteoporosis was and why I had it: I was diagnosed with celiac disease, a malabsorption disorder in which the body's ability to absorb protein, fat, carbohydrates, vitamins and minerals, including calcium and vitamin D, is greatly reduced. Since both calcium and vitamin D are essential for bone health, this partly explains why osteoporosis is so common in people with celiac disease.

Although osteoporosis had been diagnosed, the medical centre could offer me very little information. I was lucky that I was accepted for a self help course, which was organised by the Finnish Osteoporosis society. I met people who were in the same position as I was. Through this group, I found out how I could cope and move forward with my life.

Now I am retired. My back is fragile and I can't lift anything heavier than 5 kg. How I wish that I could lift our sweet little grandchild on to my lap! Shopping bags quickly become too heavy for me to lift safely. Sitting for long periods is very difficult, and walking at times very painful. But I keep myself moving by doing gardening and Nordic walking.

Because one reason for my osteoporosis was celiac disease, I follow a strict gluten-free diet. During the last five years I have taken osteoporosis treatment including calcium and vitamin D tablets. Exercise is now a routine part of my daily life.

Now I am not afraid of ageing. I know that by taking charge of my lifestyle, I can positively influence my bone health – and my bones will continue to carry me into the future."

Ciara Shouldice, Ireland

"I had neglected my nutrition to a degree where my bone density was critically low"

Osteoporosis has been called the "silent disease" and that was all too true in my case. I had been participating in combat sports, doing sit-ups at twice weekly visits to the gym – whilst walking around with the bones of an 80 year old woman!

I was a 23 year old college graduate full of energy. I regarded myself as leading a healthy active life; I didn't smoke, ate healthy food and was training hard to keep fit. In reality I had neglected my nutrition to a degree where my bone mineral density was critically low: it was time to take action.

My first realization that something was amiss was when I attended my local G.P. following a period spent traveling overseas. She was immediately concerned about my weight-loss; at 5 foot and 5 inches tall, I was under 7 and a half stone and clinically underweight. I had noticed it also, but had attributed it to the traveling and skipping meals with erratic eating habits. She asked me in depth about my diet which revealed that I was eating fewer and fewer dairy and egg products. Since I was already a lacto-ovo vegetarian, this concerned her. She revealed that I was doing too much exercise for the amount of calories I was taking in. And, she could see another worrying change taking place. I had noticed skipped periods which I had put down to exam stress, however during traveling they never returned. In total I had experienced cessation of periods for over a year and a half. Based on this information, my G.P. advised me to get a DXA scan as quickly as possible – this was the first time I had

been informed of the connection between diet, exercise, hormonal imbalances (particularly estrogen) and osteoporosis.

My G.P. mentioned that the Anatomy Department of Trinity College Dublin (TCD) was researching the association between eating disorders amongst teenagers and the incidence of osteoporosis. They agreed for me to take a scan within a week. My lumbar spine and both hips were scanned and I received my results approximately 10 minutes later. The results shocked me. I remember walking over the cobblestones of Trinity College in disbelief – I had osteoporosis in my lumbar spine, with a T-Score of less than -2.5 (anything above -1.0 is considered normal when compared with normative values based on age and gender). My hips displayed moderate osteopaenia; with a score of -1.7 my left hip was worse than my right.

I discussed the results with a specialist, Professor Moira O'Brien, who advised me on treatment, but stressed the importance of lifestyle change. I started taking calcium and vitamin D supplements, as well as half a litre of milk, which in total amounted to 1000 mg calcium and 800 IU vitamin D. I was given a prescription for HRT, which was subsequently changed to a low dose contraceptive pill due to complications. I am still taking these medications 18 months later. Regarding lifestyle changes, I have cut down on combat sport and have focused on more moderate exercise. In addition I have cut down on caffeine and reduced alcohol intake. My eating patterns have improved and I take a more varied diet which includes dairy products.

Six months ago, almost one year post diagnosis, a follow up DXA scan showed very positive improvements. The osteoporosis in my lumbar spine had improved to moderate osteopaenia and my hips were within the normal range. As changes in bone density are generally slow to occur, this was a very encouraging result.

I have joined the Irish Osteoporosis Society and am learning of the huge amount of work they are putting into educating the general public about the risk factors of osteoporosis.

My parents and friends were shocked that I had what they perceived an "old woman's disease" – they could not believe that such an apparently healthy, active and young person could have this condition. Even amongst sufferers of osteoporosis, who will know the risk factors and etiology of the disease, there is still the misconception that it only affects older women.

Roswitha Horn, Austria

"We never got enough to eat and there were practically no dairy products for us children."

Roswitha Horn was born in 1935, growing up in hardship during World War II and the post-war years in Europe.

"Healthy food, vitamins – catchwords of today – didn't exist then. My mother, a widow with two children, had her hands full just trying to keep our stomachs full. Since we lived in the city, we never got enough to eat and there were practically no dairy products for us children," recalls Roswitha.

Although not a particularly robust child, Roswitha had the good fortune to avoid illness despite the lack of food. At 19 she married, became the mother of three children, and continued to enjoy good health. Roswitha made sure that her children were getting healthy food, and even today she is very aware of the importance of good nutrition. In 1994, at 57, she had a DXA scan (a bone density test) for the first time. Osteoporosis was diagnosed.

"I didn't take it seriously at all. I was not in pain, I felt good, and I assumed that since I was leading a healthy lifestyle I could simply ignore the diagnosis. I was not aware of the implications of osteoporosis or the importance of taking medication," recalls Roswitha. She further explained that her husband of 50 years, who passed away recently, had always been rather 'anti-medicine' and had never been to a doctor. This viewpoint reinforced her own reluctance to deal with her diagnosis. In addition, her husband had been a chain smoker and as a result Roswitha was a 'passive' smoker for five decades.

In 2002 Roswitha became a member of a newly founded self-help group organized by the umbrella initiative 'Aktion Gesunde Knochen' (Healthy Bones Initiative). In the self-help group she learned about the dangers of osteoporosis and began sharing her experiences with other osteoporosis patients.

"I'd like to maintain my current quality of life as long as I can – to stay mobile and active. Exercise is important to me, whether it is bike riding, swimming, Nordic walking or dancing. I am conscious of what I eat and take my medication regularly," she says.

"My generation experienced food deprivation, but now we have the opposite," says Roswitha. "Today there is too much. Too many unhealthy beverages and fast food, combined with lack of exercise."

Roswitha firmly believes that those responsible for health care and the media should concentrate on raising awareness among children and teenagers. She volunteered to be a patient speaker at the May 2006 'Staying Power' press conference, at which a new IOF report detailed the significant personal, social and economic costs associated with women not staying on their osteoporosis treatment.

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Are you among the one in three women and the one in five men over 50 who will be affected by osteoporosis? Osteoporosis weakens bones. It causes severe disability. It can be fatal. But osteoporosis can be detected early. It can be treated.

Are you at risk of osteoporosis?

Take the One-Minute Osteoporosis Risk Test

1. Have either of your parents been diagnosed with osteoporosis or broken a hip after a minor bump or fall?
❑ Yes ❑ No

2. Have you broken a bone after a minor bump or fall?
❑ Yes ❑ No

3. Have you taken corticosteroid tablets (cortisone, prednisone, etc) for more than 3 months?
❑ Yes ❑ No

4. Have you lost more than 3 cm (just over 1 inch) in height?
❑ Yes ❑ No

5. Do you regularly drink alcohol in excess of safe drinking limits?
❑ Yes ❑ No

6. Do you smoke more than 20 cigarettes a day?
❑ Yes ❑ No

7. Do you suffer frequently from diarrhoea (caused by problems such as celiac disease or Crohn's disease)?
❑ Yes ❑ No

8. **For women:** Did you undergo menopause before the age of 45?
❑ Yes ❑ No

9. Have your periods stopped for 12 months or more (other than because of pregnancy or menopause)?
❑ Yes ❑ No

10. **For men:** Have you ever suffered from impotence, lack of libido or other symptoms related to low testosterone levels?
❑ Yes ❑ No

If you answered "yes" to any of these questions, it does not mean that you have osteoporosis. Diagnosis of osteoporosis can only be made by a physician through a bone density test. We recommend that you show this test to your doctor, who will advise whether further tests are necessary. The good news is that osteoporosis can be diagnosed easily and treated. Talk to your local osteoporosis society about what changes you might make in your lifestyle to reduce your osteoporosis risk. You can contact your national osteoporosis society via **www.osteofound.org**

“Osteoporosis has few visible symptoms. There are no rashes, no coughs, no headaches – which is why so many people take strong and healthy bones for granted until it is too late; until bones break, pain cripples, disability limits daily life.”

Her Majesty Queen Rania of Jordan, IOF Patron

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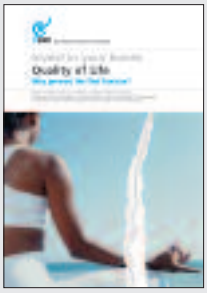

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