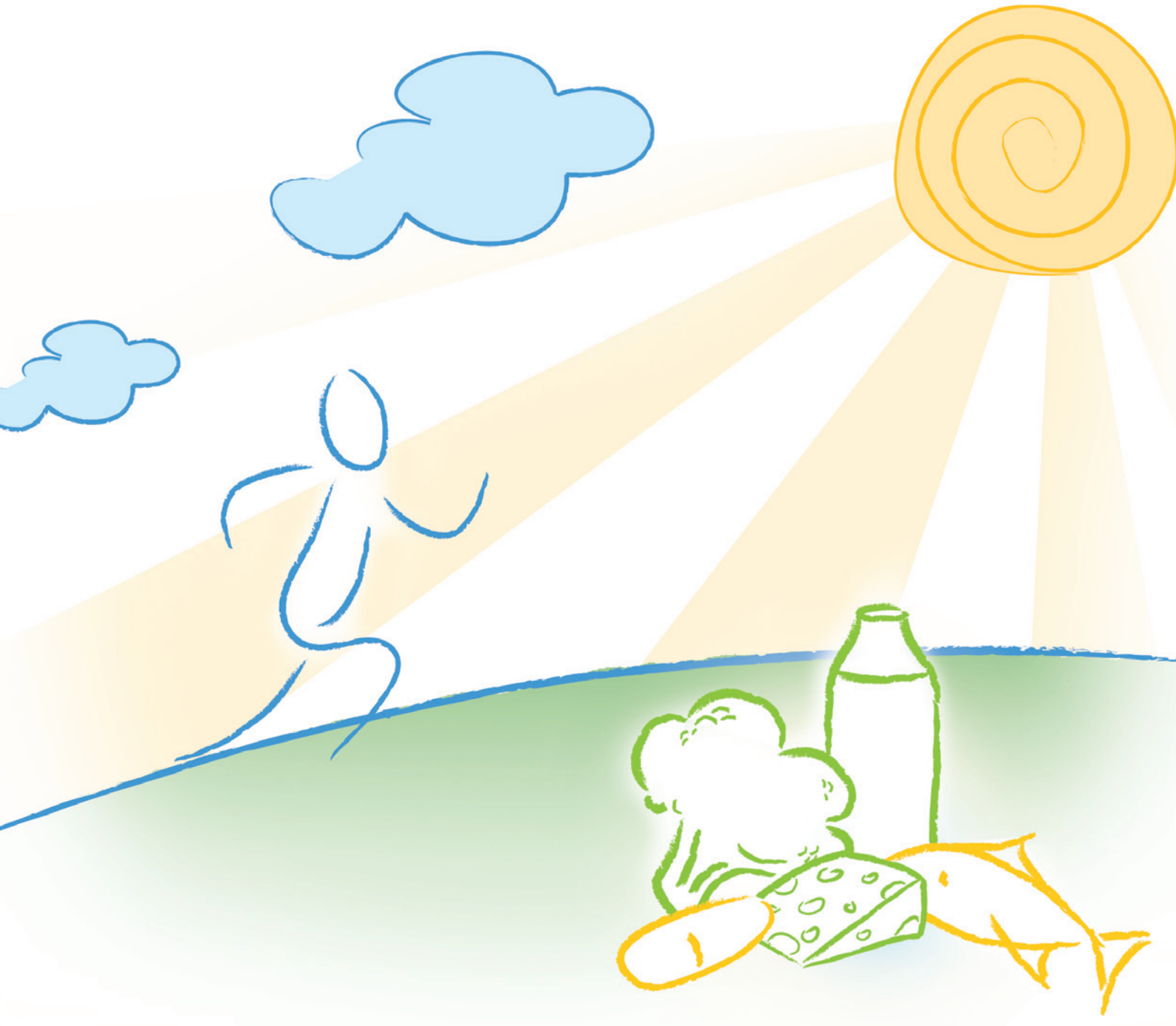
THREE STEPS TO UNBREAKABLE BONES

VITAMIN D, CALCIUM AND EXERCISE



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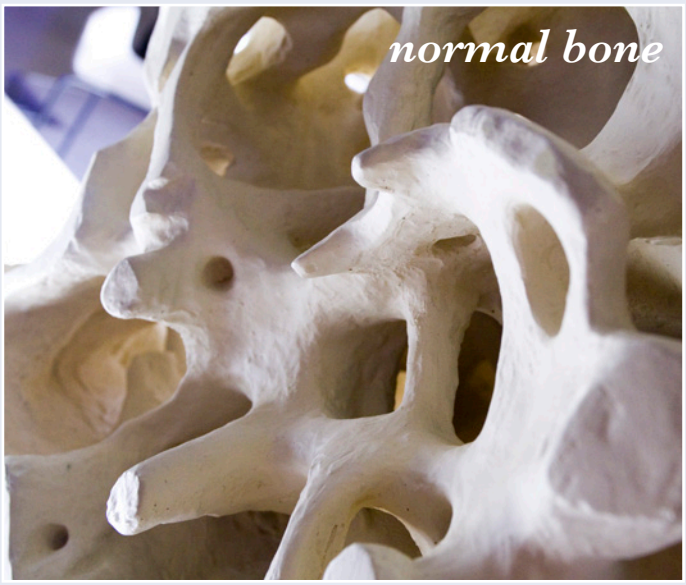

WHAT IS OSTEOPOROSIS?

Osteoporosis is a disease characterized by low bone mass and deterioration in the microarchitecture of bone tissue, leading to an increased risk of fracture. Osteoporosis occurs when the bone mass decreases more quickly than the body can replace it, leading to a net loss of bone strength. As a result the skeleton becomes fragile, so that even a slight bump or fall can lead to a broken bone, (referred to as a fragility fracture). Osteoporosis has no signs or symptoms until a fracture occurs – this is why it is often called a 'silent disease'.

Osteoporosis affects all bones in the body, however fractures occur most frequently in the vertebrae (spine), wrist and hip. Osteoporotic fractures of the pelvis, upper arm and lower leg are also common. Osteoporosis itself is not painful but the broken bones can result in severe pain, significant disability and even mortality. Both hip and spine fractures are also associated with a higher risk of death - 20% of those who suffer a hip fracture die within 6 months after the fracture.

A COMMON DISEASE

It is estimated that worldwide an osteoporotic fracture occurs every 3 seconds. At 50 years of age, one in three women and one in five men will suffer a fracture in their remaining lifetime. For women this risk is higher than the risk of breast, ovarian and uterine cancer combined. For men, the risk is higher than the risk for prostate cancer. Approximately 50% of people with one osteoporotic fracture will have another, with the risk of new fractures rising exponentially with each fracture.

A GROWING PUBLIC HEALTH PROBLEM

The risk of sustaining a fracture increases exponentially with age due not only to the decrease in bone mineral density, but also due to the increased rate of falls among the elderly. The elderly represent the fastest growing segment of the population. Thus as life expectancy increases for the majority of the world's population, the financial and human costs associated with osteoporotic fractures will increase dramatically unless preventative action is taken.

Fractures due to osteoporosis can cause significant *disability* and *loss in quality of life*

FOREWORD

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Eating well and staying physically active are two essential components of a healthy lifestyle. These are also the pillars of osteoporosis prevention at all stages of life. Although genetics largely determine the size and density of your bones, lifestyle factors such as regular exercise and good nutrition also play key roles.

Good nutrition fuels our bone health by providing our body with the necessary quantities of vitamins, calcium, and high quality proteins that are required to maintain bone and muscle strength. Vitamin D has been found to be of particular importance to bone health. In this report, we raise awareness of the broad prevalence of vitamin D deficiency and recommend supplementation with vitamin D in all adults age 60 years and older for its proven reduction of falls and fractures. Notably, vitamin D plays a critical role in bone development in children and correlates positively with bone density in younger adults. Apart from its benefit on calcium uptake in the bowel, vitamin D has a direct effect on muscle. As sufficient vitamin D is not obtained from an otherwise healthy diet and direct daily sun exposure, which is the main stimulus from vitamin D production in the skin, is limited in most adults, supplementation should be considered.

Engaging in physical activity has many health benefits and is absolutely essential for strong bones and muscles. Thus, it is important to strengthen your muscles and bones to reduce your risk of osteoporosis, falls and fractures. Walking 4 hours a week at a brisk speed has been associated with about a 40% reduction in hip fractures[1]. Simple targeted exercise programmes have been shown to improve bone density and functional mobility, resulting in 10 to 50% fewer falls in frail and active older adults[2,3,4]. As for a healthy diet, it is never too soon or too late to start. There is always a benefit, regardless of age.

The combination of staying active, eating a diet rich in calcium and ensuring that you are not vitamin D deficient offers tremendous opportunities to improve bone and muscle health and reduce the risk of osteoporosis. Importantly, the benefits derived from healthy nutrition with adequate vitamin D may be enhanced by greater physical activity. This is why this year's 'World Osteoporosis Day' campaign message merges these three components in "Embrace a bone healthy lifestyle". Applied together each component enhances the other for optimal bone and muscle health.

The overall objective of this year's World Osteoporosis Day campaign is to raise awareness of the importance of maintaining sufficient daily levels of vitamin D, calcium, protein and physical activity to maintain bone health, at all ages. However, as underlined by our special focus on vitamin D, we wish to address a growing public health concern: falls and fall-related fractures in our ageing populations. Seventy-five per cent of all fractures occur in individuals age 75 and older. As muscles weaken elderly people become frail, experiencing functional decline and a tendency to fall. The ultimate goal of our public healthcare policy (and certainly the personal goal of everyone as they age!) is to have seniors remain physically independent and active members of their communities. Muscle and bone health are the key targets to help achieve this goal.

BONE AND MUSCLE STRENGTH
A team in osteoporosis and falls prevention

A primary risk factor for a fracture is a fall, with over 90% of all fractures occurring after a fall[5]. Thus, critical for the understanding and prevention of fractures, especially at older age, is the close relationship between falls and muscle weakness. Individuals with better muscle strength have stronger bones, fall less, and have fewer fractures. Mechanistically, the circumstances[5] and the direction[6] of a fall determine the type of fracture, whereas bone density and mechanical factors such as better muscle strength or better padding around the hip, critically determine whether a fall will result in a fracture[7]. Moreover, falling may result in self-imposed reduction in physical activity due to fear of further falls, but which, paradoxically, may result in reduced bone density and muscle strength with a consequent increase in risk of further falls[8]. Thus, strengthening bone and muscle is critical for the prevention of falls and fractures.

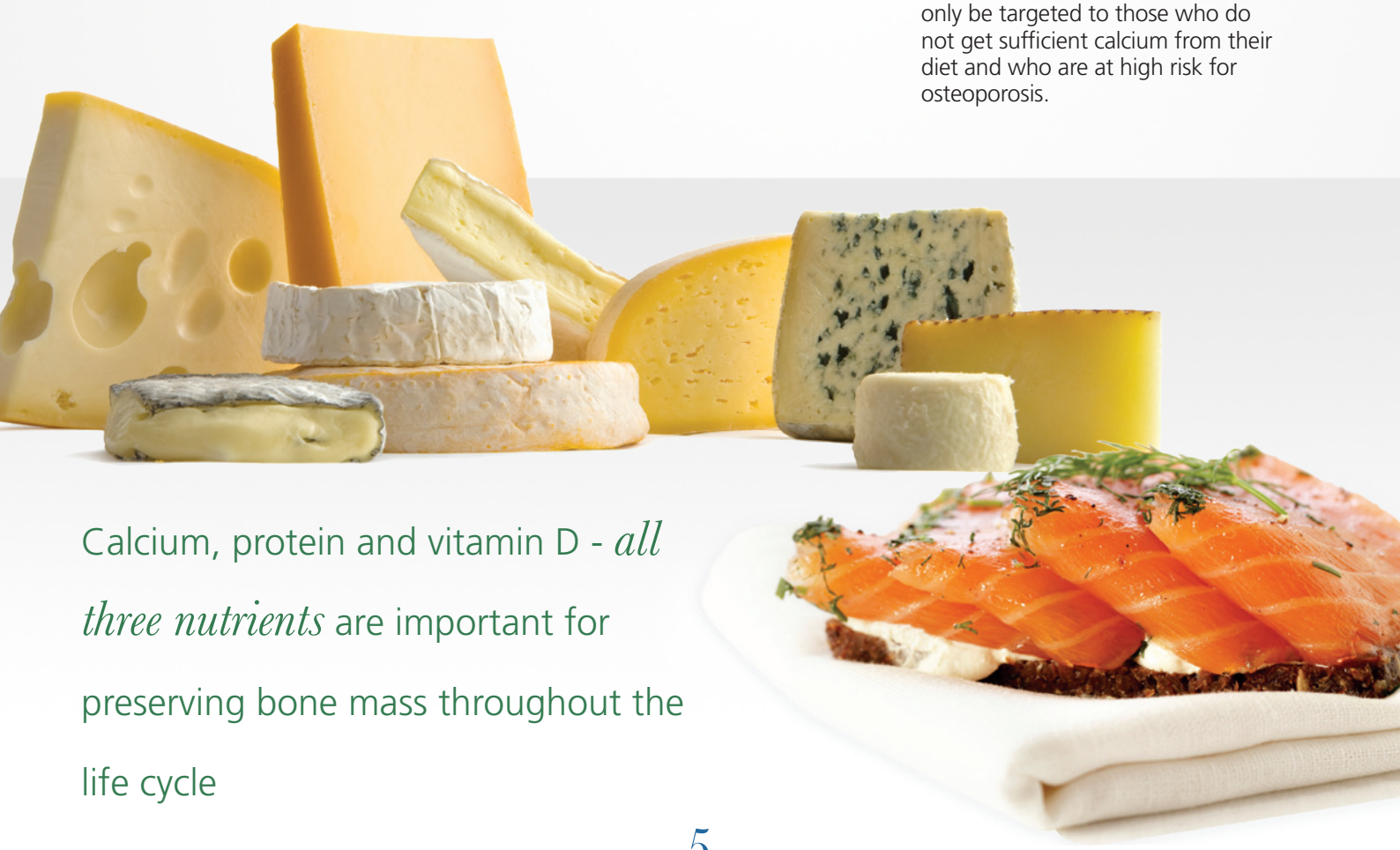
Better muscle strength for the prevention of falls is also important as falling is a frequent event at older age. Thirty percent of those 65 years or older, and 40-50% of those 80 years or older, report having had a fall over the past year[9, 10]. Serious injuries occur with 10-15% of falls, resulting in fractures in 5% and hip fracture in 1-2%[11]. As an independent determinant of functional decline[12], falls lead to 40% of all nursing home admissions[13]. Recurrent fallers may have close to a 4-fold increased odds of sustaining a fall-related fracture compared to individuals with a single fall[14]. As the proportion of individuals aged 65 and older is predicted to increase from 25% to 40% by 2030 in Europe[15-19] and in large parts of the Western World[20, 21], the number of fall related fractures will increase substantially. As both vitamin D and exercise have been proven to improve bone health and reduce falls by 20 to 50%, this report promotes these two effective, well-tolerated and easy to implement strategies for unbreakable bones.

EAT WELL: Calcium, protein & vitamin D!

Our skeleton is sensitive to mechanical loading ,and bone mineral density can be improved by weight-bearing physical activity. In addition, our bones have nutritional needs. Thus, the combination of staying active, eating a healthy, calcium-rich diet plus taking a vitamin D supplement offers tremendous opportunities to improve bone and muscle health and reduce the risk of osteoporosis. Moreover, the benefit of a "bone healthy diet rich in natural calcium sources with added vitamin D" may be enhanced by greater physical activity or reduced by the lack of it. This is why this report merges all concepts — applied together each concept elevates the other for optimal bone and muscle health.

Bone is a living and metabolically active tissue and therefore undergoes constant renewal throughout life. As with other organs, our bones need to be fueled with key nutrients and energy. A healthy and balanced diet for strong bones will provide key micronutrients (vitamins and minerals) as well as macronutrients (protein, fat, carbohydrates) to provide the building blocks for bone and the energy needed for its renewal. This report highlights the importance of two significant nutrients, calcium and protein, which are building blocks for healthy bones and muscles plus one nutrient, vitamin D, that allows optimal availability of calcium from a healthy diet and has a direct effect on muscle strength. All three nutrients have been shown to be important for preserving bone mass throughout the life cycle. In addition, vitamin D supplementation has been shown to improve function and reduce the risk of falls and fractures among older adults.

While our calcium needs can be covered by a nutritious diet, it is important to realize that the same is not true for vitamin D. It is nearly impossible to get enough vitamin D from food as it is only found in small amounts in certain foods; secondly, it is difficult for most adults (especially older people) to get enough daily sunlight exposure to also reach adequate levels. Therefore supplementation is recommended in those over 60 years. For calcium, as highlighted in this report, dietary sources are the preferred option and supplementation with calcium should only be targeted to those who do not get sufficient calcium from their diet and who are at high risk for osteoporosis.



Calcium, protein and vitamin D - *all three nutrients* are important for preserving bone mass throughout the life cycle

CALCIUM

Calcium is a key structural component of bone and is built into bone as a mineral complex that includes calcium and phosphate. Our skeleton houses 99% of our body's calcium stores. Calcium built into bone also serves as a calcium reservoir for maintaining calcium levels in the blood. Calcium is absorbed in the small intestine both by passive diffusion and by active absorption regulated by vitamin D. Individuals who have more vitamin D are able to absorb more calcium[22]. Therefore, in combination with vitamin D, it is thought that a minimum total calcium intake of about 800 mg per day may be sufficient[23,24]. This amount of calcium can be achieved by a healthy diet that contains a daily dose of calcium-rich foods (for example: 1 glass of milk or slice of hard cheese = 300 mg calcium; 1 glass of calcium-rich mineral water = 200 mg calcium; 4 sardines = 500 mg; 28 grams of almonds = 75 mg calcium).

See food table on right

Individuals who have *more* vitamin D are able to absorb *more* calcium

APPROXIMATE CALCIUM LEVELS IN FOODS

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

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

embrace calcium rich foods

Dietary sources of calcium are preferred to supplementation for several reasons:

1. calcium-rich foods such as dairy (milk, yoghurt, cheese) and nuts contain additional nutrients valuable for bone and muscle health, especially high-quality protein;

2. high-dose calcium supplementation (1000 mg and more) may not be beneficial for cardiovascular health[25] whereas calcium-rich foods are not associated with an increased cardiovascular risk;

3. calcium tablets can reduce intestinal phosphate absorption[26], which may be detrimental as a balanced calcium-phosphate ratio is needed for bone mineralization. The latter may be primarily a concern in the senior population[27], where phosphate deficiency is found in about 10 to 15% of women over 60 years old[28]. Each increase in calcium supplement intake by 500 mg/day decreases phosphorus absorption by 166 mg[26], so a calcium supplement of 1000 mg may shift an elderly person on a relatively low phosphorus intake into phosphate deficiency[26,29]. Conversely, dairy products provide both calcium and phosphate.

IOM* DIETARY REFERENCE INTAKES FOR CALCIUM

	Calcium	
Life Stage Group	Estimated Average Requirement (mg/day)	Recommended Dietary Allowance (mg/day)
Infants 0 to 6 months	-	-
Infants 6 to 12 months	-	-
1-3 years old	500	700
4-8 years old	800	1,000
9-13 years old	1,100	1,300
14-18 years old	1,100	1,300
19-30 years old	800	1,000
31-50 years old	800	1,000
51-70 year old males	800	1,000
51-70 year old females	1,000	1,200
>70 years old	1,000	1,200
14-18 years old, pregnant/lactating	1,100	1,300
19-50 years old, pregnant/lactating	800	1,000

** Institute of Medicine of the National Academies in the USA*
***For infants, Adequate Intake is 200 mg/day for 0 to 6 months of age and 260 mg/day for 6 to 12 months of age.*

HOW DOES CALCIUM IMPROVE BONE HEALTH?

Calcium performs various functions in the body and is needed for muscle contraction and as a building block of bone. A calcium-rich diet is especially important to build bone during the highest rate of bone growth, which is in childhood and adolescence. Supporting bone health early in life will help protect us from developing osteoporosis later in life. As well, when bone density is decreasing in later years, a calcium-rich diet helps us to maintain bone mineral density. This applies to men and women of all ages.

While calcium supplements in later life have shown a small benefit on bone mineral density[30,31], calcium supplements in vitamin D deficient individuals have not been shown to reduce the risk of fracture[27]. Also, calcium supplementation without vitamin D supplementation may contribute to an increased risk of hip fracture[27]. Thus, vitamin D supplementation plays a key role in bone health — calcium supplementation alone is insufficient to prevent fractures. The focus in fracture prevention has therefore shifted to vitamin D supplementation in combination with a healthy calcium-rich diet. *See table on left*

Notably, these recommendations of total calcium intake do not take additional vitamin D supplementation into consideration. As discussed in the text above, individuals who have more vitamin D are able to absorb more calcium. Therefore, in combination with vitamin D, a lower total calcium intake of about 800 mg per day is likely sufficient. This is the amount of calcium that can be achieved by a healthy diet that contains a daily dose of calcium-rich foods.

PROTEIN

HOW DOES PROTEIN IMPROVE BONE HEALTH?

Protein is a building block for strong bones and muscles. Similar to calcium and vitamin D, insufficient protein intake is detrimental to bone development[32] and bone mass maintenance later in life[33-36]. As well, a low protein intake is associated with a reduction in muscle mass throughout the life cycle and seniors with decreased protein intake are more vulnerable to muscle weakness, sarcopenia (age-related decline in muscle mass and function) and frailty, all contributing to an increased risk of falling[37-39].

As with vitamin D, protein intake has a dual benefit on osteoporosis prevention, as it helps build stronger bones and muscles. One of the mechanisms by which a higher protein intake may have a positive influence on bone and muscle health is via an increase in blood levels of Insulin-like Growth Factor -1 (IGF-1). Regular daily milk intake results in a measurable increase in IGF-1 blood levels in children[40]. This may also be achieved with protein supplements as demonstrated in one study among senior hip fracture patients[35]. IGF-1, produced by the liver, promotes bone and muscle formation, and supports the conversion of vitamin D into its active form (1,25-dihydroxyvitamin D)[41].

The latter mechanism (via vitamin D) explains in part how a higher protein intake promotes calcium and phosphate uptake in the intestine. In addition, some amino acids (protein components) have a direct stimulatory effect on calcium uptake in the intestine[42]. In children, a higher protein intake has been shown to increase the benefit of exercise on bone mineral content[43], confirming that the benefit of staying active for stronger bones is enhanced with protein-rich nutrition.

ARE THERE ADVERSE EFFECTS OF A HIGHER PROTEIN INTAKE ON BONE HEALTH?

Some studies have claimed that a high protein intake may contribute to increased calcium loss via the kidneys and have suggested that a protein rich diet may be detrimental for bone health. This hypothesis has been disproved as the increased calcium excretion after a protein-rich meal does not contribute to a negative calcium balance[44]. Furthermore, it could not be confirmed that animal proteins, by increasing the acid load in our body, lead to bone loss. In fact, there is no

Low protein intake is associated with a reduction of muscle mass throughout the life cycle

embrace protein rich foods

convincing evidence that plant protein sources are superior to animal protein sources[44]. **Both plant and animal protein sources appear to promote stronger bones and muscles for osteoporosis prevention.**

SOURCES OF PROTEIN

Dairy products are a good dietary source of protein necessary for stronger bones and muscles. Additional protein sources include nuts, legumes, fish and meat. The current Recommended Daily Allowance (RDA)* is 1.5 g/kg each day in infants, 1.1 g/kg each day in children age 1 to 3 years, 0.95 g/kg each day in children age 4 to 13, 0.85 g/kg each day in teens age 14 to 18, and 0.8 g/kg per day for adults aged 19 and older. Notably, based on recent epidemiological and clinical studies, a protein intake higher than the current RDA (1.0 to 1.2 g/kg per day) may be beneficial for bone and muscle health among the senior population[39].

PROTEIN BENEFITS SPECIFIC TO SENIORS AT RISK OF HIP FRACTURES

Elderly hip fracture patients are the most vulnerable to malnutrition and protein deficiency. Low protein intake, like vitamin D deficiency, contributes to an increased risk for hip fracture[36,45], although a higher milk intake did not reduce the risk of hip fracture in a summary of available data from large cohort studies among women, while a benefit among men could not be excluded[46]. Notably, several clinical trials with protein supplementation in senior hip fracture patients resulted in fewer deaths, shorter hospital stay, and a higher likelihood of return to independent living[35,47,48]. In one of these studies it was demonstrated that blood IGF-1 levels increased in seniors who received protein supplements[35]. Furthermore, increasing protein intake has a beneficial effect on bone mineral density in senior men and women taking vitamin D plus calcium supplements, suggesting an additive benefit of these nutrients[49].

PROTEIN SOURCES	
Food	Protein (g)
1 ounce meat, fish, poultry	7
1 large egg	6
4 ounces milk	4
4 ounces low-fat yoghurt	6
4 ounces soy milk	5
3 ounces tofu, firm	13
1 ounce cheese	7
1/2 cup low-fat cottage cheese	14
1/2 cup cooked kidney beans	7
1/2 cup lentils	9
1 ounce nuts	7
2 tablespoons peanut butter	8
1/2 cup vegetables	2
1 slice bread	2
1/2 cup of most grains/pastas	2

**Recommended Daily Allowances; US Department of Agriculture*

OTHER LIFESTYLE FACTORS THAT NEGATIVELY IMPACT ON BONE HEALTH

There are other important lifestyle factors that impact negatively on bone health. These include smoking, excessive alcohol and low body mass index.

ALCOHOL

Studies have shown that more than two units of **alcohol** per day can increase the risk of osteoporotic and hip fractures in both men and women[50]. More than four units of alcohol per day can double the fracture risk. While some of this increased risk is due to decreased bone mineral density, some of the risk is also due to other poorly understood factors, which may include general deterioration of health and the increased likelihood of falling, especially in the elderly[51].

SMOKING

Smoking also increases the risk of osteoporotic fractures[52]. Studies of nearly 60,000 people in Canada, U.S.A., Europe, Australia and Japan show that smoking increases the risk of hip fracture by up to 1.8 times[52]. Conversely, the risk of hip fracture declines after smoking cessation[53]. Although the risk of fracture from smoking increases with age, cigarette smoke has an early effect on bones. Studies have shown that young male smokers, 18-20 years old, have reduced bone mineral densityand an increased risk of osteoporosis later in life [54,55].

LOW BODY MASS INDEX

The **body mass index**, or BMI, is a measure of how lean someone is and can be used as a guide to measure his or her osteoporosis risk[56]. A BMI of 20 to 25 is generally considered to be ideal. BMI below 19 is considered underweight and a risk factor for osteoporosis.

HOW DOES VITAMIN D IMPROVE BONE HEALTH?

Vitamin D is essential for bone development and maintenance throughout life. Vitamin D has several key functions:

- it assists in calcium absorption[22]
- it has a downward regulatory effect on parathyroid hormone level[23] resulting in reduced bone loss[57]
- it ensures correct renewal and mineralization of bone[58]
- it has a direct stimulatory effect on muscle tissue[59] and thereby reduces the risk of falling[60]
- it improves strength and function[61], increases bone mineral density[24], and reduces the risk of falls and fractures by about 20%, including fracture of the hip (based on evidence from clinical trials of oral vitamin D supplementation[60,62])

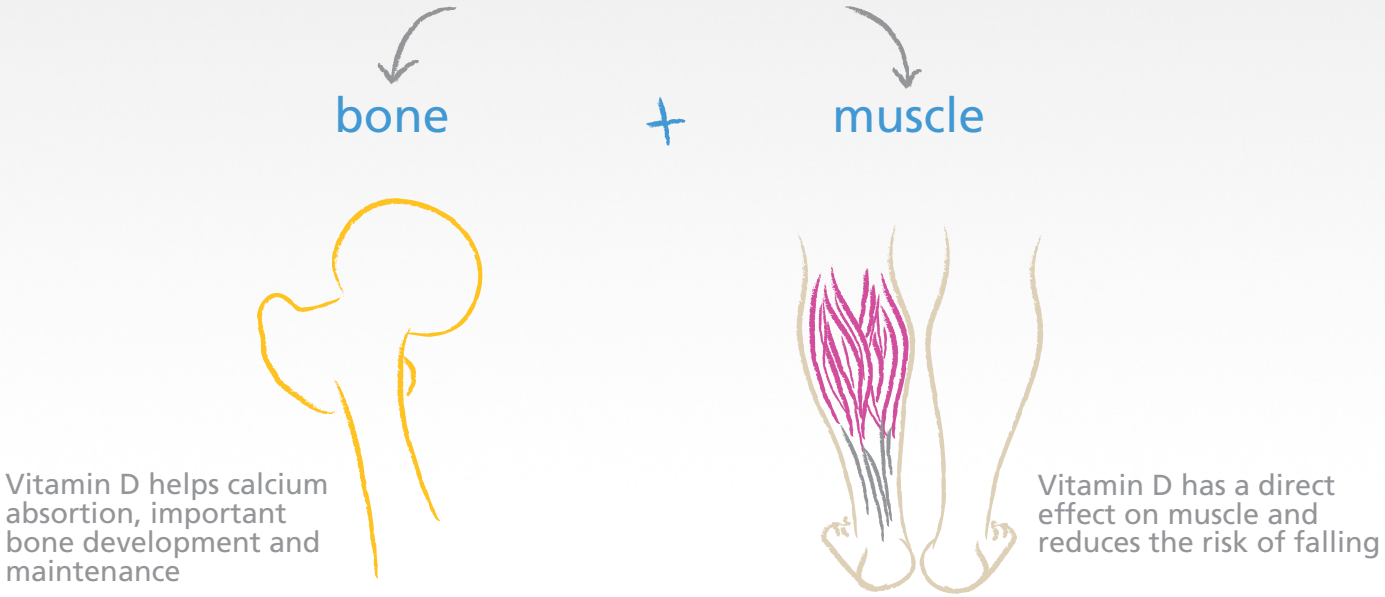
VITAMIN D DEFICIENCY

Prevalence

Depending on the threshold *(see Thresholds on page 12)* it has been established that 50 to 70 percent of the European and 30 to 50 percent of the US adult population is vitamin D deficient. When applying the same thresholds, a similar distribution is found in children.

Most vulnerable to vitamin D deficiency are:

- seniors in general and especially those living in nursing homes or institutionalized care
- individuals living in northern latitudes with minimal sunshine exposure
- individuals who are obese
- individuals who have a disease that reduces vitamin D uptake from the intestine (i.e. inflammatory bowel disease)



- individuals who have a darker skin tone
- individuals who for medical or cultural reasons cannot expose their skin to the sun

Definition

Defining universal diagnostic thresholds of vitamin D status is complicated due to the lack of standardized testing methods and the variability across population groups. However, as a general guidance, vitamin D deficiency can be defined as a 25(OH)D level of less than 50 nmol/l (< 20 ng/ml) , where increased bone resorption and increased parathyroid hormone (PTH) levels have been documented. Levels lower than 25 nmol/l (< 10 ng/ml) are considered severe deficiency, and can induce adverse effects such as rickets in infants and osteomalacia in adults. Between 50 and 74 nmol/l (20–29 ng/ml), vitamin D levels are not considered optimal and therefore termed insufficient. In this range, PTH levels may be in the normal range, but fracture risk reduction may not be achieved. Vitamin D adequacy is defined in adults as a threshold of at least 75 nmol/l (30 ng/ml), the threshold where fracture risk reduction was achieved in randomized controlled trials[62].

Vitamin D adequacy needs to be established in children, however in younger (age 19-49),middle-aged (age 50-64) and senior adults (age 65+) most data suggest that a level of no less than 75 nmol/l is needed for optimal bone health (hip bone density – data in younger, middle-aged, and senior adults[73], fracture prevention – data in senior adults[62]). Based on large cohort studies, additional safety advantages of reaching the desirable threshold of 75 nmol/l include a reduction in cardiovascular risk and colo-rectal cancer[74]. These additional benefits of vitamin D need to be confirmed in large clinical trials.

See table below

Who should be tested for vitamin D deficiency with a 25-hydroxyvitamin D measurement?

We can assess vitamin D status by measuring 25-hydroxyvitamin D in the blood. International guidelines recommend this measurement should not be used as a screening tool in a large majority of the population, but should be targeted to those at risk for severe vitamin D deficiency that may need greater doses of vitamin D than recommended at the population level. In people with osteoporosis, a 25-hydroxyvitamin D measurement is advised. People at risk of osteoporosis and generally everyone aged 60 years and older are advised to take vitamin D supplements at a dose of 800 – 1000 IU per day based on the 2010 IOF Position Statement on vitamin D[75].

This recommendation is based on:

- the broad deficiency of vitamin D,
- the evidence from clinical trials that showed that vitamin D supplementation at a dose of 700 to 1000 IU per day reduces the risk of falls[60] and fractures[62] by about 20%,
- and the safety of such a recommendation[74].

Therefore, measurement of serum 25-hydroxyvitamin D level in the blood to evaluate vitamin D status should be targeted to individuals at risk for severe vitamin D deficiency and the potential need of larger vitamin D doses to correct their deficiency. Individuals who:

- have a minimal trauma fracture
- have dark skin tone
- are obese
- are taking anti-epileptic drugs
- have malabsorption
- have medical conditions that prevent them from going into the sun without protection
- cover most of their body for cultural or religious reasons

We do not recommend broad population screening for vitamin D deficiency in individuals who are not at risk because the prevalence of vitamin D insufficiency is high and the cost of screening far exceeds the minimal cost of supplementation.

OVERVIEW OF VITAMIN D THRESHOLDS	
< 25 nmol/l (< 10 ng/ml)	= severe deficiency
25 - 49 nmol/l (10 -19 ng/ml)	= deficiency
50 -74 nmol/l (20 -29 ng/ml)	= insufficiency
75 - 110 nmol/l (30 - 44 ng/ml)	= adequacy

IOF vitamin D *recommendations* are 800 to 1000 IU/day for fall and fracture prevention in adults aged 60 and older

Why seniors are most vulnerable to vitamin D deficiency

Vitamin D deficiency is very common in the elderly. The reasons for this are:

- In the elderly, the skin produces 4-times less vitamin D when exposed to the sun, as compared to younger people.
- Seniors tend to avoid direct sunshine exposure – avoiding the hot weather by staying cool at home or using sun protective measures such as wearing a hat and sunscreen.
- Seniors generally have a decreased consumption of fish (possibly driven by economic reasons and decreasing protein intake with age).

Why children and younger adults are at risk of vitamin D deficiency

- The average person exposes only about 5% of their skin to the sun.
- Nowadays, most people are aware of the dangers of sunburn and skin cancer and wear sun protective clothing and sunscreen. However, a sunscreen of factor 6 already blocks most of the vitamin D production in the skin.
- In today's society, children tend to spend less time playing outdoors. The majority of adults work indoors, for example in offices, stores or factories.

SOURCES OF VITAMIN D – SUNLIGHT, FOOD, SUPPLEMENTATION

Sunlight

The main source of vitamin D is sunlight (UVB irradiation). Our skin can make vitamin D from exposure to sunlight. However, for the reasons outlined below, sunlight is not a reliable source of vitamin D and there are also associated risks of skin ageing and cancer.

Reasons why sunshine exposure is not a reliable source of vitamin D

- All of Europe (and in many other parts of the globe...) does not get sufficient UVB irradiation intensity during the months November to end of March, allowing for minimal skin production of vitamin D independent of age during the winter season. Notably, at latitudes of above and below 33° , vitamin D synthesis in the skin is low or absent during most of the winter. This area includes all of Europe (and also the Mediterranean).

- As the half-life of vitamin D is 3 to 6 weeks, there is a seasonal peak of vitamin D status in northern latitudes in September, followed by a rapid decrease, with the lowest point beginning in November and reaching an all-time low in early spring. Thus, even if we get sufficient vitamin D during the summer, this may not secure vitamin D status in the winter months and early spring time.
- Skin production of vitamin D declines with age, leaving seniors with a 4-times lower capacity to produce vitamin D in their skin compared to younger adults[63]. Further, seniors tend to avoid direct sun exposure which explains the large segment of seniors with vitamin D deficiency residing in southern areas with ample sunshine availability (e.g. Mediterranean, Northern Australia).
- The use of sunscreen and sun protective clothing reduces skin production of vitamin D independent of age[64,65]. Several studies have shown that clothing worn for cultural or religious reasons can have an adverse effect on vitamin D status and bone health[66]. A sunscreen factor of 6 already blocks most of the vitamin D production in the skin[65]. Solar elevation angle (i.e. time of day), cloud cover, air pollution, altitude, and surface reflection have an impact on vitamin D production in the skin[67]. Exposure measurements are related to a horizontal plane, while vertical surfaces such as the

Natural Nutritional Sources of Vitamin D	IU vitamin D
Wild salmon	600 to 1000 IU per 100 grams
Farmed salmon	100 to 250 IU per 100 grams
Sardines, canned	300 to 600 IU per 100 grams
Mackerel, canned	250 IU per 100 grams
Tuna, canned	236 IU per 100 grams
Cod liver oil	400 to 1000 IU per table spoon
Shiitake mushrooms, fresh	100 IU per 100 grams
Shiitake mushrooms, sun dried	1600 IU per 100 grams
Egg yolk	20 IU/yolk

face, arms and legs receive much lower UVB doses compared to a horizontal plane. Thus, in practice much longer exposure times than expected are needed to produce a certain amount of vitamin D. The UVB exposure time needed to produce 800 IU vitamin D differs by skin type and season. For an 8% body surface exposure (face and hands) during midday the exposure time will vary between about 30 minutes to 1 hour in the summer time, and up to about 20 hours in the winter [68-70].

Nutritional sources of vitamin D

Food sources of vitamin D are rather limited, and include fatty fish, such as salmon, mackerel, and herring. Farm salmon will provide only half as much vitamin D as wild salmon[71]. We would have to eat two servings of fatty fish a day to reach a recommended intake of 800 IU vitamin D per day for fracture reduction[72]. Additional sources are eggs and liver (1 egg contains about 40 IU of vitamin D). Some countries fortify margarines and milk with vitamin D. For example, in the USA, one glass of milk is fortified with 100 IU vitamin D.

Vitamin D comes in two forms. Vitamin D_3 (cholecalciferol) is the version of vitamin D that is made in our skin and found in fatty fish and eggs. Vitamin D_2 (ergocalciferol) is a closely related molecule of plant origin. Both vitamin D_2 and vitamin D_3 are used in supplements and for food fortification. Vitamin D that is taken orally as a supplement is best absorbed if taken with food as it is a fat-soluble vitamin[72]. When compared in clinical trials, vitamin D_3 has been shown to be more efficient than vitamin D_2 in reducing falls[60] and fractures[62].

Natural nutritional sources of vitamin D are limited. Larger amounts are only present in fatty fish, such as salmon[72].
See table on previous page

Vitamin D supplementation and recommendations

There are two international recommendations regarding vitamin D that are relevant to the population at large and individuals at risk of osteoporosis. For the population at large the Institute of Medicine of the National Academies in the USA (IOM) defined vitamin D recommendations throughout the life cycle with the goal to reach a 25-hydroxyvitamin D threshold of about 50 nmol/l *(see recommendations below)*[76]. The IOM recommends 600 IU vitamin D per day in all individuals age 1-70, and 800 IU in adults age 71 years and older.

The IOF had a different target in their 2010 position paper for vitamin D, designed to ensure optimal fall and fracture reduction[75]. Based on this target, IOF defined a 25-hydroxyvitamin D threshold of 75 nmol/l. Given the broad prevalence of vitamin D deficiency, IOF recommends 800 to 1000 IU in all adults at 60 years and older for fall and fracture reduction without prior testing for vitamin D deficiency. Thus, both institutions have similar recommendations on the dose of vitamin D as this reflects the vitamin D doses tested in clinical trials, however, they differ in their threshold recommendation. For osteoporosis prevention and the prevention of falls and fractures, the higher threshold of 75 nmol/l is recommended by this report. *See table below*

Safety of vitamin D supplementation

Vitamin D is a fat soluble vitamin. Therefore very high doses may lead to intoxication. A safe upper intake level has been defined for all age groups[76]. The safe upper limit intake recommendation is 1000 IU/day from 0 to 6 months, 1500 IU/day from 6 to 12 months, 2500 IU from age 1-3 years, 3000 IU from age 4-8 years, and 4000 IU from age 9 and older, including pregnant and lactating women.

In a 2010 benefit-risk assessment of vitamin D the authors found no pattern of evidence to suggest that risk (hypercalcemia – increased blood calcium levels) is elevated from daily intakes of vitamin D up to 10,000 IU or serum 25(OH)D up to 240 nmol/L[74], which are far higher intakes and blood concentrations than those necessary to achieve the benefits for bone and muscle strength (800 IU vitamin D intake per day and target 25-hydroxyvitamin D blood level of 75 nmol/l).

Age Group in Years	Public Intake Recommendations for Vitamin D *Institute of Medicine*	Public Intake Recommendations for Vitamin D *IOF*
0-1	*	Not assessed
1-59	600 IU/day	Not assessed
60-70	600 IU/day	800 to 1000 IU/day
71+	800 IU/day	800 to 1000 IU/day
Target 25(OH)D level in nmol/l	50 nmol/l for bone health in all ages	75 nmol/l for fall and fracture prevention

**adequate intake is 400 IU/day*
IOF includes all individuals with osteoporosis independent of age and states that higher intake levels may be needed in some individuals to reach a serum blood level of 75 nmol/l 25(OH)D

KEEP MOVING: Exercise & bone

Our skeleton is sensitive to gravity and weight-bearing physical activity as a stimulus to maintain and build bone and prevent muscles from wasting.

HOW DOES PHYSICAL ACTIVITY IMPROVE BONE HEALTH?

It is thought that exercise, especially during childhood and adolescence, may change bone structure and geometry (such as greater diameter of bones and stronger trabecular architecture), which may reduce the risk of fracture later in life[77]. Throughout the life cycle, there is a strong positive relationship between physical activity and bone health. Being active benefits bone and muscle strength regardless of age[1,78]. In contrast, immobilization of the skeleton (in the form of bed rest, casting or spinal cord injury) leads to bone loss, muscle wasting, and increased susceptibility to fracture within a few weeks[79]. A perfect example of unloading of the skeleton can be seen with astronauts, who lose considerable bone and muscle mass due to prolonged periods of weightlessness in space.

The rapid bone loss with immobilization mimics many years of 'ageing' and may help us understand how detrimental inactivity is to our bones and how important it is to maintain a physically active lifestyle. Clinical studies which compare individuals who exercise with groups who do not have demonstrated significantly higher BMD in those who exercise regularly[80]. Exceptions occur with high-intensity non weight-bearing activities, such as swimming, and in amenorrhoeic athletes (hormonal changes due to high-intensity sportive activities), who may have a BMD similar or worse than controls.

Measurable differences in fracture risk are also observed between those habitually active (non-athletic) and sedentary individuals[81].

THE IMPORTANCE OF PHYSICAL ACTIVITY IN YOUTH

Laying down the 'bone foundation' in youth gives advantages later in life. Most people reach their 'peak bone mass' in their 20s. This is when bones have achieved their maximum density and strength. For example, in girls, the bone tissue accumulated during the ages 11 to 13 approximately equals the amount of bone lost during the 30 years following menopause. Studies have shown that the most physically active young girls gain about 40% more bone mass than the least active girls of the same age. Other studies have shown that boys who did the most vigorous daily activity had 9% more bone area and 12% more bone strength than less active boys[81].

Studies confirm *a benefit* of exercise on BMD, muscle strength and the prevention of falls

The concern is that, with the advent of computers, TV and electronic games, many children and teenagers are living increasingly sedentary lifestyles. To ensure that their children are getting enough exercise, parents need to encourage daily weight-bearing physical activities and sports.

embrace an active lifestyle

LIFETIME PHYSICAL ACTIVITY AND PRESERVATION OF BONE HEALTH AT OLDER AGE

Several observational studies support a beneficial association between a greater lifetime physical activity and preservation of BMD, as well as a lower risk of hip, humerus and vertebral fracture, at older age[1,82]. It was also suggested that exercising prior to age 40 is associated with a lower risk of falling in seniors[83]. Thus, we get rewarded for being active when we were young even much later in life.

WHICH EXERCISE PROGRAMMES ARE EFFECTIVE?

While we lack evidence from large trials that test exercise in the prevention of fractures, several studies confirm a benefit of exercise on BMD, muscle strength, and the prevention of falls. Based on these studies[78], moderate to high intensity weight-bearing aerobic exercise (such as brisk walking, hiking, stair climbing or jogging), high intensity progressive resistance training (lifting weights) and high impact exercise (such as jumping or rope skipping) increase BMD by 1 to 4% per year in pre- and postmenopausal women[84]. More vigorous exercise interventions seem to produce greater effects[84]. It should be noted that casual walking may not reduce fracture risk. However, a large cohort study supports a benefit of brisk walking on reducing the risk of hip fracture (more than 4 hours a week may reduce hip fractures by 41%[1]).

FACTS ABOUT EXERCISE AND BONE HEALTH[85]

- Rapid, short bursts of high intensity and/or high impact activities such as jogging, jumping and rope skipping are more stimulating to bone cells than sustained, low impact activity such as walking.
- Effective activity does not have to be weight-bearing. Resistance training (lifting weights) is an effective non weight-bearing activity.
- Aerobic activity that is non weight-bearing (such as swimming or cycling) does not enhance bone density.
- Lifting heavy weights is more effective than lifting light weights.
- Lifting heavy weights rapidly (power training) seems to be more effective than lifting heavy weights slowly (traditional resistance training).
- Rapid movements are more stimulating than slow movements.
- Muscles connected to the bones that are most susceptible to fracture (hip, wrist, thoracic spine) should be targeted with specific exercises.

SIMPLE STEPS TO KEEP MOVING!

Staying active by brisk walking or other weight-bearing physical activities directly addresses key risk factors for osteoporotic fractures. These include low bone mineral density, muscle weakness, poor balance, falling and fear of falling. **The first step** is to overcome being inactive - in your daily life. Include simple strategies to keep moving!

1. Take the stairs instead of the elevator.
2. Walk small distances instead of relying on the car or public transportation.
3. Make it a habit to go for a walk (or some other activity) each day – set daily and weekly goals.
4. Stand on one leg while performing tasks of daily living: i.e. while brushing your teeth, waiting for the coffee machine, washing up.

EXERCISE PRECAUTIONS IN PEOPLE WITH DIAGNOSED OSTEOPOROSIS AND FRACTURES

- With existing osteoporosis, caution should be applied with activities and sports that have the potential of severe injury, such as ice skating, downhill skiing, mountain biking.
- People at risk for osteoporotic fracture should avoid deep backbends and activities that involve forward bending of the spine, particularly while carrying an object (for example, lawn bowls, sit ups with straight legs or simply bending over to pick up something from the floor), as this movement in the presence of osteopenia increases the risk of anterior compression fractures of the thoracic vertebrae.
- Involve a health care professional (your doctor, physiotherapist, exercise physiologist) in your exercise programme design as supervised, targeted exercise programmes are recommended.
- Programmes that include muscle strengthening, balance training and coordination exercises are highly recommended.
- In frail seniors with poor balance, mobilization without balance and strength training may increase the risk of fracture. Thus, mobilization should be supervised by physiotherapists and supported by strength and balance training.

ADD EXERCISE TO YOUR DAILY ACTIVITIES

Find ways to incorporate short exercise intervals into normal daily activities. For many people, this may be more successful than planning structured exercise classes away from home.

- insert a few jumps during television commercials.
- jump or hop rather than walk up a flight of stairs.
- stand on one leg while washing the dishes or while you wait for the coffee machine.
- use stairs instead of elevators.
- walk briskly for 10 minutes or more several times a day.

Strengthening the upper extremities is also important for falls prevention.

Notably, these exercise programmes are effective in seniors living in the community and those living in nursing care. Further, recent studies suggest that instructed but unsupervised exercise programmes are effective and demonstrate a significant reduction of falls, both in seniors living in the community[86] and seniors with an acute hip fracture[87].

Weight-bearing exercise programmes that improve gait speed, muscle strength and balance in seniors can translate into a *25-50% reduction* in falls

EXERCISE BENEFITS ON FALLS PREVENTION

Many studies demonstrate that simple weight-bearing exercise programmes improve gait speed, muscle strength, and balance in seniors, which translates into a 25-50% fall reduction[2,3,4]. As falls are the primary risk factor for fractures, the rationale is that these interventions should also protect against fractures, although this needs confirmation in large clinical studies. The recommendation is that exercise programmes for fall and fracture prevention should include balance training and lower and upper extremity strength training.

Tai Chi has been successful in reducing falls among healthy older individuals, and physically inactive community-dwelling older individuals, while frail older individuals and fallers may not benefit as much. Programmes that support cognitive function within an exercise programme may be of great value for fall prevention. Earlier studies suggested that fall risk is increased in seniors unable to walk while talking (stop walking when talking – reduced ability to perform two tasks simultaneously). This concept was tested in a music-based multitask exercise programme, which improved gait and balance and reduced fall risk in community-dwelling seniors[4].

EXAMPLES OF EXERCISE PROGRAMMES THAT ARE SUCCESSFUL IN INCREASING BONE DENSITY

1 about 50 jumps (approximately 8 cm high) three to six days per week.

2 two or three sets of 8 to 10 repetitions of each of 6 to 8 weight lifting exercises three days per week.

3 45 to 60 minutes of weight-bearing aerobic exercise three days per week (i.e. brisk walking)

LOVE YOUR BONES

FAST FACTS

NUTRITION & EXERCISE:

THE BUILDING BLOCKS FOR HEALTHY BONES

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EXERCISE

- Move it or lose it! Longer term immobilization, such as through bed rest, leads to rapid bone loss and increased susceptibility to fracture.
- Studies comparing groups of individuals who exercise compared to those who don't have demonstrated higher BMD in the athletic group.
- Exercising prior to age 40 is associated with a lower risk of falling in seniors.
- Moderate to high intensity weight-bearing aerobic exercise, high intensity progressive resistance training (lifting weights) and high impact exercise (e.g. jumping or rope skipping) has been shown to increase BMD by 1 to 4% per year in pre- and postmenopausal women.
- Rapid, short bursts of high intensity and/or high impact activities such as jogging, jumping and rope skipping are more stimulating to bone cells than sustained, low impact activity such as walking. Aerobic activity that is nonweight-bearing (such as swimming or cycling) does not enhance bone density.
- Simple targeted exercise programmes have been shown to improve bone density and functional mobility, result in 25 to 50% fewer falls in frail and active older adults.
- Mobilization in frail seniors should be supervised and supported by strength and balance training.

CALCIUM & PROTEIN

- Calcium is a key structural component of bone.
- Natural calcium sources, such as dairy products, sardines and nuts, are preferred calcium sources and also provide high-quality protein.
- Individuals who have more vitamin D are able to absorb more calcium. Therefore, in combination with vitamin D, a minimum total calcium intake of about 800 mg per day is likely sufficient in most individuals. This amount of calcium can be achieved by a healthy diet that contains a daily dose of calcium-rich foods.
- Calcium supplements should be combined with vitamin D for optimum effect.
- Both plant and animal protein sources appear to promote stronger bones and muscles for osteoporosis prevention.
- In children, a higher protein intake has been shown to increase the benefit of exercise on bone mineral content.
- Seniors with decreased protein intake are more vulnerable to muscle weakness, sarcopenia, and frailty, all contributing to an increased risk of falling.
- Several clinical trials with protein supplementation in senior hip fracture patients resulted in fewer deaths, shorter hospital stay, and a higher likelihood of return to independent living.

embrace calcium rich foods

VITAMIN D

- Vitamin D assists calcium absorption and has a direct effect on muscle.
- Vitamin D deficiency is common and a healthy nutrition cannot compensate deficiency.
- Above and below latitudes of approximately 33°, vitamin D synthesis in the skin is low or absent during most of the winter (which includes all of Europe, including the Mediterranean area).
- Skin production of vitamin D declines with age, leaving seniors with a 4-times lower capacity to produce vitamin D in their skin compared to younger adults.
- Evaluation of vitamin D status should only be targeted to individuals at risk for severe deficiency: people who have suffered a minimal trauma fracture, have dark skin tone, are obese, have malabsorption, have medical conditions which prevent them from going outdoors without protection or cover most of their body for cultural or religious reasons.
- Vitamin D supplementation has been shown to reduce the risk of falls and fractures by about 20%, including fractures of the hip.
- IOF recommends vitamin D supplementation for people at risk of osteoporosis and generally everyone aged 60 years and older (recommendation: 1000 IU vitamin D per day).

embrace vitamin D

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"The combination of staying active, eating a diet rich in calcium and ensuring you are not vitamin D deficient offers great opportunities to improve bone and muscle health and to reduce your risk of osteoporosis and fractures"

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