

## Calcium

**Calcium** (pronounced /ˈkælsiəm/) is the chemical element with the symbol **Ca** and atomic number 20. It has an atomic mass of 40.078. Calcium is a soft grey alkaline earth metal, and is the fifth most abundant element by mass in the Earth's crust. Calcium is also the fifth most abundant dissolved ion in seawater by both molarity and mass, after sodium, chloride, magnesium, and sulfate.<sup>[1]</sup>

Calcium is essential for living organisms, particularly in cell physiology, where movement of the calcium ion  $\text{Ca}^{2+}$  into and out of the cytoplasm functions as a signal for many cellular processes. As a major material used in mineralization of bones and shells, calcium is the most abundant metal by mass in many animals.

Calcium is a major mineral essential for healthy bones and teeth. There are several minerals known to be essential to the human body and which must be obtained from food. The major minerals (calcium, magnesium, phosphorus, sodium, chloride and potassium) are needed in the greatest quantities or are present in large amounts in the body. The three main functions of minerals are as constituents of the skeleton, as soluble salts which help control the composition of the body fluids, and as essential adjuncts to the action of many enzymes and other proteins.

### Notable characteristics

The most abundant isotope, Ca, has a nucleus of 20 protons and 20 neutrons. This is the heaviest stable isotope of any element which has equal numbers of protons and neutrons. In supernova explosions, calcium is formed from the reaction of carbon with various numbers of alpha particles (helium nuclei), until the most common calcium isotope (containing 10 helium nuclei) has been synthesized. Calcium is the seventh most common element, by mass, in Earth's oceans (hydrogen and oxygen must be added to the list in the introduction).

Chemically calcium is reactive and moderately soft for a metal (though harder than lead, it can be cut with a knife with difficulty). It is a silvery metallic element that must be extracted by electrolysis from a fused salt like calcium chloride. Once produced, it rapidly forms a grey-white oxide and nitride coating when exposed to air. It is somewhat difficult to ignite, in character rather like magnesium, but when lit, the metal burns in air with a brilliant high-intensity red light. Calcium metal reacts with water, evolving hydrogen gas at a rate rapid enough to be noticeable (unlike its sister magnesium) but not fast enough at room temperature to generate much heat. Part of the slowness of the calcium-water reaction results from the metal being partly protected by insoluble white calcium hydroxide. In water solutions of acids where the salt is water soluble, calcium reacts vigorously.

Calcium salts are colorless from any contribution of the calcium, and ionic solutions of calcium ( $\text{Ca}^{2+}$ ) are colorless as well. Many calcium salts are not soluble in water. When in solution, the calcium ion to the human taste varies remarkably, being reported as mildly salty, sour, "mineral like" or even "soothing." It is apparent that many animals can taste, or develop a taste, for calcium, and use this sense to detect the mineral in salt licks or other sources. In human nutrition, soluble calcium salts may be added to tart juices without much effect to the average palate.

Calcium is the fifth most abundant element by mass in the human body, where it is a common cellular ionic messenger with many functions, and serves also as a structural element in bone. It is the relatively high atomic-numbered calcium in the skeleton which causes bone to be radio-opaque. Of the human body's solid components after drying (as for example, after cremation), about a third of the total mass is the approximately one kilogram of calcium which composes the average skeleton (the remainder being mostly phosphorus and oxygen).

## Nutrition

Recommended Adequate Intake by the IOM for Calcium:<sup>[5]</sup>

| <b>Age</b>  | <b>Calcium (mg/day)</b> |
|-------------|-------------------------|
| 0–6 months  | 210                     |
| 7–12 months | 270                     |
| 1–3 years   | 500                     |
| 4–8 years   | 800                     |
| 9–18 years  | 1300                    |
| 19–50 years | 1000                    |
| 51+ years   | 1200                    |

Calcium is an important component of a healthy diet. Calcium is essential for the normal growth and maintenance of bones and teeth, and calcium requirements must be met throughout life. Long-term calcium deficiency can lead to osteoporosis, in which the bone deteriorates and there is an increased risk of fractures. While a lifelong deficit can affect bone and tooth formation, over-retention can cause hypercalcemia (elevated levels of calcium in the blood), impaired kidney function and decreased absorption of other minerals.<sup>[6]</sup>

High calcium intakes or high calcium absorption were previously thought to contribute to the development of kidney stones. However, more recent studies show that high dietary calcium intakes actually decrease the risk for kidney stones.<sup>[7]</sup> Vitamin D is needed to absorb calcium. Dairy products, such as milk and cheese, are a well-known source of calcium. However, some individuals are allergic to dairy products and even more people, particularly those of non Indo-European descent, are lactose-intolerant, leaving them unable to consume non-fermented dairy products in quantities larger than about half a liter per serving. Others, such as vegans, avoid dairy products for ethical and health reasons. Fortunately, many good

sources of calcium exist. These include seaweeds such as kelp, wakame and hijiki; nuts and seeds (like almonds and sesame); blackstrap molasses; beans; oranges; amaranth; collard greens; okra; rutabaga; broccoli; dandelion leaves; kale; and fortified products such as orange juice and soy milk. An overlooked source of calcium is eggshell, which can be ground into a powder and mixed into food or a glass of water.<sup>[8]</sup> Cultivated vegetables generally have less calcium than wild plants.<sup>[9]</sup>

The calcium content of most foods can be found in the USDA National Nutrient Database.

### Calcium Requirements

The UK Department of Health recommended Reference Nutrient Intake (RNI) for calcium is as follows. The RNI is a daily amount that is enough or more than enough for 97% of people. The RNI is similar to the Recommended Daily Amount used previously in the UK.

| Age/Sex                              | Calcium requirement (mg/day) |
|--------------------------------------|------------------------------|
| Infants & children, depending on age | 350-550                      |
| Teenage girls                        | 800                          |
| Teenage boys                         | 1000                         |
| Adult men & women                    | 700                          |
| Breast-feeding women                 | extra 550                    |

The 1989 US recommendations are generally slightly higher. In 1994 the US recommendations for children aged 1-10 was increased from 800mg to 1,200mg daily and for young adults aged 11-24 years it was increased from 1,200 to 1,500mg. During pregnancy and breast feeding women in the USA are now advised to have 1,400mg calcium daily and American men and women over the age of 50 years are advised to increased their calcium intake towards 1,500mg because the intestinal absorption of calcium declines with age.

## Dietary calcium supplements

Calcium supplements are used to prevent and to treat calcium deficiencies. There are conflicting recommendations about when to take calcium supplements. However, most experts agree that no more than 500 mg should be taken at a time because the percent of calcium absorbed decreases as the amount of calcium in the supplement increases.<sup>[5]</sup> It is recommended to spread doses throughout the day, with the last dose near bedtime. Recommended daily calcium intake varies from 1000 to 1500 mg, depending upon the stage of life.

In July 2006, a report citing research from Fred Hutchinson Cancer Research Center in Seattle, Washington claimed that women in their 50s gained 5 pounds less in a period of 10 years by taking more than 500 mg of calcium supplements than those who did not. However, the doctor in charge of the study, Dr. Alejandro J. Gonzalez also noted it would be "going out on a limb" to suggest calcium supplements as a weight-limiting aid.

- Calcium carbonate is the most common and least expensive calcium supplement. It can be difficult to digest and causes gas in some people. Taking magnesium with it can help to prevent constipation. Calcium carbonate is 40% elemental calcium. 1000 mg will provide 400 mg of calcium. It is recommended to take this supplement with food to aid in absorption. In some calcium supplements based on calcium carbonate, vitamin D is added to aid in absorption. Vitamin D is needed for the absorption of calcium from the stomach and for the functioning of calcium in the body.<sup>[12][13]</sup>
- Coral Calcium is a salt of calcium derived from fossilized coral reefs. Coral calcium is comprised of calcium carbonate and trace minerals.
- Calcium citrate is more easily absorbed (bioavailability is 2.5 times higher than calcium carbonate), easier to digest and less likely to cause constipation and gas than calcium carbonate. It also has a lower risk of contributing to the formation of kidney

stones. Calcium citrate is about 21% elemental calcium. 1000 mg will provide 210 mg of calcium. It is more expensive than calcium carbonate and more of it must be taken to get the same amount of calcium.

- Calcium phosphate costs more than calcium carbonate, but less than calcium citrate. It is easily absorbed and is less likely to cause constipation and gas than either.
- Calcium lactate and calcium aspartate are both more difficult to digest and are more expensive than calcium carbonate
- Calcium chelates have been chemically bonded with an agent that the body recognizes as food. This form is generally known to be better absorbed by the human body than all other forms of calcium due to the bond.

The National Nutritional Food Association — NNFA (Newport Beach, Calif.) defines a chelate very specifically, and several criteria must be met in order for chelation to actually occur. Some of the claimed "chelates" on the market are the various Krebs (Citric Acid) Cycle chelates, such as citrate, malate, and aspartate. Dicalcium malate (chelated with malic acid) is a newer form of a true calcium chelate. It contains a high amount of elemental calcium (30%).

### **Vegan Sources of Calcium**

Good plant sources of calcium include tofu (if prepared using calcium sulphate contains more than four times the calcium of whole cow's milk), green leafy vegetables, seeds and nuts. The calcium in green vegetables which are not high in oxalate e.g. kale, is absorbed as well or better than the calcium from cow's milk. Some soya milks are fortified with calcium. Drinking hard water can provide 200mg of calcium daily but soft water contains almost none. Other calcium rich foods include black molasses, edible seaweeds, watercress, parsley and dried figs.

### **Examples of amounts of foods providing 100mg calcium**

|                 |      |
|-----------------|------|
| Type of Food    |      |
| Black molasses  | 20g  |
| Dried figs      | 40g  |
| Almonds         | 42g  |
| Soya flour      | 44g  |
| Parsley         | 50g  |
| Kale            | 67g  |
| Brazils Nuts    | 59g  |
| Wholemeal bread | 185g |

## Protein & Calcium

A high protein diet, especially derived from animal foods, causes calcium loss in the body. The higher sulphur-to-calcium ratio of meat increases calcium excretion, and a diet rich in meat can cause bone demineralisation. A report published in 1988 comparing the amounts of calcium excreted in the urine of 15 subjects showed that the animal-protein diet caused greater loss of bone calcium in the urine (150mg/day) than the all-vegetable protein diet (103mg/day). These findings suggest that diets providing vegetable rather than animal protein may actually protect against bone loss and hence osteoporosis. In one study adults on a low-protein diet were in calcium balance regardless of whether calcium intake was 500mg, 800mg or 1400mg a day. Interestingly The American Dietetic Association, in its 1993 policy statement on vegetable diets, pointed out that the calcium intakes recommended in the USA were increased specifically to offset calcium losses caused by the typically high protein consumption in that country.

## **Prevention of fractures due to osteoporosis**

Such studies often do not test calcium alone, but rather combinations of calcium and vitamin D. Randomized controlled trials found both positive<sup>[14][15]</sup> and negative<sup>[16][17][18][19]</sup> benefit. The different results may be explained by doses of calcium and underlying rates of calcium supplementation in the control groups.<sup>[20]</sup> However, it is clear that increasing the intake of calcium promotes deposition of calcium in the bones, where it is of more benefit in preventing the compression fractures resulting from the osteoporotic thinning of the dendritic web of the bodies of the vertebrae, than it is at preventing the more serious cortical bone fractures which happen at hip and wrist.

## **Prevention cancer?**

A meta-analysis by the international Cochrane Collaboration of two randomized controlled trials found that calcium "might contribute to a moderate degree to the prevention of adenomatous colonic polyps".

More recent studies were conflicting, and one which was positive for effect (Lappe, et al.) did control for a possible anti-carcinogenic effect of vitamin D, which was found to be an independent positive influence from calcium-alone on cancer risk.

- A randomized controlled trial found that 1000 mg of elemental calcium and 400 IU of vitamin D<sub>3</sub> had no effect on colorectal cancer
- A randomized controlled trial found that 1400–1500 mg supplemental calcium and 1100 IU vitamin D<sub>3</sub> reduced aggregated cancers with a relative risk of 0.402.
- An observational cohort study found that high calcium and vitamin D intake was associated with "lower risk of developing premenopausal breast cancer"



## **Calcium Absorption**

Only 20-30% of calcium in the average diet is absorbed. Calcium absorption can be reduced because it binds to fibre, phytate or oxalate in the intestine. Vegan diets contain more than average of these substances. Fibre is no longer thought to limit the availability of calcium from food. Phytate or phytic acid is found in grains, nuts and seeds and can bind with calcium making it less absorbable. However, the body does adapt to lower levels of available calcium and the American Dietetic Association and the UK's Ministry of Agriculture, Fisheries & Foods as well as the Department of Health believe that fibre, phytate and oxalate do not have a significant effect on calcium intake overall.

Although the calcium intake of adult vegans tends to be lower than the recommended optimum, it is close to the Estimated Average Requirement. There have been no reports of calcium deficiency in adult vegans.

The Estimated Average Requirement (UK) of a nutrient in the diet is an estimate of the average needs of a group of people. About half may need more, and half may need less.

## **Osteoporosis**

Osteoporosis is the major cause of bone fractures in the elderly. One in four British women are affected by this disease. It is better prevented than treated and prevention includes an adequate intake of calcium throughout life, but especially in childhood and young adulthood; and minimizing major risk factors e.g. smoking, heavy alcohol use and lack of physical exercise. Diets high in protein and in salt (sodium chloride) also increase calcium loss from the body and may have an effect on osteoporosis. Post-menopausal women are more prone to osteoporosis because they produce less estrogen, which protects the skeleton in younger women.

There has been much publicity about the role of dietary calcium in preventing osteoporosis but the fact remains that it is more common in Westernized countries where calcium intakes and consumption of dairy products are high compared to the rest of the world.

Osteoporosis is comparatively rare in rural subsistence cultures, even though calcium intakes are much lower. Lifestyle factors, such as physical activity, lower protein intakes, little alcohol consumption and the rarity of smoking, may offer protection to people in these populations.

### **Cow's Milk & Health**

The advertising blurb surrounding cow's milk would make anyone think it is an absolutely essential and natural product for humans. Most people when thinking of increasing their calcium intake would immediately reach for a carton of milk or slab of cheese. However, there are several reasons for not using these products as a nutrient source. Whole cow's milk is suited to the nutritional needs of calves who double their weight in 47 days and grow to 300 pounds within a year. In fact, human beings are the only species to drink the milk of another species, and the only species to drink milk beyond infancy. In addition about 90% of the world's adult population (in Britain the figure is probably 25%) is deficient in the enzyme needed to digest milk properly. The enzyme lactase is present in infants for digesting their mother's milk, but levels decline after the age of five years. Adults who lack the enzyme suffer from bloating, cramping, wind and diarrhea if they drink milk.

The most significant connection between milk and ill-health is probably through its contribution to heart disease. Too much saturated fat in the diet can lead to atherosclerosis, where the arteries 'fur up' with cholesterol deposits and cannot deliver enough blood to the vital organs. The heart is particularly susceptible. Milk and other dairy products account for about half of all saturated fats eaten in this country. Meat accounts for the rest. The UK has the highest level of heart disease in the world.

Child-care expert Dr Benjamin Spock, once an advocate of drinking cow's milk, has joined several doctors questioning its nutritional value and warning of a possible link to juvenile onset diabetes and allergies. "Breast-feeding is the best milk feeding for babies," says Dr Spock. Dr Spock is backed up by Dr Frank Oski, director of pediatrics at John Hopkins University and Dr Neal Barnard, president of the 2000-member Physicians' Committee for Responsible Medicine. Dr Oski states that cow's milk is overrated as a source of calcium, is often contaminated with traces of antibiotics, can cause allergies and digestive problems and has been linked to juvenile diabetes.

## **Conclusions**

Vegans need to get at least 500 mg of calcium from calcium rich foods, such as tofu, fortified milks and greens, or supplements. Together with calcium from other less concentrated sources, this would give an overall calcium intake between 700 mg per day and 1000 mg per day. There is very little evidence that higher intakes than this would be beneficial.

However, bone health is about much more than calcium. The fact that osteoporosis risk is high in countries consuming relatively high amounts of calcium/dairy products illustrates this. Studies comparing individuals within developed countries also indicate that the benefit of calcium alone for reducing fracture risk is modest. Vitamins D and K may be more important while potassium (fruits, vegetables, roots and beans) reduces calcium losses and bone turnover and sodium (salt) increases these. Moderate, rather than low or high, protein intake is probably best. Physical activity plays a vital role. The best approach to prevention takes all these factors into account.

Calcium, the most abundant mineral in the human body, has several important functions. More than 99% of total body calcium is stored in the bones and teeth where it functions to support their structure. The remaining 1% is found throughout the body in blood, muscle,

and the fluid between cells. Calcium is needed for muscle contraction, blood vessel contraction and expansion, the secretion of hormones and enzymes, and sending messages through the nervous system. A constant level of calcium is maintained in body fluid and tissues so that these vital body processes function efficiently.

Bone undergoes continuous remodeling, with constant resorption (breakdown of bone) and deposition of calcium into newly deposited bone (bone formation). The balance between bone resorption and deposition changes as people age. During childhood there is a higher amount of bone formation and less breakdown. In early and middle adulthood, these processes are relatively equal. In aging adults, particularly among postmenopausal women, bone breakdown exceeds its formation, resulting in bone loss, which increases the risk for osteoporosis (a disorder characterized by porous, weak bones).

### **What foods provide calcium?**

In the United States (U.S.), milk, yogurt and cheese are the major contributors of calcium in the typical diet. The inadequate intake of dairy foods may explain why some Americans are deficient in calcium since dairy foods are the major source of calcium in the diet. The U.S. Department of Agriculture's Food Guide Pyramid recommends that individuals two years and older eat 2-3 servings of dairy products per day. A serving is equal to:

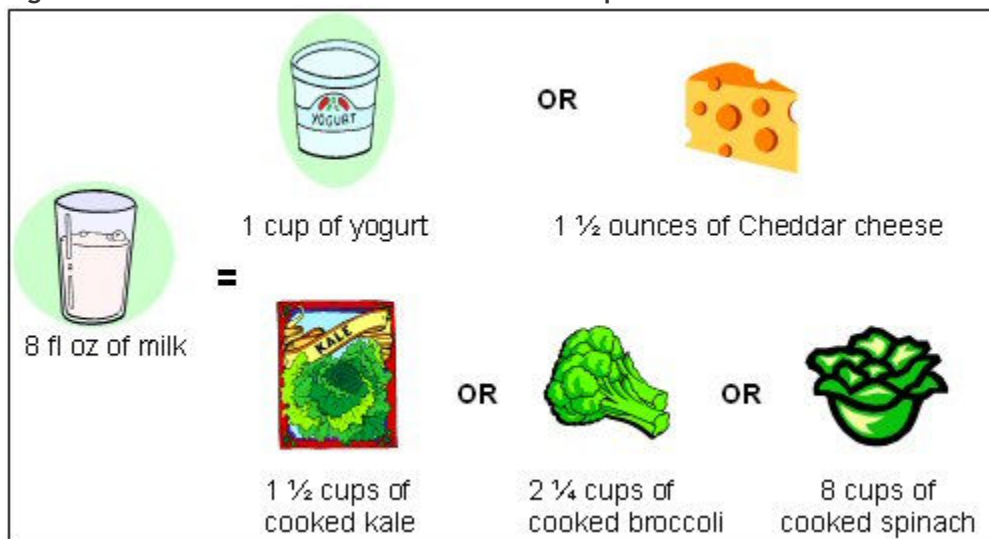
- 1 cup (8 fl oz) of milk
- 8 oz of yogurt
- 1.5 oz of natural cheese (such as Cheddar)
  
- 2.0 oz of processed cheese (such as American)

A variety of non-fat and reduced fat dairy products that contain the same amount of calcium as regular dairy products are available in the U.S. today for individuals concerned about saturated fat content from regular dairy products.

Although dairy products are the main source of calcium in the U.S.

diet, other foods also contribute to overall calcium intake. Individuals with lactose intolerance (those who experience symptoms such as bloating and diarrhea because they cannot completely digest the milk sugar lactose) and those who are vegan (people who consume no animal products) tend to avoid or completely eliminate dairy products from their diets. Thus, it is important for these individuals to meet their calcium needs with alternative calcium sources if they choose to avoid or eliminate dairy products from their diet. Foods such as Chinese cabbage, kale and broccoli are other alternative calcium sources. Although most grains are not high in calcium (unless fortified), they do contribute calcium to the diet because they are consumed frequently. Additionally, there are several calcium-fortified food sources presently available, including fruit juices, fruit drinks, tofu and cereals. Figure 1 compares portion sizes of various foods that provide the amount of calcium in one cup of milk. This figure takes into account that calcium absorption varies among foods. Certain plant-based foods such as some vegetables contain substances which can reduce calcium absorption. Thus, you may have to eat several servings of certain foods such as spinach to obtain the same amount of calcium in one cup of milk, which is not only calcium-rich but also contains calcium in an easily absorbable form. Table 2 contains additional listings of food sources of calcium.

**Figure 1: Calcium Content of 8 fl oz of Milk Compared to Other Food Sources of Calcium**



## Selected Food Sources of Calcium

| Food  | Calcium (mg) | % DV*    |
|---|--------------|----------|
| Yogurt, plain, low fat, 8 oz.   | 415          | 42%      |
| Yogurt, fruit, low fat, 8 oz.   | 245-384      | 25%-38%  |
| Sardines, canned in oil, with bones, 3 oz.  | 324          | 32%      |
| Cheddar cheese, 1 ½ oz shredded   | 306          | 31%      |
| Milk, non-fat, 8 fl oz.   | 302          | 30%      |
| Milk, reduced fat (2% milk fat), no solids, 8 fl oz.                                      | 297          | 30%      |
| Milk, whole (3.25% milk fat), 8 fl oz   | 291          | 29%      |
| Milk, buttermilk, 8 fl oz.  | 285          | 29%      |
| Milk, lactose reduced, 8 fl oz.**   | 285-302      | 29-30%   |
| Mozzarella, part skim 1 ½ oz.   | 275          | 28%      |
| Tofu, firm, made w/calcium sulfate, ½ cup***  | 204          | 20%      |
| Orange juice, calcium fortified, 6 fl oz.   | 200-260      | 20-26%   |
| Salmon, pink, canned, solids with bone, 3 oz.   | 181          | 18%      |
| Pudding, chocolate, instant, made w/ 2% milk, ½ cup                                       | 153          | 15%      |
| Cottage cheese, 1% milk fat, 1 cup unpacked   | 138          | 14%      |
| Tofu, soft, made w/calcium sulfate, ½ cup***  | 138          | 14%      |
| Spinach, cooked, ½ cup  | 120          | 12%      |
| Instant breakfast drink, various flavors and brands, powder prepared with water, 8 fl oz. | 105-250      | 10-25%   |
| Frozen yogurt, vanilla, soft serve, ½ cup   | 103          | 10%      |
| Ready to eat cereal, calcium fortified, 1 cup   | 100-1000     | 10%-100% |
| Turnip greens, boiled, ½ cup  | 99           | 10%      |

|   |        |       |
|---|--------|-------|
| Kale, cooked, 1 cup                                 | 94     | 9%    |
| Kale, raw, 1 cup                                    | 90     | 9%    |
| Ice cream, vanilla, 1/2 cup                         | 85     | 8.5%  |
| Soy beverage, calcium fortified, 8 fl oz.           | 80-500 | 8-50% |
| Chinese cabbage, raw, 1 cup                         | 74     | 7%    |
| Tortilla, corn, ready to bake/fry, 1 medium         | 42     | 4%    |
| Tortilla, flour, ready to bake/fry, one 6" diameter | 37     | 4%    |
| Sour cream, reduced fat, cultured, 2 Tbsp           | 32     | 3%    |
| Bread, white, 1 oz                                  | 31     | 3%    |
| Broccoli, raw, 1/2 cup                              | 21     | 2%    |
| Bread, whole wheat, 1 slice                         | 20     | 2%    |
| Cheese, cream, regular, 1 Tbsp                      | 12     | 1%    |

Daily Values (DV) were developed to help consumers determine if a typical serving of a food contains a lot or a little of a specific nutrient. The DV for calcium is based on 1000 mg. The percent DV (% DV) listed on the Nutrition Facts panel of food labels tells you what percentages of the DV are provided in one serving. For instance, if you consumed a food that contained 300 mg of calcium, the DV would be 30% for calcium on the food label.

A food providing 5% of the DV or less is a low source while a food that provides 10-19% of the DV is a good source and a food that provides 20% of the DV or more is an excellent source for a nutrient.

"Different foods contain different nutrients and other healthful substances. No single food can supply all the nutrients in the amounts you need". The following are strategies and tips to help you meet your calcium needs each day:

- Use low fat or fat free milk instead of water in recipes such as pancakes, mashed potatoes, pudding and instant, hot breakfast cereals.
- Blend a fruit smoothie made with low fat or fat free yogurt for a great breakfast.
- Sprinkle grated low fat or fat free cheese on salad, soup or pasta.
- Choose low fat or fat free milk instead of carbonated soft drinks.
- Serve raw fruits and vegetables with a low fat or fat free yogurt based dip.
- Create a vegetable stir-fry and toss in diced calcium-set tofu.
- Enjoy a parfait with fruit and low fat or fat free yogurt.
  
- Complement your diet with calcium-fortified foods such as certain cereals, orange juice and soy beverages.

### **What affects calcium absorption and excretion?**

Calcium absorption refers to the amount of calcium that is absorbed from the digestive tract into our body's circulation. Calcium absorption can be affected by the calcium status of the body, vitamin D status, age, pregnancy and plant substances in the diet. The amount of calcium consumed at one time such as in a meal can also affect absorption. For example, the efficiency of calcium absorption decreases as the amount of calcium consumed at a meal increases.

- Age:  
Net calcium absorption can be as high as 60% in infants and young children, when the body needs calcium to build strong bones. Absorption slowly decreases to 15-20% in adulthood and even more as one ages. Because calcium absorption declines with age, recommendations for dietary intake of calcium are higher for adults ages 51 and over.
- Vitamin D:  
Vitamin D helps improve calcium absorption. Your body can obtain vitamin D from food and it can also make vitamin D when your skin is exposed to sunlight. Thus, adequate vitamin



- D intake from food and sun exposure is essential to bone health.
- **Pregnancy:**  
Current calcium recommendations for non-pregnant women are also sufficient for pregnant women because intestinal calcium absorption increases during pregnancy. For this reason, the calcium recommendations established for pregnant women are not different than the recommendations for women who are not pregnant.
  - **Plant substances:**  
Phytic acid and oxalic acid, which are found naturally in some plants, may bind to calcium and prevent it from being absorbed optimally. These substances affect the absorption of calcium from the plant itself not the calcium found in other calcium-containing foods eaten at the same time. Examples of foods high in oxalic acid are spinach, collard greens, sweet potatoes, rhubarb, and beans. Foods high in phytic acid include whole grain bread, beans, seeds, nuts, grains, and soy isolates. Although soybeans are high in phytic acid, the calcium present in soybeans is still partially absorbed. Fiber, particularly from wheat bran, could also prevent calcium absorption because of its content of phytate. However, the effect of fiber on calcium absorption is more of a concern for individuals with low calcium intakes. The average American tends to consume much less fiber per day than the level that would be needed to affect calcium absorption.

Calcium excretion refers to the amount of calcium eliminated from the body in urine, feces and sweat. Calcium excretion can be affected by many factors including dietary sodium, protein, caffeine and potassium.

- **Sodium and protein:**  
Typically, dietary sodium and protein increase calcium excretion as the amount of their intake is increased. However, if a high

protein, high sodium food also contains calcium, this may help counteract the loss of calcium.

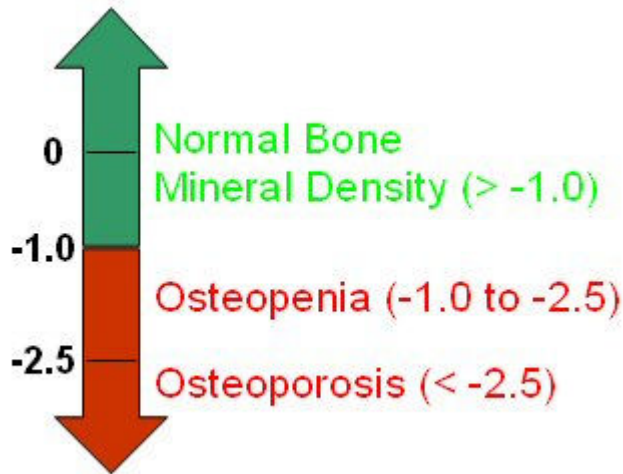
- **Potassium:**  
Increasing dietary potassium intake (such as from 7-8 servings of fruits and vegetables per day) in the presence of a high sodium diet (>5100 mg/day, which is more than twice the Tolerable Upper Intake Level of 2300 mg for sodium per day) may help decrease calcium excretion particularly in postmenopausal women.
- **Caffeine:**  
Caffeine has a small effect on calcium absorption. It can temporarily increase calcium excretion and may modestly decrease calcium absorption, an effect easily offset by increasing calcium consumption in the diet. One cup of regular brewed coffee causes a loss of only 2-3 mg of calcium easily offset by adding a tablespoon of milk. Moderate caffeine consumption, (1 cup of coffee or 2 cups of tea per day), in young women who have adequate calcium intakes has little to no negative effects on their bones.

Other factors:

- **Phosphorus:** The effect of dietary phosphorus on calcium is minimal. Some researchers speculate that the detrimental effects of consuming foods high in phosphate such as carbonated soft drinks is due to the replacement of milk with soda rather than the phosphate level itself.
- **Alcohol:** Alcohol can affect calcium status by reducing the intestinal absorption of calcium. It can also inhibit enzymes in the liver that help convert vitamin D to its active form which in turn reduces calcium absorption. However, the amount of alcohol required to affect calcium absorption is unknown. Evidence is currently conflicting whether moderate alcohol consumption is helpful or harmful to bone.

In summary, a variety of factors that may cause a decrease in calcium absorption and/or increase in calcium excretion may negatively affect bone health.

Figure 2: Interpreting Bone Mineral Density Scores



### Calcium and high blood pressure

Some *observational* studies (type of research study in which the treatment/intervention is observed and not controlled by the researchers) and *experimental* studies (type of research study in which the researchers control the treatments/interventions and that are assigned to participants) indicate that individuals who eat a vegetarian diet high in minerals (including calcium, magnesium and potassium) and fiber, and low in fat, tend to have reduced blood pressure.

Findings from some *clinical trials* (a specific type of experimental study) used to evaluate the effects of one or more treatments/interventions in humans) indicate that an increased calcium intake lowers blood pressure and the risk of hypertension (high blood pressure). However, the results of some studies produced small and inconsistent reductions in blood pressure. One reason for these results is because these research studies tended to test the effect of single nutrients rather than foods on blood pressure.

To help test the combined effect of nutrients including calcium from food on blood pressure, a study was conducted to investigate the impact of various dietary eating patterns on blood pressure. This study titled "Dietary Approaches to Stop Hypertension (DASH)" was reported in 1997 by the National, Heart, Lung and Blood Institute of the National Institutes of Health. It investigated the effect of various eating patterns on lowering blood pressure. The DASH study was a multi-center research trial where food was provided to over 450 adults. It examined the effects of three different diets on high blood pressure: a control, "typical American" diet and two modified diets (high fruits-and-vegetables and a combination "DASH" diet - high in fruits, vegetables, and low fat dairy). See Table 3 for a comparison of some of the components of the three diets.

### Comparison of the Three Diets Tested in the "DASH" Study

| Diet Components                 | Fruit & Vegetable Servings | Lowfat Dairy Servings | Calcium (mg) | Fat (% of total calories) | Sodium (mg) | Cholesterol (mg) | Fiber (g) |
|---------------------------------|----------------------------|-----------------------|--------------|---------------------------|-------------|------------------|-----------|
| Control "Typical American" diet | 3.5                        | 0.1                   | 450          | 37                        | 3000        | 300              | 9         |
| Fruits-and-Vegetables diet      | 8.5                        | 0.0                   | 450          | 37                        | 3000        | 300              | 31        |
| Combination "DASH" diet         | 9.5                        | 2.0                   | 1240         | 27                        | 3000        | 150              | 31        |

Of the three diets tested, the combination "DASH" diet resulted in the greatest decrease in blood pressure. Thus, this finding from a large and carefully executed clinical trial helped demonstrate that the

combination "DASH" diet, with increased calcium, decreased blood pressure. A number of further studies have been done, all showing a similar relationship between increasing calcium intakes and decreased blood pressure. A study conducted after the original "DASH" study, referred to as the "DASH-Sodium" study showed that the DASH diet without sodium restriction provided as much blood pressure reduction as did severe sodium restriction on the control diet (1500 mg sodium/day). Overall it appears that consuming an adequate intake of fruits and vegetables as well as calcium from low fat dairy products plays a significant role in controlling blood pressure.

## **Calcium and cancer**

### Colorectal cancer

The relationship between calcium intake and the risk of colon cancer has not been conclusively determined. Observational and experimental research studies investigating the role calcium plays in the prevention of colon cancer show mixed results. Some studies suggest that increased intakes of dietary (low fat dairy sources) and supplemental calcium are associated with a decreased risk of colon cancer. Supplementation with calcium carbonate is reported to lead to reduced risk of adenomas (nonmalignant tumors) in the colon, a precursor to colon cancer, but it is not known if this will ultimately translate into reduced cancer risk. Another study reported on the association between diet and colon cancer history in 135,000 men and women participating in two large health surveys, the Nurses' Health Study and the Physicians' Health Study. The authors found that those who consumed 700 to 800 mg calcium per day had a 40 to 50% lower risk of developing left side colon cancer. However, a few other observational studies found inconclusive evidence regarding any association of calcium intake with colon cancer. Although some research findings indicate a protective effect of calcium or low fat dairy foods against colon cancer, further studies are necessary to confirm this role for calcium.

## **Prostate cancer**

There is some evidence to suggest that higher calcium (ranging from 600 mg to >2000 mg of calcium) and/or dairy intakes (>2.5 servings) may be associated with the development of prostate cancer.

However, these studies are observational in nature rather than clinical trials and cannot establish a definite causal relationship between calcium and prostate cancer. Other findings only show a weak relationship, no relationship at all or the opposite relationship between calcium and prostate cancer. Thus, the relationship between calcium intake, dairy intake and prostate cancer risk remains unclear. At the present time, it is recommended that men ages 19 and over consume a "modest" intake of calcium ranging from 1000-1200 mg per day and maintain an intake below the upper tolerable limit (2500 mg).

## **Calcium and kidney stones**

Kidney stones are crystallized deposits of calcium and other minerals in the urinary tract. Calcium oxalate stones are the most common form of kidney stones in the US. High calcium intakes or high calcium absorption were previously thought to contribute to the development of kidney stones. However, more recent studies show that high dietary calcium intakes actually decrease the risk for kidney stones. Other factors such as high oxalate intake and reduced fluid consumption appear to be more of a risk factor in the formation of kidney stones than calcium in most individuals.

## **Calcium and weight management**

Several studies, primarily observational in nature, have linked higher calcium intakes to lower body weights or less weight gain over time. Two explanations have been proposed for how calcium may help to regulate body weight. First, high-calcium intakes may reduce calcium concentrations in fat cells by lowering the production of two hormones (parathyroid hormone and an active form of vitamin D), which in turn increases fat breakdown in these cells and discourages

its accumulation. In addition, calcium from food or supplements may bind to small amounts of dietary fat in the digestive tract and prevent its absorption, carrying the fat (and the calories it would otherwise provide) out in the feces.

Dairy products in particular may contain additional components that have even greater effects on body weight than their calcium content alone would suggest. Three small, recently published clinical trials show that calcium-rich dairy products may help obese individuals following reduced-calorie diets to lose some excess weight and fat. In one trial, 32 obese adults were randomized to one of three groups: eating a standard diet providing 400-500 mg calcium, eating a standard diet supplemented with 800 mg calcium, and eating a diet with 3 servings/day of dairy products to provide 1,200-1,300 mg calcium. The subjects ate 500 fewer calories a day over the 24 weeks of the study. All lost weight and body fat, but those taking the calcium supplements lost significantly more than subjects eating the unsupplemented standard diet, and those on the high-dairy diet lost by far the most. Dairy products also favorably affected body composition in a small group of obese African-American adults who followed a weight-maintenance program for 24 weeks [69]. Subjects who ate 3 servings/day of dairy products, which increased calcium intakes to 1,200 mg/day, lost significantly more fat (both total body and abdominal) and preserved lean body mass as compared to those who consumed less than one daily serving of these foods and 500 mg/day total calcium.

Despite the hopeful results of these studies, other recent clinical trials make it clear that the involvement of calcium and dairy products in weight regulation and body composition is complex, inconsistent, and not well understood. For example, one study in young women of normal body weight found that higher intakes of dairy products had no effect on weight or fat mass over the course of one year. Another study in which 100 overweight and obese pre- and post-menopausal women on reduced-calorie diets received either 1,000 mg/day calcium or a placebo for 25 weeks found no significant differences in

weight or fat loss between the groups. Similar results were obtained in a study of 1,471 postmenopausal women (somewhat overweight on average) who were randomly assigned to take 1,000 mg/day calcium or a placebo for 30 months, though there was a trend toward greater weight loss in those who took the calcium supplement and whose calcium intakes from food averaged less than 600 mg/day. Clearly, larger clinical trials are needed to better assess the effects of calcium and dairy products on body weight, composition, and fat distribution.

### **When can a calcium deficiency occur?**

Inadequate calcium intake, decreased calcium absorption, and increased calcium loss in urine can decrease total calcium in the body, with the potential of producing osteoporosis and the other consequences of chronically low calcium intake. If an individual does not consume enough dietary calcium or experiences rapid losses of calcium from the body, calcium is withdrawn from their bones in order to maintain calcium levels in the blood.

### **Signs of calcium deficiency**

Because circulating blood calcium levels are tightly regulated in the bloodstream, hypocalcemia (low blood calcium) does not usually occur due to low calcium intake, but rather results from a medical problem or treatment such as renal failure, surgical removal of the stomach (which significantly decreases calcium absorption), and use of certain types of diuretics (which result in increased loss of calcium and fluid through urine). Simple dietary calcium deficiency produces no signs at all. Hypocalcemia can cause numbness and tingling in fingers, muscle cramps, convulsions, lethargy, poor appetite, and mental confusion. It can also result in abnormal heart rhythms and even death. Individuals with medical problems that result in hypocalcemia should be under a medical doctor's care and receive specific treatment aimed at normalizing calcium levels in the blood. *[Please note that the symptoms described here may be due to a medical condition*



*other than hypocalcemia.*] It is important to consult a health professional if you experience any of these symptoms.

### **Is there a health risk of too much calcium?**

The Tolerable Upper Limit (UL) is the highest level of daily intake of calcium from food, water and supplements that is likely to pose no risks of adverse health effects to almost all individuals in the general population [2]. The UL for children and adults ages 1 year and older (including pregnant and lactating women) is 2500 mg/day. It was not possible to establish a UL for infants under the age of 1 year.

While low intakes of calcium can result in deficiency and undesirable health conditions, excessively high intakes of calcium can also have adverse effects. Adverse conditions associated with high calcium intakes are hypercalcemia (elevated levels of calcium in the blood), impaired kidney function and decreased absorption of other minerals. Hypercalcemia can also result from excess intake of vitamin D, such as from supplement overuse at levels of 50,000 IU or higher. However, hypercalcemia from diet and supplements is very rare. Most cases of hypercalcemia occur as a result of malignancy - especially in the advanced stages.

Another concern with high calcium intakes is the potential for calcium to interfere with the absorption of other minerals, iron, zinc, magnesium, and phosphorus.

### **Calcium and Medication Interactions**

Calcium supplements have the potential to interact with several prescriptions and over the counter medications. Some examples of medications that may interact with calcium include:

- digoxin
- fluroquinolones
- levothyroxine
- antibiotics in tetracycline family

- tiludronate disodium
- anticonvulsants such as phenytoin
- thiazide, type of diuretic
- glucocorticoids
- mineral oil or stimulant laxatives
- aluminum or magnesium containing antacids

Calcium supplements may decrease levels of the drug digoxin, a medication given to heart patients [112]. The interaction between calcium and vitamin D supplements and digoxin may also increase the risk of hypercalcemia. Calcium supplements also interact with fluoroquinolones (a class of antibiotics including ciprofloxacin), levothyroxine (thyroid hormone) used to treat thyroid deficiency, antibiotics in the tetracycline family, tiludronate disodium (a drug used to treat Paget's disease), and phenytoin (an anti-convulsant drug). In all of these cases, calcium supplements decrease the absorption of these drugs when the two are taken at the same time.

Thiazide, and diuretics similar to thiazide, can interact with calcium carbonate and vitamin D supplements to increase the chances of developing hypercalcemia and hypercalciuria (elevated levels of calcium in urine). Aluminum and magnesium antacids can both increase urinary calcium excretion. Mineral oil and stimulant laxatives can both decrease dietary calcium absorption. Furthermore, glucocorticoids (for example: prednisone) can cause calcium depletion and eventually osteoporosis, when used for more than a few weeks.

### **Supplemental sources of calcium**

The two main forms of calcium found in supplements are carbonate and citrate. Calcium carbonate is the most common because it is inexpensive and convenient. The absorption of calcium citrate is similar to calcium carbonate. For instance, a calcium carbonate supplement contains 40% calcium while a calcium citrate supplement only contains 21% calcium. However, you have to take more pills of

calcium citrate to get the same amount of calcium as you would get from a calcium carbonate pill since citrate is a larger molecule than carbonate. One advantage of calcium citrate over calcium carbonate is better absorption in those individuals who have decreased stomach acid. Calcium citrate malate is a form of calcium used in the fortification of certain juices and is also well absorbed. Other forms of calcium in supplements or fortified foods include calcium gluconate, lactate, and phosphate.

The amount of calcium your body obtains from various supplements depends on the amount of elemental calcium in the tablet. The amount of elemental calcium is the amount of calcium that actually is in the supplement. Calcium absorption also depends on the total amount of calcium consumed at one time and whether the calcium is taken with food or on an empty stomach. Absorption from supplements is best in doses 500 mg or less because the percent of calcium absorbed decreases as the amount of calcium in the supplement increases. Therefore, someone taking 1000 mg of calcium in a supplement should take 500 mg twice a day instead of 1000 mg calcium at one time.

Some common complaints of calcium supplement use are gas, bloating and constipation. If you have such symptoms, you may want to spread the calcium dose out throughout the day, change supplement brands, take the supplement with meals and/or check with your pharmacist or health care provider.

The table compares the amount of calcium (elemental calcium) found in some different forms of calcium supplements.

Figure 3: Comparison of Calcium Content of Various Supplements

