CALCIUM: MINERAL THAT MAKES STRONG BONES

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Calcium is an essential nutrient for all living organisms wherein movement of calcium ion in and out of cytoplasm functions as a signal for many cellular processes. Calcium is the most abundant metal element present in many animals mostly as a component of bones and shells. In human body calcium is the fifth most abundant element that body needs for numerous functions, including making bones and teeth, blood clotting, transmission of nerve impulses and regulation of heart's rhythm. Combined with phosphate in the form of hydroxylapatite, it is the mineral portion of bones and teeth which contain ninety nine percent of total calcium stored in body. The rest of the calcium has other important functions including neurotransmitter release, muscle contraction, blood vessel expansion and contraction, secretion of hormones and enzymes among others.

Calcium is obtained in two ways namely by eating foods that contain calcium and by taking supplements. Good sources of calcium are dairy products having highest concentration of highly absorbable calcium and dark green leafy vegetables or dried beans having varying amounts of absorbable calcium. Body also takes it from bones when dietary calcium is low and blood levels of calcium drop too low. Replacement of this calcium later when dietary calcium is available does not always happen completely.

Bones are living tissues always in flux as during lifespan, bones are constantly remodelled as bone cells, osteoblasts build bone while osteoclasts break it down. In healthy individuals that get adequate calcium and physical activity, bone production or formation exceeds bone destruction up to age 30; thereafter destruction typically exceeds production more particularly in ageing adults especially in menopausal women increasing the risk of osteoporosis. As the National Osteoporosis Foundation states, "calcium plays an important role in building stronger, denser bones early in life and keeping bones strong and healthy later in life."

While long-term deficiency can affect bone and tooth formation and maintenance, over-retention can cause hypercalcemia (higher levels of calcium in blood), impaired kidney function and decreased absorption of other minerals. High calcium intakes or absorption were earlier thought to help formation of kidney stones, but in more recent research, it is thought to lower the risk of kidney stones. Vitamin D is needed for absorption of calcium.

Calcium Deficiency

Inadequate intakes of dietary calcium produce no obvious symptoms in short term. Blood levels of calcium are rigidly regulated. Hypocalcemia is caused due to medical problems or treatments including renal failure, surgical removal of stomach and use of medications like diuretics. Symptoms of hypocalcemia include numbness and tingling of fingers, muscle cramps, convulsions, lethargy, poor appetite and abnormal heart rhythms. If untreated calcium deficiency may result in death.

Although hypocalcemia is uncommon, dietary intakes of calcium below recommended levels might have undesirable health consequences over the long period. Certain groups are likely to need extra calcium including postmenopausal women, individuals that do not consume dairy products, vegetarians who avoid dairy products etc.

Menopause leads to bone loss because lower oestrogen production increases bone resorption as well as lower calcium absorption. Decrease in bone mass can be as high as 3 to 5% per year in initial years of menopause and then it becomes less than 1% per year after 65. Increased calcium intake does not completely prevent this bone loss. Hormone replacement therapy helps increase calcium levels and prevents osteoporosis and fractures however, there are certain potential health risks associated with it.

Individuals having lactose intolerance due to deficiency of lactase enzyme to digest lactose in milk products resulting in lactose entering in large intestine and being used by intestinal bacteria producing symptoms like bloating, flatulence and diarrhoea. Severity of symptoms varies with the amount of lactose and on individuals. Such individuals although can tolerate fermented dairy foods, they usually tend to avoid milk resulting in lack of calcium intake.

Vegetarians consume plenty of plant products containing oxalic and phytic acids so they absorb less of calcium as these acids reduce the absorption of calcium by binding it. Although many plant products are good sources of calcium due to lower absorption calcium intake drastically reduces. Vegans avoid all animal products including dairy products so their calcium intake drastically reduces.

These groups are at greater risk of calcium inadequacy and must take calcium supplements to get adequate quantities of calcium per day.

Recommended Intakes

Food & Nutrition Board of Institute of Medicine of National Academies have recommended calcium intakes for various ages and gender and physiological conditions. These are given in table 1 below

Table 1: Recommended Adequate Intake by the IOM for Calcium

Age	Male	Female	Pregnant	Lactating
Birth to 6 months	210 mg	210 mg		
7-12 months	270 mg	270 mg		
1-3 years	500 mg	500 mg		
4-8 years	800 mg	800 mg		
9-13 years	1,300 mg	1,300 mg		
14-18 years	1,300 mg	1,300 mg	1,300 mg	1,300 mg
19-50 years	1,000 mg	1,000 mg	1,000 mg	1,000 mg

50+ years	1,200 mg	1,200 mg		

Sources of Calcium
Milk and products like cheese are well-known sources of calcium. Some individuals are allergic to milk products and some are lactose-intolerant so they cannot consume unfermented milk products more than a couple of glasses at a time. There are many other good sources of calcium exist including seaweeds, nuts and seeds like almonds and sesame, beans, spinach, amaranth, okra, broccoli etc. Most grains do not have high amounts of calcium unless they are fortified; however, since these are consumed in larger amounts they supply significant amounts of calcium. Other fortified sources of calcium include fruit juices, soya milk, breakfast cereals etc. Table 2 gives the amounts of calcium present in different foods.

Table 2: Selected Food Sources of Calcium

Food	Milligrams (mg) per serving	Percent DV*
Yogurt, plain, low fat, 8 ounces	415	42
Sardines, canned in oil, with bones, 3 ounces	324	32
Cheddar cheese, 1.5 ounces	306	31
Milk, non-fat, 8 ounces	302	30
Milk, whole (3.25% milk fat), 8 ounces	291	29
Milk, buttermilk, 8 ounces	285	29
Mozzarella, part skim, 1.5 ounces	275	28
Yogurt, fruit, low fat, 8 ounces	245-384	25-38
Black-eyed peas, boiled1 cup	211	21
Tofu, firm, made with calcium sulphate, ½ cup***	204	20
Baked beans, canned,1 cup	154	15
Pudding, chocolate, instant, made with 2% milk, ½ cup	153	15
Cottage cheese, 1% milk fat, 1 cup unpacked	138	14
Tofu, soft, made with calcium sulphate, ½ cup***	138	14
Spinach, cooked, ½ cup	120	12
Ready-to-eat cereal, calcium-fortified, 1 cup	100-1,000	10-100
Turnip greens, boiled, ½ cup	99	10
Ice cream, vanilla, ½ cup	85	8.5
Soy beverage, calcium-fortified, 8 ounces	80-500	8-50
Chinese cabbage, raw, 1 cup	74	7
Almonds,1 oz (24 nuts)	70	7
Sour cream, reduced fat, cultured, 2 tablespoons	32	3
Bread, white, 1 ounce	31	3
Broccoli, raw, ½ cup	21	2
Bread, whole-wheat, 1 slice	20	2
Cheese, cream, regular, 1 tablespoon	12	1

USDA Nutrient Database

Dietary Supplements
Calcium deficiencies are prevented or treated using calcium supplements if dietary calcium through foods is inadequate. It is recommended that supplements be taken along with foods and over 500 or 600mg doses at a time are wasteful as calcium absorption decreases with higher amounts in supplements. It is therefore recommended that intake should be spread over the day in two or three doses with food for better absorption. Vitamin D is added in some supplements are proper vitamin D status is important for calcium absorption. Vitamin D is converted to a hormone that induces synthesis of intestinal proteins responsible for absorption of calcium.

Although it was previously believed that calcium supplements of different chemical nature differed in absorption, the recent findings indicate that absorption of calcium from different commonly used dietary supplements is very similar although there might be some differences due to composition of food taken along. Milk is an excellent dietary source with high concentration of calcium which is excellently absorbed. Of the supplements, calcium carbonate is least expensive and should be taken along with food. It requires somewhat lower pH for proper absorption in the intestine. Some studies indicate its absorption similar to that from milk but some people might develop gastrointestinal discomfort, gas or constipation. Coral calcium is a salt of calcium derived from fossilised coral reefs and is composed of calcium carbonate and trace minerals.

Calcium citrate can be taken with or without food and is more easily digested without constipation and gas compared to carbonate. Also individuals with less stomach acid can absorb it better than carbonate. However, it is more expensive and more of it is needed to get similar amounts of calcium that carbonate. Calcium phosphate is less expensive than citrate with similar benefits of citrate. Lactate and gluconate are expensive and have lesser amounts of calcium. Chelates are prepared by binding calcium to organic molecules like malate, aspartate or fumarate and can be taken on empty stomach as they mimic the action of natural food keeping calcium soluble in intestine.

Most people think of milk when thinking about calcium sources. However, there are many individuals who have lactose intolerance as they cannot digest lactose resulting in problems like cramps, bloating, gas and diarrhoea when they consume dairy products. Fermented products like yogurt or curd and buttermilk are tolerated. Alternatively lactase enzyme can be added to milk to predigest lactose as some products are available in western markets.

Many dairy products are also high in fat especially in saturated fat, which is a risk factor for heart disease. Although some dairy products are now available with lower fat options, majority are still with high fats. This may make people think of other sources of calcium. Those with milk allergy or lactose intolerance can take orange juice, soya milk or breakfast cereals fortified with calcium.

There are several factors that affect calcium absorption in the intestine. These are

- Amount consumed: the efficiency of absorption decreases as amount of intake increases especially above 500 to 600 mg per intake.
- Age: calcium absorption is as high as 60% in children who need substantial amounts to build bones. Absorption decreases to 15 to 20% in adults and decreases further in seniors.
- Vitamin D intake: this obtained either from food or sunlight, improves calcium absorption
- Anti-nutritional factors: phytic and oxalic acids found naturally in some plants bind to calcium inhibiting its absorption. Foods with oxalic acid are spinach, collard greens, sweet potatoes and beans while foods with phytic acid are whole grain wheat, beans, seeds, nuts and soy isolates. For people who eat a variety of foods, these interactions probably have little or no nutritional consequence.
- Sodium, potassium and protein intakes: high intakes of sodium and protein increase calcium excretion but more potassium to high-sodium diet helps decrease calcium excretion particularly in postmenopausal women.
- Caffeine intake: caffeine from tea and coffee can modestly increase calcium excretion and reduce absorption.
- Alcohol intake: this can reduce absorption and inhibiting enzymes in liver that help convert vitamin D to its active form.
- Phosphorus intake: the effect of this mineral on calcium excretion is minimal. Studies suggest that consuming carbonated soft drinks with high levels of phosphate is associated with reduced bone mass and increased fracture risk. However, studies have shown that the effect is probably due to replacing milk with soda rather than the phosphorus itself.
- Fruit and vegetable intakes: these foods when metabolised shift acid/base balance of body towards alkaline by producing bicarbonate, which reduces calcium loss. On the other hand, diets high in protein and cereal grains produced metabolic acids causing bone to release minerals like calcium and phosphates and alkaline salts that neutralise the excess acid.

Calcium and Osteoporosis

Osteoporosis or “porous bones” is weakening of bones caused due to imbalance between bone building and bone destruction. People commonly lose bone as they become old in spite of consuming calcium recommended for optimal bone health maintenance. In the US, 10 million (8 million women and 2 million men) have osteoporosis and another 34 million have low bone mass with increased risk of osteoporosis. Achieving adequate calcium intake with sufficient bone stores when bone is rapidly deposited i.e. up to about 30 years provides important foundation to protect in old age. However, this does not guarantee bone loss in later years.

Loss of bone during aging has several factors including genetic factors, physical inactivity, and lower levels of hormones. In postmenopausal women oestrogen production rapidly declines making them osteoporosis prone. As testosterone levels do not drop so sharply in men, they show similar effects 5 to 10 years later than women. It is estimated that half the women over 50 years suffer fracture of hip, wrist or vertebra due to osteoporosis.

Making the strongest and densest bones during first 30 years is just one way of fighting osteoporosis. Getting adequate exercise, especially muscle strengthening, getting enough vitamin D, consuming enough calcium to reduce the amount body has to borrow from bones, consuming adequate vitamin K from green leafy vegetables, and not getting too much preformed vitamin A are some of the ways during old age that can reduce chances of getting osteoporosis.

Physical activity puts some strain or stress on bones causing them to retain or even get more density throughout life. Cells within the bone sense this stress and respond by making bones stronger and denser. These activities include walking, dancing, jogging, weightlifting, stair climbing, racquet sports, hiking etc. Swimming helps heart and cardiovascular system but as water supports bones rather than putting stress on them it does not help much in making bones strong. Since activities do not stress all the bones a variety of activities may be useful to keep all bones healthy. Activities also make muscles strong so one can avoid falls by maintaining balance.

Despite debates about milk and calcium, it is clear that adequate calcium, for both bone development and non-bone functions, is necessary for reducing risk of osteoporosis. However, amounts of dietary calcium that are adequate are still being debated. Maximum calcium retention studies trying to find how much calcium can be forced into bones indicate a fairly high requirement indicated in Table 1. However, these studies are short term and have limitations. While importance of calcium in maximising bone strength is unquestionable, the amounts necessary need to be properly investigated. Some studies suggest that high calcium intake doesn’t actually appear to lower the risk for osteoporosis. When data from different studies were combined there was still no association between calcium intake and fracture risk. There was, however, some suggestion that calcium supplement taken without vitamin D might even increase the risk of hip fractures. These issues might be clarified by long term studies with large group of adults getting different amounts of calcium and following them to see the eventual process of breaking bones.

Vitamin D is critical in maintaining bone health. When calcium levels in blood start dropping it promotes conversion of vitamin D into its active form, which travels to intestines to encourage more absorption of calcium and to kidneys to reduce loss of calcium in urine. Thus adequate intake of vitamin D is important for bone health along with calcium. Sunlight does not uniformly promote formation of vitamin D in body as sunlight intensity may vary due to latitude especially in winter, use of sunscreen and dark skins. In urban areas, due to high rise buildings even direct exposure of sunlight is difficult so dietary vitamin D may be necessary. Clinical trials have shown that 700 to 800 IUs of vitamin D per day may be necessary to reduce the risk of hip and non-vertebral fractures especially when taken along with calcium. About 1000 to 2000 IUs of vitamin D may be adequate (higher in case sunlight does not provide enough like in above cases) along with calcium.

Vitamin K also plays a very important role in calcium regulation and bone formation. Low levels of vitamin K in blood have been linked to low bone density which shows improvement with vitamin K supplementation. A report suggests that women getting 110 micrograms or more per day are 30% less likely to break hip that those getting less. Also women eating a serving of lettuce or other green, leafy vegetable a day have half the chance of hip fracture compared to those consuming the same per week.

There are also some other requirements like getting enough protein and vitamin A but not too much. Body needs proteins for strong bones but as body digests proteins acids released in blood lower the pH and to neutralise it body draws calcium from bones. This would not affect bone strength if happens infrequently but high protein diet for a prolonged period could weaken bones. In one study, women consuming over 95 g protein everyday were found to be 20% more likely to have a broken wrist over a 12-year period when compared with those consuming average amount of less than 68 g per day. However, research in this area is still controversial. Secondly vitamin A has been involved in direct process of calcium transfer in bone. However, it has been noted that too much of preformed vitamin A (as retinol) can promote fractures, whereas its precursor beta-carotene does not increase fracture risk.

Calcium and Health Benefits

Clinical trials have demonstrated a relationship between higher calcium intakes and lower blood pressure and risk of hypertension although reductions are inconsistent. The results may also have been due to other components like fibre and lower fat content that also tend to lower blood pressure. DASH (Dietary Approaches to Stop Hypertension) study used typical American diet as control and the other two high in fruit and vegetables with and without low-fat dairy products. The diet containing dairy products showed the greatest decrease in blood pressure.

Several studies have been conducted with high intakes of calcium from low-fat dairy foods and have been shown to decrease risk of colon cancer. Supplementation with calcium carbonate has been shown to reduce the risk of adenoma in the colon in another study, while two large epidemiological trials have shown that consumption of 700-800 mg per day of calcium was associated with 40-50% lower risk of colon cancer. However, other studies have been inconclusive.

Kidney stones are mostly composed of calcium oxalate. In one study, postmenopausal women consuming 1000 mg of supplemental calcium with 400 IU vitamin D per day for 7 years had higher risk of kidney stones than control. However, other studies have found that high dietary calcium intake decrease this risk. High intake of oxalates from food and lower fluid intake seem to play bigger role in kidney stones than calcium.

Several studies have linked higher calcium intakes to lesser weight gain. It is possible that calcium might affect hormones controlling fat breakdown in fat cells and discourage fat accumulation or alternatively calcium might bind to dietary fat inhibiting its absorption. It is possible that dairy products may have additional components that have greater effects on body weight than calcium alone. Clinical trials have not been able to correlate the effect of calcium on weight reduction.

Health Risks from Excessive Calcium

Very high levels of calcium in blood known as hypercalcemia impair kidney function and lead to reduced absorption of other essential minerals like iron, zinc, magnesium and phosphorus. However, hypercalcemia rarely results from dietary or supplemental calcium intake. Calcium intakes of up to 2500 mg have been shown to be safe. In one study diet high in calcium has been implicated as a probably risk factor for prostate cancer. But studies of excess intakes are not many and more research is needed before higher limit for calcium could be recommended. Some interactions of calcium supplements with certain medications have been observed, so those taking medications regularly should discuss their calcium intake with doctors. Calcium can decrease absorption of biphosphonates, fluoroquinolone and tetracycline antibiotics, levothyroxine, phenytoin, tiludronate etc. Diurectic of thiazide-type can interact with calcium carbonate.

Conclusions

Adequate dietary calcium is necessary throughout life to reduce the risk of osteoporosis and other problems of bone health. Along with adequate calcium, vitamin D and regular exercise are also important to build maximum bone density and strength. Although bone loss due to aging cannot be completely prevented this precaution slows down bone loss. Milk and dairy products are very convenient for many people as dietary source of calcium but sometimes it is necessary to resort to supplements or other sources of dietary calcium. Plant sources especially green and leafy vegetables like spinach, broccoli, amaranth, okra (ladies' fingers), nuts and oilseeds, beans etc. are good sources of calcium but many also contain phytic and oxalic acids that reduce absorption of calcium by body. Many food products are now fortified with calcium so they can provide supplementary calcium needed.

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