

Boning up on calcium

Why plant calcium is best

Most people in developed countries have been brought up to believe that our teeth and bones can only grow healthily if we drink cow's milk. Over the last decades we have witnessed a barrage of marketing campaigns designed to reinforce the idea that only dairy milk can supply calcium in sufficient quantities to help us grow big and strong. But is it true? And what truly matters when it comes to strong and healthy bones?

Firstly, it makes no sense that calcium is needed from cow's milk. Because we are not cows! Like all 6,000 or so species of mammals on this planet, we have evolved to drink the milk of our mothers until weaned. But we are the only mammal to drink milk after weaning (apart from animals we control of course) – and certainly the only one to drink the milk of another species. We have evolved over millions of years to be able to absorb calcium from plants – and we are very good at it.

What is calcium and why do we need it?

Calcium is a soft grey metallic element. It is the fifth most abundant element in the Earth's crust and occurs in compounds such as limestone, chalk and marble. Calcium is required for normal growth and development in animals. It is the most abundant mineral in the human body accounting for around two per cent of our total body weight.

Calcium plays an important structural role in maintaining bone health and strength; in fact, around 99 per cent of our calcium is stored in our bones and teeth. The other one per cent is responsible for a range of important functions, such as regulating muscle contraction and heartbeat, blood clotting and functioning of the nervous system.

How much calcium do we need?

There is no international consensus on what the healthiest or safest amount of calcium we need is. The UK Government currently suggests that adults over 19 years of age need 700 milligrams per day (NHS, 2020). According to the British Dietetic Association (2021), these are the recommended daily intakes for different age groups:

| Group | Daily amount of calcium (mg) |
|---------------------|------------------------------|
| 0-12 months | 525 |
| 1-3 years | 350 |
| 4-6 years | 450 |
| 7-10 years | 550 |
| 11-14 years | 800 (girls), 1,000 (boys) |
| 19+ (adults) | 700 |
| Breastfeeding women | 1250 |

However, actual daily intakes of calcium vary widely across the world. According to one large study, the lowest average intakes among adults are in Nepal with 175 milligrams and the highest in Iceland with 1,233 milligrams (Balk *et al.*, 2017). The same study also revealed that most countries in South, East and Southeast Asia have average dietary calcium intakes of less than 400 to 500 milligrams daily and most countries with data in Africa and South America have intake between about 400 and 700 milligrams per day. Interestingly, all countries with average calcium intake greater than 1,000 milligrams were in Northern Europe.





Calcium sources

The body obtains calcium in two ways: either from our diet or our bones. When the diet does not provide sufficient levels, calcium is ‘borrowed’ (reabsorbed) from the bones in order to restore blood levels and maintain calcium-dependent biological functions.

Calcium in our bones is reabsorbed and replaced continuously as old bone cells break down and new ones form. If adequate calcium is supplied in the diet, balance is maintained but if the diet fails to supply enough, calcium may be taken from the bones. This may lead to bone loss if the situation persists.

The best plant sources of calcium are kale, collard/spring/mustard greens, broccoli, Chinese leaf, bok choy, cabbage, sesame seeds and tahini (sesame seed paste), almonds, chia seeds, tofu (made with

calcium sulphate), tempeh, beans, dried figs, plant-based milks and yoghurts fortified with calcium, fortified vegan breakfast cereal (Ready Brek), wholemeal bread, butternut squash and oranges.

Calcium and bone health

As we grow, our bones grow too, increasing their size and bulk and also their density – accumulating more bone mass. After the growth stops, bones are still accumulating more mineral content and in our late twenties, we achieve the peak of our bone health – peak bone mass. We manage to keep it for a few years but afterwards, we start to slowly lose it again. Some degree of bone loss is normal but if it reaches certain level and the bones start losing their firmness, you may develop osteoporosis, which puts you at risk of fragility fractures.

A specialist scientific team (Rizzoli *et al.*, 2010) described that more than 60 per cent of how much peak bone mass you accumulate in your twenties is genetically determined and the rest depends on adequate dietary intake of calcium, protein and vitamin D and regular weight-bearing physical activity. To complement this, The National Osteoporosis Foundation (US organisation, now known as The Bone Health and Osteoporosis Foundation) stated that 20 to 40 per cent of adult peak bone mass is affected by diet and lifestyle (Weaver *et al.*, 2016).

Eating calcium-rich foods is vital for healthy bones at any age – studies of children and adults confirm that having a calcium intake at or slightly above the recommended intake produces stronger bones and reduces the risk of fracture (Khan *et al.*, 2015; Weaver *et al.*, 2016; Pan *et al.*, 2020). However, having an adequate calcium intake during early teenage years is particularly important for developing sufficient bone mineral density that can determine your future bone health (Abrams, 2021).

The idea that cow’s milk is the best source of calcium is deeply entrenched in the British psyche and is sustained by the government-sponsored dairy industry and the industry-funded Agriculture and Horticulture Development Board (AHDB) who work with schools and universities to encourage children and young people to drink dairy milk. However, a review of 37 studies on dairy products and bone health published in the official journal of the American Academy of Paediatrics challenged this misleading notion by concluding that there is no solid evidence that the consumption of dairy products improves bone health in children and young adults (Lanou *et al.*, 2005).

A recent study reviewed over 90 studies on milk, dairy products and bone health in an attempt to find the answer to whether cow’s milk is good, bad or neutral for our bones. The results were mixed –

| Food (and serving size) | Calcium (milligrams) |
|--|----------------------|
| Cauldron tofu, 100 g (it’s made with calcium sulphate) | 405 |
| Kale, cooked, 1 cup (118 g) | 177 |
| Plant milks, calcium-fortified, 100 ml | 120 |
| Plant yoghurts, calcium fortified, 100 g | 120 |
| Chinese leaf, raw, 100 g | 105 |
| Tempeh, cooked, 100 g | 96 |
| Beans in tomato sauce, ½ tin (210 g) | 71-88 |
| Butternut squash, cubed, 1 cup (205 g) | 84 |
| Almonds, small handful (28 g) | 76 |
| Black beans, 10 tbsp (110 g) | 74 |
| Cabbage, cooked, 1 cup (150 g) | 72 |
| Dried figs, 5 pieces | 68 |
| Tahini, 1 tbsp | 64 |
| Kidney beans, 10 tbsp (110 g) | 63 |
| Chia seeds, 1 tbsp | 63 |
| Tofo, smoked, 100 g (it’s not made with calcium sulphate) | 57 |
| Orange, medium | 52 |
| Wholemeal bread, 1 thick slice (made with fortified flour) | 50 |
| Chickpeas, 10 tbsp (100 g) | 45 |
| Oats, 1 cup (80 g) | 42 |
| Broccoli, cooked, 100 g | 40 |
| Olives, 10 medium pieces | 18 |

Source: Manufacturer’s data and Cronometer database, 2024.

some studies showed cow's milk and dairy products had no benefit, others found them beneficial, but only for some bones in some people, and a few studies found they were bad for the bones (Wallace *et al.*, 2021). However, taken together, the evidence produced one clear result – it's important to take in enough calcium and vitamin D but it absolutely doesn't have to be from dairy products.

Indeed, in many studies, milk improved bone health in children and adults with previously low calcium intake but did nothing for those with sufficient calcium (van den Heuvel and Steijns, 2018; Wallace *et al.*, 2021). So it's not about milk but about a balanced diet and healthy lifestyle! And there are other – healthier and better sources of calcium.

A study analysing data from over 10,000 US children and adolescents found that higher calcium intake was associated with higher bone density but extremely high calcium intakes, of over 2,000 micrograms a day, led to lower bone density (Pan *et al.*, 2020). A large, long-running study from China found that while low calcium intakes increased the risk of fractures, so did high intakes (Fang *et al.*, 2016). It is generally accepted that daily calcium intake shouldn't go above 2,000 milligrams and the UK Government warns that taking more than 1,500 milligrams can lead to stomach pain and diarrhoea. Your body cannot immediately build all calcium into the bones and if you take in too much on a daily basis, your body may store it in the wrong places, such as blood vessel walls, making them harder and limiting their function (Tankeu *et al.*, 2017). This has raised concerns that calcium supplements may increase the risk of cardiovascular disease. For most people, it's better to obtain calcium from your diet than from supplements.

It's interesting that the number of fractures resulting from low bone mineral density is highest in some of the countries with the highest daily calcium intakes, such as the US, Germany and France (Shen *et al.*, 2022). Calcium is one of the main players in bone health but isn't the only one.

Calcium uptake and absorption

The amount of calcium present in a particular food is not the only important factor to consider. The bioavailability of the calcium should be considered when deciding which foods are a good source. This means how much calcium is actually available for absorption into the body.

The calcium in dairy products is not as well absorbed as that in many dark green leafy vegetables, such as kale, bok choy, Chinese leaf or broccoli (Weaver *et al.*, 2024). While spinach contains a relatively high amount of calcium, it is bound to a substance called oxalate which hinders calcium absorption. It's important not to rely on high-oxalate vegetables for your calcium – these include spinach, Swiss chard and rhubarb.

Grains, pulses, nuts and seeds contain a substance called phytic acid which was also considered to hinder calcium absorption but it's been shown that it only has a minor influence and is reduced by food preparation methods, such as soaking before cooking, sprouting and fermenting (Gupta *et al.*, 2015). Interestingly, you absorb more calcium from wholemeal bread than from milk (Weaver *et al.*, 2024).

Calcium-set tofu is a good source of the mineral and you absorb about 30 per cent of it – the same as from milk (Weaver *et al.*, 2024). When it comes to beans, nuts and seeds, you absorb a little less calcium from them than from leafy greens, tofu and wholemeal bread but they are still valuable sources.

However, how much calcium you can absorb from food doesn't depend only on what you eat – too much caffeine, excessive alcohol intake (three drinks or more per day) and smoking have all been shown to reduce calcium absorption and compromise bone health (Al-Bashaireh *et al.*, 2018; Reuter *et al.*, 2021; Godos *et al.*, 2022).



Osteoporosis

Bones consist of a thick outer shell and a strong inner mesh filled with a protein called collagen, calcium salts and other minerals. Osteoporosis (meaning porous bones) occurs when too much calcium is lost from the bones and they become fragile and prone to fracture.

This debilitating condition tends to occur mostly in postmenopausal women due to a lack of the hormone oestrogen, which helps to regulate the incorporation of calcium into the bones. However, osteoporosis affects men as well.

Osteoporosis is sometimes called the silent disease as there are often no symptoms until a fracture occurs. Although the whole skeleton is usually affected, fractures happen mostly in the wrist, spine and hip. One in two women and one in five men in the UK will suffer a fracture after the age of 50 but osteoporosis has been diagnosed in people as young as 20 (ROS, 2024).

Some people think osteoporosis is only about calcium intake but it's more complicated than that. It's about calcium balance including both intake and loss – and the latter can be sped up by a number of factors. But it's also about other nutrients vital for bone health, physical activity, genetics and hormone levels.

Protein, acids and bone health

Bone is 22 per cent protein, so having a sufficient protein intake is vital for bone health (Lu *et al.*, 2024). The recommendations for protein consumption are 0.8 grams per kilogram of bodyweight, rising to 1 to 1.5 grams for active people, athletes, pregnant and breastfeeding women. The source of protein, however, can have very different effects on the body.

As food is digested, acids or alkaline molecules are released into the blood. There are usually more acids and as the body needs to maintain a steady pH of the blood, it rapidly neutralises these acids with calcium. There's a certain level of calcium available in the blood but if that isn't enough, calcium may be drawn from the body's main reserve – the bones.

Animal protein has a particularly acid-forming effect because of the greater content of sulphur-containing amino acids (the building blocks of protein) compared to plant protein. It has been suggested that consumption of animal protein sources (meat, eggs, cheese) might increase the risk of bone loss, while plant protein based diets may have protective effects on bone health (Isanejad *et al.*, 2017).

A vegan diet, rich in plant protein, produces much less acid and more alkalis in the body (Penczynski *et al.*, 2022). It's not simply about plant protein on its own but about the fact that protein-rich plant foods are usually also sources of alkalis, such as potassium and magnesium, so plant foods are an excellent package deal.

Things are a little more complex, however, because while animal protein requires more calcium to neutralise the resulting acids, higher protein intake also increases calcium absorption in the gut (Isanejad *et al.*, 2017). While the negative effects of animal foods may be countered, to some degree, by a diet rich in alkali-producing fruits and vegetables, most people who eat meat, eggs and cheese also eat plenty of processed foods (which also produce acids) and may have a low calcium and wholefood intake so, on balance, their bodies are losing calcium which puts them at risk of low bone mineral density.

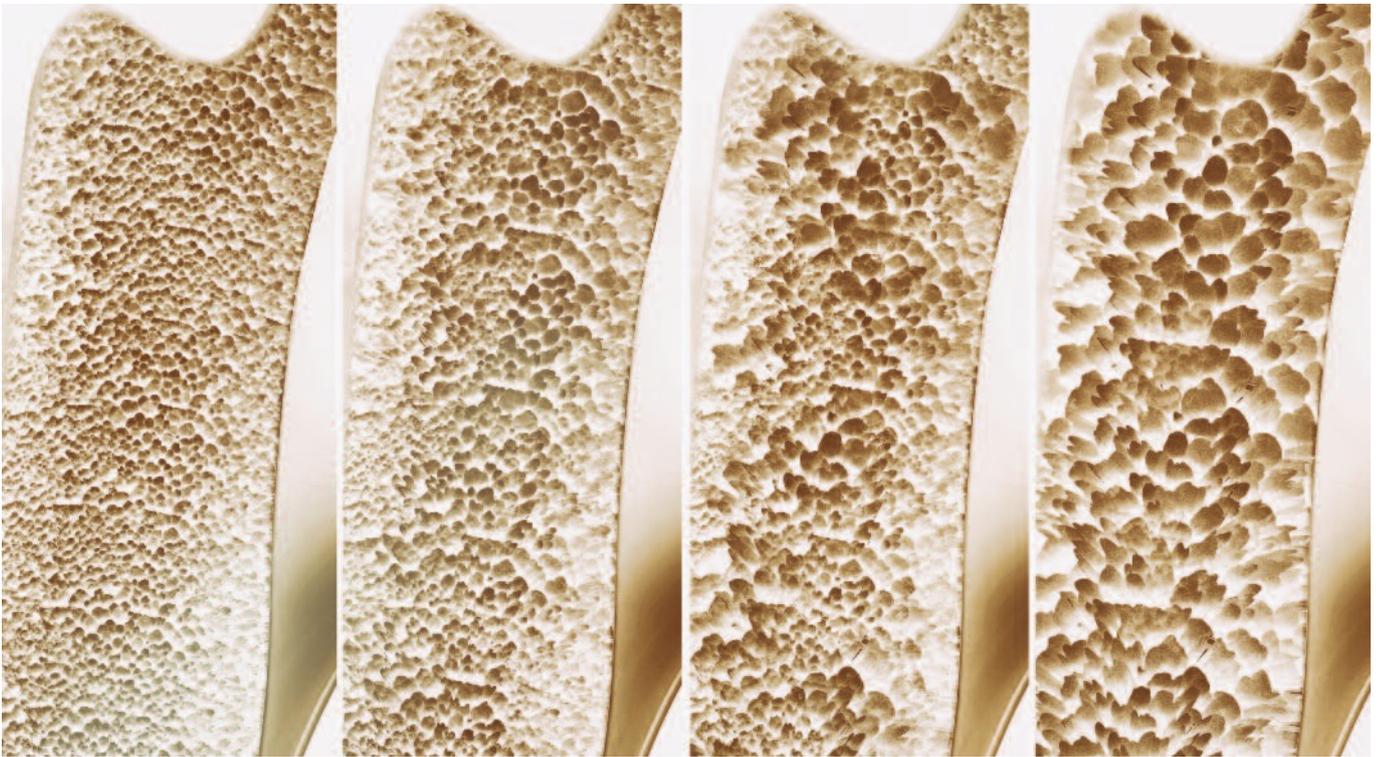
Studies show that when people eat a diet that consistently produces too much acid in the body, their bone mineral content decreases and risk of fractures increases (Alexy *et al.*, 2005; Remer *et al.*, 2011; Carnauba *et al.*, 2017; Hayhoe *et al.*, 2020). In other words, an unhealthy diet may contribute to weaker bones.

In studies of postmenopausal women, plant protein seems to have a positive effect on bone health while animal protein has a neutral or detrimental effect (Sellmeyer *et al.*, 2001; Hu *et al.*, 2014; Isanejad *et al.*, 2017). A recent study from Sweden that analysed data from over 80,000 people (men and women) found that meat consumption increased hip fracture risk (Warensjö Lemming *et al.*, 2024). The participants did not eat large amounts of meat – the lowest intakes were around 45 grams daily and the highest intakes were around 165 grams a day, yet the risk increased with each daily serving.

Researchers suggested that the negative effect of meat on bone health is not only about the acids produced during its digestion but also about the fact that it increases the formation of harmful free radicals and promotes inflammatory reactions in the body (Warensjö Lemming *et al.*, 2024). These effects are linked with increased bone loss.

However, not all studies have found animal protein to be harmful to the bones (Darling *et al.*, 2019) and some even found the opposite (Groenendijk *et al.*, 2023). The National Osteoporosis Foundation meta-analysis found that results of studies on the effect of protein on bone health varied widely (Shams-White *et al.*, 2017). And their next review comparing animal and plant protein intake in adult women found no





significant differences in their bone health (Shams-White *et al.*, 2018). The explanation is likely due to the fact that it's the overall diet and lifestyle that matters.

A large analysis of dietary patterns and bone health discovered that people who eat a Western diet rich in red and processed meat, eggs, refined grains and sweets have lower bone mineral density and higher fracture risk (Fabiani *et al.*, 2019).

Vitamin D

The body requires vitamin D to absorb and retain calcium in the bones (Abrams, 2021). If you lack vitamin D, you can develop calcium deficiency even if the diet provides enough. The consequences may be serious, resulting in rickets or osteomalacia (softening of the bones).

Vitamin D is either obtained from the diet or it is made in the skin following exposure to sunlight. However, having fortified foods such as plant milks, cereals and margarines may not be enough and regardless of diet, some people may need to supplement vitamin D from October to April because our skin simply cannot make enough. During warmer months, your skin can probably make sufficient vitamin D when exposed to natural sunlight, unless you spend your days indoors or always protect your skin, in which case you may need a supplement all year long. The recommended daily dose is 10 micrograms or 400 IU (international units).

It is important to get the balance right between being cautious about exposure to the sun and aware of the need for some exposure. It is recommended to spend at least 15 to 20 minutes a day outside during the warmer months with exposed face and hands to give the skin a chance to make enough vitamin D for your daily needs. The skin reacts to daylight even when it's cloudy so the weather doesn't need to be sunny for your skin to do its job. If you get enough exposure over the summer months, you may store up sufficient vitamin D to see you through the winter.

Fruit and veg

Studies show that regular fruit and vegetable consumption leads to healthier bones (Weaver *et al.*, 2016). This is probably thanks to the many vitamins and minerals they supply and their alkalisising effect which supports bone metabolism (Knurick *et al.*, 2015).

A Swedish study found that people who don't eat any fruit or vegetables on a daily basis have 88 per cent higher risk of hip fracture compared to people who get their five-a-day (Byberg *et al.*, 2015).

A team of researchers explained why fruit and vegetables are so important for good bone health (Fabiani *et al.*, 2019) – they are excellent sources of potassium and magnesium, vitamin C, vitamin K, folic acid and carotenoids. Potassium and magnesium help to balance out acids in the body, preventing bone loss and reducing fracture risk. In fact, research suggests that magnesium may be as important as calcium for maximising bone health in children but it also plays an important role in adults (Abrams, 2021). Vitamin C plays an important role in bone health, supporting bone maintenance and collagen formation, while vitamin K is a nutrient vital for bones and osteoporosis prevention. Low levels of vitamins C and K can weaken bone structure (Weaver *et al.*, 2016; Thaler *et al.*, 2022). Folic acid (together with vitamin B12) helps to maintain healthy levels of homocysteine in the blood and that is also linked to a lower risk of fractures. Lastly, carotenoids and other antioxidants reduce oxidative stress which helps to preserve bone health.

Vegan diet and bone health

A balanced vegan diet can be truly the best for the bones but an unhealthy vegan (or any other) diet may lead to less than ideal bone health. Thanks to decades of research, we know what's important for healthy bone growth and maintenance and we can confidently say that a vegan diet based on fruit and vegetables, pulses, wholegrains and nuts and seeds, with sufficient calcium intake and vitamins D (from supplements if sunlight exposure is limited) and B12 (from a supplement) is excellent for the bones.

Findings from the US Nurses' Health Study (based on over 70,000 postmenopausal women) revealed no difference in the risk of hip fracture among women following a plant-based diet over many years (Sotos-Prieto *et al.*, 2024). However, when researchers looked at recent food intakes alone, those with a healthy plant-based diet had a 21 per cent lower risk of fracture while those eating an unhealthy plant-based diet had a 28 per cent higher risk. This shows that a healthy vegan diet is paramount.

A meta-analysis of older studies revealed that vegans had slightly lower bone mineral density than meat-eaters but the

difference was only small and unlikely to result in an increased fracture risk (Ho-Pham *et al.*, 2009). Several other studies have also shown that vegans may have had a slightly higher risk of fractures (Ogilvie *et al.*, 2022).

However, newer studies don't agree – one new study found no significant bone health differences between vegans, vegetarians and meat-eaters (Gachenko *et al.*, 2024). While all groups had 'strengths and weaknesses' regarding nutrient intake, the authors noted how vegans now have access to a variety of ethically sourced supplements and foods fortified with vitamins D and B12, as well as calcium, which may be why their bone density was no different to the other groups.

Another recent study found exactly the same – vegans had healthy bones and there were no differences between them and other diet groups (Austin *et al.*, 2024). The authors pointed out that they all had good protein, vitamin D and calcium intake. And that may be the key ingredient – modern vegans have better nutritional knowledge, which not only helps them to achieve optimal bone health, it also ensures a healthy diet that reduces the risk of many diseases, including the major killers, such as cancer, heart disease and type 2 diabetes.

A small study of meat-eaters, vegetarians and vegans found only small, insignificant differences in the participants' bone density but it also found that the meat-eaters' diet produced more acid and they were losing more calcium in their urine than the other two groups (Knurick *et al.*, 2015).

And there's more positive research. For example, one study found that a diet rich in fruit and vegetables, calcium-fortified milk alternatives, pulses, nuts and wholegrains during adolescence is excellent for long-term bone health (Movassagh *et al.*, 2018). It's because these foods naturally contain nutrients essential for bones and don't produce excessive acid. The same study also found that diets high in fat and protein (high in red meat and full-fat dairy) produce poorer bone health later in life.

Physical activity

Being physically active is as vital for strong and healthy bones as a balanced diet (Weaver *et al.*, 2016). Our bones respond and adapt to pressure applied to them, which happens when you are active – without that, bone structure gets weaker because there's no stimulation. It's well known that astronauts lose bone density when they're in space.

Bone is the most responsive to physical activities that make you carry some weight (at least your own body weight) and create impact either with the ground or objects – it means that any exercise where you use your full body weight or added weight and move around with it are great, for example hiking, running, ball games, racket sports, dancing, weight-lifting, Pilates, yoga, gardening, DIY projects, even cleaning the house and dog walking. On the other hand, swimming and cycling don't do much for bone health because you don't carry your full weight and there's no impact on landing.

A study of identical twins revealed a clear distinction – twins that are more active have higher bone density than their more sedentary twin (Kujala *et al.*, 2022). Without weight-bearing activity, neither nutritional nor hormonal regulation can maintain optimal bone health (Murphy and Carroll, 2003).

As one study put it, exercise is the best non-pharmacologic tool for osteoporosis prevention and even treatment (Faenza *et al.*, 2020). Move it or lose it!

Take home message

A healthy, balanced vegan diet is great for bone health and provides more than enough calcium. There's absolutely no need for cow's milk or any other animal products in our diet. Eat a healthy plant-based diet, engage in regular physical activity and your bones will be in top shape.



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