Dietary Calcium and Health

Calcium is an essential nutrient as all living cells require calcium to remain viable; calcium is also required for a number of specific roles in the body. The majority (~99%) of calcium present in the body is found in bone, with a smaller amount found in teeth. The remainder is found in soft tissues and body fluids. The average adult skeleton contains 1200g of calcium, present in the form of hydroxyapatite, an inorganic crystalline structure made up of calcium and phosphorus ($\text{Ca}_{10} \text{(PO}_4\text{)}_6 \text{(OH)}_2$), which provides rigidity. Calcium is essential for bone growth as it is required for the mineralisation (impregnation of the bone matrix with minerals) of bone; the rate of calcium deposition in bone is proportional to rate of growth. An adequate intake of calcium is one of a number of factors which are important for acquiring bone mass and attaining peak bone mass. Diets containing insufficient amounts of calcium may lead to lower bone mineral density, which may have implications for bone health, notably risk of osteoporosis, in later life.

As well as having a skeletal function, calcium plays a regulatory role in a number of specialised functions in the body. Calcium plays a role in muscle (including cardiac muscle) contraction, neurotransmitter secretion, digestion and blood coagulation (clotting). Calcium also plays a structural role outside of the skeleton, for example in organelles and membranes. Disturbances in the structural and regulatory roles of calcium can have implications for health and disease. For this reason, calcium homeostasis is tightly regulated to ensure that plasma concentrations of calcium ions are maintained within a set range (i.e. 1.1-1.3 mmol/L). Homeostasis is controlled at three main sites: the kidneys, bone and the gastrointestinal tract. Control is mediated through the calciotropic hormones; parathyroid hormone (PTH), calcitriol and calcitonin. In response to changes in plasma calcium concentrations, absorption of calcium from the gastrointestinal tract can be altered, along with urinary excretion and calcium resorption from bone.

The UK reference nutrient intake (RNI) for calcium for adults aged over 19 years is 700mg/day; requirements are higher during childhood, adolescence and during lactation. No guidance has been issued on high intakes, although exceeding an intake of 1500mg calcium in the form of supplements is discouraged as this can cause stomach pain and diarrhoea. Calcium intake appears to have increased over the last thirty years or so. On average, British men consume 1007mg calcium/day, whilst the average British woman consumes 777mg/day (Henderson et al, 2003). Intakes of calcium are a concern amongst certain groups of the population. For example, a high proportion of teenage boys and girls and women aged 19-24 years fail to meet the lower reference nutrient intake (LRNI) for calcium, i.e. their intakes are likely to be inadequate.

A wide number of foods contain calcium, but the amount of calcium, provided per 100g or per serving, and its bioavailability vary considerably. The major source of calcium in British diets is milk and milk products (providing more than 40% of calcium intake amongst adults), followed by cereals and cereal products (providing 30% of intake). The contribution from cereals is high because although they are not a rich source, they are consumed in relatively large amounts and also some cereal products are fortified with calcium. For example, it is a mandatory requirement that white and brown wheat flours contain specified amounts of calcium, which is achieved through fortification. Additional sources of calcium include plant foods, including soya beans, some animal products (e.g. eggs) and water. The bioavailability of calcium from a food is influenced by the presence of a number of other compounds within a food. Dietary factors that influence absorption of calcium include fat (reduces absorption), protein and phosphorus (both increase absorption). The bioavailability of calcium from milk and milk products is in the region of 30% compared to 5% from spinach. Spinach, although containing a relatively large amount of calcium, is not considered a bioavailable source, as it contains a high concentration of oxalic acid which inhibits the absorption of calcium. Phytic acid and uronic acid, also found in plant foods, have a similar effect. However, the bioavailability of calcium from other plant foods is good, e.g. broccoli (see section 9). Soya beans are also a notable exception, in that they contain high quantities of both oxalic and phytic acids, yet are a bioavailable source of
calcium (bioavailability is in the region of 30-40%). The bioavailability of calcium from soya products will vary depending on the product.

Deficiency of calcium during growth has implications for bone mass, as the amount of calcium consumed in the diet influences the amount of calcium that can be retained by the skeleton during periods of growth. An inadequate intake of calcium combined with adequate energy and protein intakes may result in a low calcium content of bone, which may have implications for bone health later in life. The attainment of a high peak bone mass in early adulthood is important as bone mineral (including calcium) content starts to decline thereafter. Peak bone mass has been reported to be reached as early as 17-18 years or as late as 30-35 years; this depends on the site in the skeleton (e.g. peak bone mass is reached in the femoral neck (hip) before it is reached in the forearm). A number of factors influence bone mineral losses, e.g. physical activity (immobility accelerates loss), hormonal status and gender. In women, loss of bone mineral is accelerated around the time of the menopause, as a result of a fall in circulating oestrogen concentrations. An excessive loss of bone associated with ageing can lead to osteoporosis, which is characterised by micro-architectural changes in bone tissue, loss of bone mineral and reduced strength of bone which ultimately increases the risk of bone fracture. Osteoporosis is associated with morbidity and increased mortality and is a major concern in the UK and across the developed world. As the population ages, the incidence of osteoporosis will increase and bring with it additional costs to the health system and the economy.

There is some evidence that increased intakes of calcium later in life may help slow the rate of bone loss associated with ageing. The evidence is strongest amongst older postmenopausal women, rather than during the early stages (first five years) of the menopause. It appears that most benefit is obtained from consuming additional calcium in the long term. Further research is needed to investigate optimal dietary calcium intakes in relation to minimising bone mineral losses and reducing the risk of osteoporosis.

Calcium may have a role in the aetiology of chronic disease, with evidence suggesting that increased calcium intakes may help in the prevention of colorectal cancers. There is weaker evidence to suggest that calcium may offer some protection against breast cancer and more research needs to be conducted to confirm or refute an effect. Calcium has long been suggested to play a role in the aetiology of cardiovascular disease; early ecological studies suggested that consumption of hard (calcium containing) water was associated with a reduced risk. Calcium exerts modest blood pressure and lipid lowering effects, which may be of relevance in reducing risk of cardiovascular disease. In addition, there is preliminary evidence suggesting that calcium may play a role in weight management. Data from epidemiological studies suggests an inverse association between calcium intake and body weight. Human trials in this area are still in their infancy; at present findings must be interpreted with caution. A number of mechanisms that may underlie this effect of calcium on body weight are currently being investigated and more human trials are underway.

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