The growing years and prevention of osteoporosis in later life

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Ca is the major mineral in bone, and 99 % of the Ca in the body resides in the skeleton. Skeletal mass is a determinant of risk of fracture in childhood as well as adulthood. Over 40 % of adult peak bone mass is acquired during adolescence. This period is when lifestyle choices, including ensuring adequate dietary Ca, regular weight-bearing exercise and avoiding hormonal insufficiency, are especially important. Current Ca intakes for adolescent females are woefully inadequate.

Calcium: Peak bone mass

Development of maximal bone mass during growth and reduction of loss of bone later in life are the two main strategies for preventing osteoporosis. In order to achieve this goal, three main guidelines are recommended: (1) consume adequate nutrition to provide the raw materials for building bone; (2) participate in regular weight-bearing exercise to provide the stimulus to the body to build and retain bone; (3) maintain hormonal sufficiency to utilize Ca and maintain bone. In post-menopausal women oestrogen replacement therapy maintains hormone sufficiency, but during growth practices which lead to amenorrhoea, including eating disorders, extreme exercise and extreme low fat intakes, are indicative of hormonal insufficiency. Of the bone-building nutrients, Ca is the most likely to be inadequate. Ca requirements are considerably higher than average intakes during adolescence for much of the world, even for countries where Ca requirements are set much lower than those for North America. Early man is thought to have consumed much higher Ca intakes than in modern societies where cultivated grains (low in Ca) are the staple foods (Eaton & Konner, 1985). The main source of dietary Ca for modern man is dairy products, whereas early man consumed in excess of 3 g Ca/d from roots and tubers. Since osteoporosis occurs largely during post-reproductive periods, there is little evolutionary pressure to adapt to the lower Ca intakes of modern man. Thus, the trend among adolescents to replace milk as the primary beverage of choice with soft drinks is particularly troublesome.

Peak bone mass

Bone mass accrues until the peak is reached by early adulthood. Maximizing peak bone mass within an individual's genetic potential requires optimal Ca intakes throughout growth, but especially during adolescence when the rate of Ca accretion is highest. Approximately half an adult's bone mass accumulates during these few short years. The age of attaining peak bone mass differs with specific sites. Peak is achieved in the femoral neck by age 14–18 years (Matkovic *et al*. 1994). The age at which 90 % of total body peak bone mineral content is attained is 16·9 (SE 1·3) years and for 95 % 19·8 (SE 2·1) years (Teegarden *et al*. 1995). Blacks attain greater peak bone mass than whites or Asians, and have higher bone mineral densities as adults. Low bone density is associated with risk of fracture even in children (Goulding *et al*. 1998).

Calcium requirements for adolescents

In determining Ca requirements for North America the Calcium and Related Nutrients Panel appointed by the Institute of Medicine, National Academy of Sciences, reviewed relevant epidemiological studies, randomized controlled trials and balance data for evaluation of intakes required for maximal Ca retention. Epidemiological studies suggest that Ca intakes should exceed 1g/d for children to prevent low bone mineral density (Ruiz *et al*. 1995). Randomized controlled trials consistently show that higher

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Ca intakes, whether provided through supplements, fortified foods or dairy products, result in increased bone mineral content or density during the intervention period compared with non-supplemented controls (Johnston *et al.* 1992; Lloyd *et al.* 1993; Chan *et al.* 1995; Lee *et al.* 1995; Bonjour *et al.* 1997; Cadogan *et al.* 1997; Smart *et al.* 1998). However, studies using only two levels of Ca intake cannot determine Ca intakes for maximal Ca retention and bone accretion. The study of a range of Ca intakes is required in order to determine the intake which provides no additional benefit to Ca retention or bone accretion. This intake value for maximal retention is depicted in Fig. 1. Maximal Ca retention during growth should lead to maximal peak bone mass which is thought to minimize susceptibility to fracture. Ca requirements for North America and Ireland are compared in Table 1.

Our laboratory determined the Ca intake for maximal retention for adolescents to be 1300 mg/d (Jackman *et al.* 1997). We study Ca requirements in adolescent girls through metabolic research studies run as summer camps known as Camp Calcium. The girls live together on campus for 3-week sessions where they participate in educational and recreational activities. The diets are completely controlled and all excreta is collected. The first week serves as the adaptation period, and Ca retention is determined during the next 2 weeks. In 1993 subjects participated in two 3-week sessions, one of which used a lower Ca intake and the other used a higher Ca intake. In total, the Ca intakes studied ranged from 800 to approximately 2300 mg/d. Gains in Ca retention were not statistically significant after 1300 mg/d. Ca retention was highest at the onset of menarche. Ca retention decreased with increasing post-menarcheal age, but the intake required for maximal retention remained at 1300 mg/d.

The requirement for adolescents aged 11–17 years in Ireland is similar at 1200 mg/d. The Department of Health (1998) report on *Nutrition and Bone Health* released their new requirements for Ca. The Committee on Medical Aspects of Food and Nutrition Policy who prepared the report recommended no changes from the previous requirement of 800 mg and 1000 mg Ca/d for females and males aged 11–18 years set in 1991 (Department of Health, 1991). Although they reviewed the same literature as the North American group, the Committee on Medical Aspects of Food and Nutrition Policy concluded that there was insufficient data to warrant an increase in Ca recommendations, partly because they felt that the increases observed in bone mineral content or density on higher Ca intakes may not be associated with increases in skeletal size, and that short-term increases may not persist until adult peak bone mass is achieved. Ongoing research may answer these questions ultimately. Meanwhile, the risks lie with consuming insufficient Ca intakes to optimize bone mass, which may influence risk of fracture at any age.

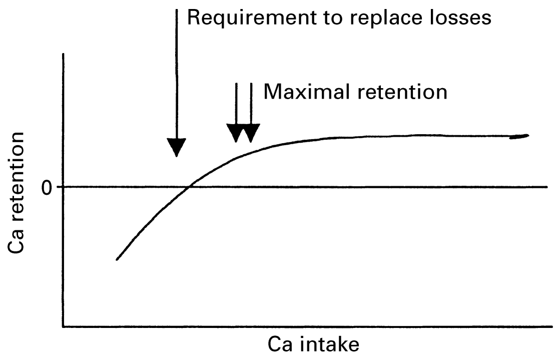

Fig. 1. Idealized relationship between calcium intake and accretion showing calcium requirement to replace losses (↓) and calcium intake to maximize calcium accretion (↓↓).

Table 1. Calcium requirements in North America and Ireland

Age (years)	North American adequate intakes* (mg/d)	Irish RDA† (mg/d)
1–3	500	800
4–8	800	800
9–18	1300	
11–17		1200
19–50	1000	800

RDA, recommended dietary allowance.
*Food and Nutrition Board (1997).
†Lee & Cunningham (1990).

Achieving adequate calcium intakes

The gap between current Ca intakes and requirements is largest for adolescent females in both Ireland and the USA. The average Ca intake in the USA for females aged 9–13 years is 918·5 mg/d and for those aged 14–18 years is 752·9 mg/d compared with 950 mg/d for females aged 15–18 years in Ireland (Lee & Cunningham, 1990). Our challenge and responsibility as educators, health professionals and caretakers of the diets of individuals is to close this gap. Possible methods for doing so include educating consumers to eat more Ca-rich foods, fortifying foods and recommending dietary supplements. Individuals who wish to increase their Ca can consume more dairy products or fortified food products. Ca-fortified foods are not very popular in Ireland. Taking supplements such as Ca tablets may be appropriate for those at high risk of health problems due to low Ca intake. Ca absorption from most supplements is equivalent.

Dairy foods provide 75 % of the Ca in the US diet, but only 52 % in the Irish diet. Bread provides an additional 15 % of the Ca in the Irish diet (Lee & Cunningham, 1990). Vegetables can provide Ca, but the quantities required to replace the amount of Ca in even a single glass of milk practically limit the role of other unfortified foods (Weaver & Plawecki, 1994; see Table 2).

Lactose intolerance is a commonly-cited reason for minimizing dairy-product consumption, especially among non-Caucasians. In a recent Camp Calcium, we (Pribila *et al.* 2000) evaluated African-American girls for lactose intolerance by H_2 breath analysis. The majority of girls were lactose maldigesters, but tolerated 1100 mg Ca/d from dairy products and were virtually symptom-free. If dairy products are consumed with food spaced throughout the day, most individuals can meet their Ca requirements with dairy products. Barriers to dairy-product consumption

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Table 2. Food sources of bioavailable calcium (from Weaver & Plawecki, 1994)

Food*	Serving size (g)	Ca content (mg)	Estimated fractional absorption (%)	Absorbable Ca/serving† (mg)	Servings needed to be equivalent to one cup of milk
Milk or yogurt (one cup)	240	300	32·1	96·3	1·0
Beans, red	172	40·5	17·0	6·9	14·0
Broccoli	71	35	52·6	18·4	5·2
Cabbage, Chinese (pak-choi)	85	79	53·8	42·5	2·3
Kale	65	47	58·8	27·6	3·5
Spinach	90	122	5·1	6·2	15·5
Tofu, Ca set	126	258	31·0	80·0	1·2

*Based on a half cup serving size unless otherwise noted.
†Estimated absorbable Ca per serving (mg) = Ca content (mg) × estimated fractional absorption.

are frequently culturally based more than physiologically based.

Fortified foods could provide additional choices for meeting Ca requirements, with the caution that individuals who consume less milk also have lower intakes of vitamin A, folate, riboflavin, vitamin B_6, Mg and K (Fleming & Heimback, 1994). Teenagers generally know that dairy products are a good source of Ca which is important to bone health. Several barriers exist to their consuming sufficient quantities to meet their Ca needs. Those individuals who believe that milk will make them fat should consider drinking skim-milk products. In randomized controlled trials girls supplemented with low-fat milk products do not gain more weight or percentage body fat than girls in the control group (Chan *et al*. 1995; Cadogan *et al*. 1997). Teenagers who object to the taste should try various flavoured and processed products to satisfy their preferences. Above all, caretakers of children should encourage nutritious habits.

Some dietary constituents increase urinary Ca loss and, thus, affect Ca retention, even though they do not affect Ca absorption (Weaver & Plawecki, 1994). For every 1 g dietary salt consumed, approximately 26 mg Ca is lost in the urine. For every 1 g metabolizable protein, approximately 1 mg additional Ca in the urine is lost. We have established these relationships in adults, but they are not well established in children.

To achieve adequate dietary Ca individuals should try to consume at least one Ca-rich food at every meal. Adolescents could benefit from an additional Ca-rich food as a snack.

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