Adequate Calcium Intakes for Bone Health

Calcium plays a major role in virtually every cell in the body, affecting vascular contraction and dilation, muscle contraction, blood coagulation, nerve transmission, enzyme activation and hormone secretion—not to mention its structural role in teeth and bones. In addition to these basic functions, research efforts continue to help scientists better understand associations between calcium intake and reduced risk of osteoporosis, hypertension and colon cancer. More recently, researchers have begun to study potential links between calcium intake and weight management.

Bones and teeth contain 99% of the body's calcium content; bone itself is 40% calcium by weight. While calcium plays a major role in bone health, bones likewise play a major role in calcium homeostasis by serving as a calcium reservoir for maintaining normal blood calcium levels. This calcium-bone relationship underlies the Institute of Medicine's (IOM) rationale for establishing an Adequate Intake (AI) for calcium.

Nutrition professionals should know why and how AIs were set for calcium, how to use the AI for assessing and planning diets for individuals and groups, what needs to be considered when choosing sources of calcium and that bone health means more than just an adequate calcium intake.

Dietary Reference Intakes

In addition to the familiar Recommended Dietary Allowance (RDA), the IOM created the Estimated Average Requirement (EAR), AI and Tolerable Upper Intake Level (UL) when it reevaluated the 1989 RDAs. These terms collectively are called Dietary Reference Intakes (DRIs).

- EAR: Based on experimental data, the EAR is the daily intake of a nutrient estimated to meet the requirement—as defined by a specified indicator of adequacy—in 50% of healthy individuals in a life stage or gender group.
- RDA: The RDA is derived from the EAR and is the average daily intake sufficient to meet the nutrient requirements of almost all individuals.
- AI: An AI was established when experimental data were insufficient to derive an EAR (and thus an RDA). The AI is expected to meet or exceed the amount of a nutrient needed to maintain a specified criterion of adequacy in essentially all healthy members of a group.
- UL: The UL is the highest level of chronic daily nutrient intake likely to pose no risk of adverse health effects to almost all healthy individuals.

Indicator of Adequacy. The IOM committee charged with reviewing the 1989 RDAs for calcium first had to determine an appropriate indicator of nutrient adequacy. A good biochemical assay that reflects calcium nutritional status does not exist, so the committee had to rely on potential indirect indicators. After reviewing the available scientific evidence on the risk for osteoporosis, hypertension and colon cancer, the committee decided to use several different indicators related to skeletal calcium content as the criterion of dietary adequacy.

The optimum calcium intake for skeletal health ideally would be that which leads to the fewest osteoporotic fractures later in life—but such data are not available. Also, the calcium intake to achieve desirable bone accretion is difficult to estimate because many other factors play a role. Therefore, several indicators believed to be reasonable surrogate markers of changes in skeletal calcium content were used to assess dietary calcium adequacy, including:

- desirable rates of calcium retention as determined from calcium balance studies;
- reliable bone mineral accretion data;
- changes in bone mineral content, bone mineral density or fracture rates in response to varying calcium intakes.

Adequate Intake. The panel did not set an EAR and RDA for calcium for the following reasons:

- uncertainties associated with calcium balance studies and the nutritional significance of values obtained from such studies;
- lower mean calcium intakes in the US than those experimentally derived as required to achieve desirable calcium retention;
- lack of longitudinal data to verify the association between experimentally derived desirable calcium intakes and the rate and extent of long-term bone loss and fracture.

Additionally, the ability to maximize calcium retention in bone is not limited by calcium intake alone: growth velocity, hormonal status, gender, ethnicity and race, genetics, physical activity and other dietary components also affect retention.

The AI for each life stage and gender group (Table 1) represents an approximation of the calcium intake believed to be sufficient to maintain calcium nutritional status. The AIs for males and females of a given age are the same. The primary factor influencing the AI is age, which reflects what we know about skeletal growth and bone metabolism over the life span: accretion during growth, consolidation of peak bone mass, maintenance of bone

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mass and minimization of age-associated bone loss. Pregnancy or lactation does not change the AI value despite the physiological changes in calcium metabolism during these states.

Upper Level. Excessive calcium intake can give rise to a variety of adverse effects, especially those characterized by changes in extracellular ionized calcium. The IOM committee considered the most widely studied hazards associated with excessive calcium intake: kidney stone formation, milk-alkali syndrome (i.e., hypercalcemia and renal insufficiency associated with alkalosis) and interactions with other minerals. A conservative UL of 2,500 mg for all groups (except infants) was based primarily on data associated with milk-alkali syndrome in adults, but also takes into consideration kidney stones and possible effects on zinc and iron utilization.

Assessing Calcium Intakes

Dietary surveys such as the 1994-1996 Continuing Survey of Food Intakes by Individuals consistently show mean or median usual dietary calcium intakes for several life stage and gender groups well below the AI and a large proportion of individuals with usual intakes below the AI (Table 1). For example, the median usual calcium intake of girls ages 14-18 years (713 mg) is about half the AI (1,300 mg), and at least 90% of the intakes are below the AI. So, while we can say that many girls have a low calcium intake, it is inappropriate to conclude that 90% of them are calcium deficient because the distribution of calcium intake requirements to promote desirable calcium retention is not known with the AI. On the other hand, in the case of children ages 1-3 years whose median calcium intake (766 mg) exceeds the AI (500 mg), it is appropriate to conclude there is likely to be a low prevalence of inadequate intakes.

Assessing the adequacy of an individual's calcium intake also is imprecise. The first step is to estimate an individual's usual calcium intake from all sources, either qualitatively (e.g., food frequency questionnaire or checklists of calcium sources) or quantitatively (e.g., 24-hour recall or diet records). If usual intake is below the AI, it signals a concern, despite the fact that no quantitative estimate can be made of the probability of inadequacy. For example, it is inappropriate to say that a teenager with a usual calcium intake of 600 mg is deficient. However, a usual calcium intake that meets or exceeds the AI is likely to cover the individual's calcium requirement. The more days for which calcium intake is assessed, the smaller the day-to-day variation in usual intake and the larger the difference between usual intake and the AI, the greater the confidence that the usual intake meets or exceeds the AI and calcium needs are met.

Planning Calcium Intakes

When planning calcium intakes for individuals or groups, the overall goal is to optimize the prevalence of diets that are nutritionally adequate without being excessive, i.e., without chronically exceeding the UL. The AI is appropriately used to plan intakes for individuals, for which the goal should be a usual calcium intake close to the AI. The goal when planning diets for groups (such as school-age children or older adults in residential facilities) is for the median intake of the group to meet the AI. However, because the AI for calcium (beyond infancy) is not based on observed intakes of healthy populations, there is some risk that achieving a group median intake at the AI will not yield a low prevalence of inadequacy.

Calcium Intake Sources

An adequate calcium intake can be achieved through consumption of foods naturally rich in calcium (primarily dairy foods), calcium-fortified foods (e.g., some dairy foods, fruit juices and juice drinks, soy and rice milks, ready-to-eat cereals), calcium supplements or a combination of all three. Obtaining as much calcium as possible from naturally occurring food sources is preferred because these foods provide other essential nutrients and health promoting components and the probability of exceeding the UL is usually low. Calcium-fortified foods and supplements are good alternative sources to dairy foods when used appropriately.

The calcium content of a food is generally more important than the bioavailability. Calcium bioavailability is fairly similar across most foods except for those high in phytic acid (e.g., beans and soy-based products) or oxalic acid (e.g., spinach). The efficiency of calcium absorption is enhanced if intake is < 500 mg/meal and spread over the day, rather than ingested at one time. Bioavailability from supplements is better if taken with meals and the product disintegrates easily. Under standard test conditions and a 250 mg calcium dose, fractional absorption of calcium from calcium citrate malate, calcium carbonate, tricalcium phosphate and milk has been 35%, 27%, 25% and 29%, respectively.

The proliferation of calcium-fortified foods and supplements in recent years has lead to concern that the calcium intake of some individuals may exceed the UL on a regular basis. Therefore, it's important for nutrition professionals to educate consumers on the appropriate use of calcium-fortified foods and supplements. Further, consumers need to be aware of their current calcium intake, their AI and appropriate strategies for achieving their AI.

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Consumers also need to understand how their AI compares to the Daily Value used for declaring the calcium content of foods and supplements (1,000 mg).

Table 1: Calcium Intakes (mg/day)

Life Stage Group	Adequate Intake	50th Percentile[a]	90th Percentile[a]	Upper Level
Infants				
0-6 mo	210[b]	457	674	ND[c]
7-12 mo	270[b]	703	1,062	ND
Children				
1-3 y	500	766	1,151	2,500
4-8 y	800	808	1,190	2,500
Males				
9-13 y	1,300	980	1,520	2,500
14-18 y	1,300	1,094	1,785	2,500
19-30 y	1,000	954	1,536	2,500
31-50 y	1,000	857	1,393	2,500
51-70 y	1,200	708	1,122	2,500
> 70 y	1,200	702	1,064	2,500
Females				
9-13 y	1,300	889	1,313	2,500
14-18 y	1,300	713	1,144	2,500
19-30 y	1,000	612	985	2,500
31-50 y	1,000	606	961	2,500
51-70 y	1,200	571	891	2,500
> 70 y	1,200	517	774	2,500
Pregnancy				
≤ 18 y	1,300	1,154[d]	1,596[d]	2,500
19-30 y	1,000			2,500
31-50 y	1,000			2,500
Lactation				
≤ 18 y	1,300	1,050[d]	1,233[d]	2,500
19-30 y	1,000			2,500
31-50 y	1,000			2,500

a 1994-1996 Continuing Survey of Food Intakes by Individuals; data adjusted for day-to-day variation; bold values are below the AI

b Based on human milk content and solid food when age appropriate

c Not determinable due to lack of data

d Value for all ages combined; estimates less reliable due to small sample size

Beyond Calcium Intake

Many other factors influence calcium retention and bone health. Other nutrients important for bone health include phosphorus, magnesium, fluoride, boron, copper, manganese, zinc, vitamin C, vitamin D, vitamin K and protein. Weight bearing physical activity also benefits bone health; however, exercise-induced amenorrhea can have an adverse effect. High intakes of sodium, protein and caffeine may affect calcium balance, but the effects are minimized with adequate calcium intakes. Cigarette smoking and alcohol abuse also are known to adversely affect calcium or bone status. Lastly, because the DRIs are for healthy individuals, certain medications, diseases and surgical procedures may increase an individual's calcium needs or sensitivity to excessive intakes.

The challenge for nutrition professionals is to assess each person's or group's situation and help devise dietary strategies to meet their needs for not only an adequate calcium intake but for overall good health.

Further Reading:

Institute of Medicine. *Dietary Reference Intakes for Calcium, Phosphorus, Magnesium, Vitamin D, and Fluoride*. Washington, DC: National Academy Press, 1997.*

Institute of Medicine. *Dietary Reference Intakes: Applications in Dietary Assessment*. Washington, DC: National Academy Press, 2000.*

Institute of Medicine. *Dietary Reference Intakes: Applications in Dietary Planning*. Washington, DC: National Academy Press, 2003.*

International Food Information Council Foundation. Physical Activity, Nutrition and Bone Health. IFIC Review. 2002. [See also www.ific.org. (Click on Publications > IFIC Reviews.)]

Barr SI, Murphy SP, Poos MI. Interpreting and using the Dietary Reference Intakes in dietary assessment of individuals and groups. *J Am Diet Assoc*. 2002; 102:780-788.

*IOM Reports are available at www.nap.edu. (Click on Browse Categories > Food & Nutrition. Scroll down to the report.)]