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POSITION STATEMENT

The role of calcium in peri- and postmenopausal women: 2006 position statement of The North American Menopause Society

Objective: To update the evidence-based consensus opinion published by The North American Menopause Society (NAMS) in 2001 on the role of calcium in peri- and postmenopausal women.

Design: NAMS followed the general principles established for evidence-based guidelines to create this document. A panel of clinicians and researchers acknowledged to be experts in the field of calcium and women's health was enlisted to review the previous position statement and data published since then, compile supporting statements, and make recommendations. Their advice was used to assist the NAMS Board of Trustees in publishing this position statement.

Results: Adequate calcium intake (in the presence of adequate vitamin D status) has been shown to reduce bone loss in peri- and postmenopausal women and reduce fractures in postmenopausal women older than age 60 with low calcium intakes. Adequate calcium is considered a key component of any bone-protective therapeutic regimen. Calcium has also been associated with beneficial effects in several nonskeletal disorders, primarily hypertension, colorectal cancer, obesity, and nephrolithiasis, although the extent of those effects has not been fully elucidated. The calcium requirement rises at menopause. The target calcium intake for most postmenopausal women is 1,200 mg/day. Adequate vitamin D status, defined as 30 ng/mL or more of serum 25-hydroxyvitamin D (usually achieved with a daily oral intake of at least 400 to 600 IU), is required to achieve the nutritional benefits of calcium. The best source of calcium is food, and the best food source is dairy products. High-quality calcium supplements (taken in divided doses) are alternative sources for women unable to consume enough dietary calcium. There are no reported cases of calcium intoxication from food sources, and cases associated with supplements are rare (high intake levels of 2,150 mg/day have resulted in a 17% increase in renal calculi in one recent study, but not others). Because no accurate test to determine calcium deficiency exists, clinicians should focus instead on encouraging women to consume enough calcium to meet the recommended levels.

Conclusions: The most definitive role for calcium in peri- and postmenopausal women is in bone health, but, like most nutrients, calcium has beneficial effects in many body systems. Based on the available evidence, there is strong support for the importance of ensuring adequate calcium intake in all women, particularly those in peri- or postmenopause.

Key Words: Calcium – Menopause – Perimenopause – Postmenopause – Bone mass – Fractures – Osteoporosis – Vitamin D – Hypertension – Obesity – Nephrolithiasis – Colorectal cancer – NAMS.

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The Board of Trustees of The North American Menopause Society (NAMS) developed this position statement with assistance from the following Editorial Board members: Robert P. Heaney, MD (Chair); John P. Bilezikian, MD; Michael F. Holick, PhD, MD; Jeri W. Nieves, PhD; and Connie M. Weaver, PhD. Edited, modified, and subsequently approved by the NAMS Board of Trustees on August 9, 2006.

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Calcium, an essential nutrient for the human body, has received substantial attention in both the medical literature and lay press regarding its role in osteoporosis and several other chronic diseases.

In response to the need to define standards of clinical practice in North America as they relate to menopause-associated health conditions, The North American Menopause Society (NAMS) has updated this evidence-based position statement. The objective of this position statement is to provide guidance on the role of calcium in peri- and postmenopausal women to health professionals caring for this population.

This position statement is an update of the NAMS consensus opinion published in 2001.[1] Since then, additional scientific evidence has created a need to update the document.

For this revision, NAMS conducted a search of the medical literature published since the consensus opinion was submitted for publication in November 2000. Using the database MEDLINE, a search was made for systematic reviews, meta-analyses, clinical trials, and clinical practice guidelines published in English and related to calcium and calcium therapy in peri- and postmenopausal women. The Medical Subject Headings used for the search were calcium with subheadings for physiology, deficiency, dose, therapeutic use, and adverse effects. Also searched were osteoporosis, colorectal cancer, hypertension, nephrolithiasis, obesity, vitamin D, and magnesium. The Cochrane Library was searched for relevant systematic reviews, and the National Guideline Clearinghouse was searched for relevant clinical practice guidelines. Priority was given to evidence from randomized, controlled clinical trials and meta-analyses of such trials, followed by evidence from controlled observational studies, using criteria described elsewhere.[2-4] Recommendations from other evidence-based guidelines were also reviewed. Because standards of care and available treatment options differ throughout the world, the focus was limited to therapies available in North America.

The recommendations contained in this evidence-based position statement are targeted to health professionals caring for peri- and postmenopausal women, especially those in the clinical practice fields of obstetrics and gynecology, internal medicine, primary care, and geriatrics.

To help with this revision, NAMS enlisted a five-person Editorial Board composed of endocrinologists, epidemiologists, and nutritionists from both clinical practice and research with expertise in calcium and/or women's health. The Editorial Board reviewed the previous consensus opinion and the more recently published data, compiled supporting statements and conclusions, and made recommendations. If the evidence was contradictory or inadequate to form a conclusion, a consensus-based opinion was established. (Practice parameter standards related to NAMS position statements have been described in an editorial.[5]) The NAMS Board of Trustees was responsible for the final review and approval of this document. Updates to this revised position statement will be published as scientific developments occur that substantially alter the conclusions.

PHYSIOLOGY

Calcium is the most abundant mineral in the human body. Approximately 99% of the total calcium stores are contained in the skeleton. The remaining stores are in the cells of soft tissue (0.9%) and in the bloodstream and extracellular fluid (0.1%), where they exert effects on the cardiovascular, nervous, and muscular systems.

Calcium requirements for skeletal maintenance fluctuate throughout a woman's life. During the teen years, calcium requirements are high because of the demands of a rapidly growing skeleton. During a woman's 20s, less calcium is required for bone health as bone turnover stabilizes (ie, bone formation and resorption rates become balanced) and peak adult bone mass is achieved.

Calcium requirements remain stable until menopause, when the bone resorption rate increases in association with the decrease in ovarian estrogen production. Calcium needs rise at that time because of decreased efficiency in the utilization of dietary calcium, which is due, in large part, to estrogen-related shifts in intestinal calcium absorption and renal conservation.

The amount of calcium needed is also affected by the decrease in intestinal absorption that occurs with age. Gross calcium absorption averages 20% to 30%, with transient increases during adolescent growth spurts and pregnancy.[6,7] By age 65, calcium absorption efficiency is typically 50% below adolescent peak absorption.

One factor that may limit calcium absorption is a lack of vitamin D resulting from age-related declines in several functions, including ingestion, cutaneous synthesis of the parent vitamin,[8] renal synthesis of the active form of the vitamin (1,25-dihydroxyvitamin D),[9,10] and intestinal responsiveness.[11]

Dietary factors limiting calcium absorption include consuming oxalic acid (found in spinach, rhubarb, and some other green vegetables), consuming large amounts of grains that contain phytates (eg, wheat bran, soy protein isolates), and, possibly, consuming tannins (found in tea). Evidence indicates that other dietary components, such as fat, phosphorus, magnesium, and caffeine, have negligible effects on calcium absorption at generally applicable intake levels. Calcium, on the other hand, has been shown to lower the rate of iron absorption in single-meal tests;[12,13] however, the body commonly up-regulates iron absorption to compensate.[14] Nevertheless, it is generally advised that iron supplements not be taken at the same time as calcium.

The importance of an adequate calcium intake for skeletal health is well established. In addition, calcium has been associated with beneficial effects in several nonskeletal disorders, primarily colorectal cancer, hypertension, nephrolithiasis, and obesity, although the extent of those effects and the mechanisms involved have not been fully elucidated.

OSTEOPOROSIS

The skeletal disorder osteoporosis is characterized by compromised bone strength, predisposing bone to an increased risk of fracture. Bone strength reflects bone mass, bone architecture, bone size, and bone material quality. Bone mass in peri- and postmenopausal women is determined by the peak bone mass achieved during growth and the amount of bone loss thereafter. Results of standard noninvasive densitometric techniques to assess bone status are expressed as bone mineral content (BMC) or bone mineral density (BMD). BMC is expressed as grams of mineral and BMD as grams of mineral per unit area. Bone quality reflects a broad range of different features, including bone architecture, bone remodeling activity, and accumulated fatigue damage (eg, microfractures).

Osteoporosis occurs most commonly in postmenopausal women, and the incidence increases with age. In the United States, approximately 15% of women aged 50 years or older have osteoporosis by bone density criteria, and another 35% to 50% have low bone mass.[15] Because there are three times more women in this low bone mass group, they actually account for more osteoporotic fractures than those in the lowest bone mass category.[16]

It is estimated that more than 40% of US women older than age 50 will suffer an osteoporotic fracture.[17] The usual fracture sites are the vertebrae, hip, distal forearm, pelvis, ribs, and other limb bones. Up to 90% of all hip and spine fractures in older women can be attributed to osteoporosis.[18] The event precipitating a fracture can range from a traumatic high-impact fall to normal lifting and bending. Falls appear to be the most common cause of fractures at all sites (eg, wrist, spine, and hip).

Fractures are associated with significant morbidity and mortality. Hip fractures cause up to a 25% increase in mortality within 1 year of the incident. Approximately 50% of survivors will have some long-term loss of mobility.[18] Clinical (as distinguished from silent) spine compression fractures have a 15% to 20% excess mortality, in addition to their effect on quality of life.[19]

The decline in circulating levels of 17β-estradiol is the predominant factor influencing the accelerated bone loss and increased remodeling activity associated with menopause.[20,21] Bone loss at the spine begins about 1.5 years before the last menstrual period and occurs at a rate of approximately 3% per year for about 5 years, amounting to a total BMD loss of approximately 15%. Bone mass at the hip declines at a rate of about 0.5% per year before and after menopause and sustains an additional loss of 5% to 7% across the menopause transition period.[22] Bone remodeling rates, based on percutaneous transiliac bone biopsy, nearly double 1 year after menopause and increase to nearly three times the premenopausal level 13 years after menopause.[21]

The primary goal of the approach to osteoporosis is to prevent fractures by slowing or preventing bone loss, by reducing nonstructural remodeling, and by minimizing or eliminating factors that may contribute to falls. (For more information about the management of postmenopausal osteoporosis, see the NAMS 2006 position statement.[23]) Randomized clinical trial evidence evaluating the importance of adequate calcium (and vitamin D) intake in bone health is so strong that it is considered to be a key component of any therapeutic regimen for peri- or postmenopausal women. Virtually all clinical trials with antiresorptive or anabolic skeletal agents include calcium plus vitamin D in both treatment and placebo arms.

Calcium or calcium plus vitamin D

In randomized, placebo-controlled clinical trials, calcium plus vitamin D has been shown to reduce or halt bone loss in healthy postmenopausal women and in postmenopausal women with substantial bone loss or previous fracture, especially in those 5 or more years past menopause.[24-33] A review of more than 20 studies found that postmenopausal women receiving

calcium supplementation had bone losses of 0.014% per year compared with 1.0% per year in untreated women.[11] In longer term trials, the beneficial effects of calcium supplementation were sustained for up to 4 years.[33-35]

Older studies have found that calcium, in the presence of adequate vitamin D, also reduced the incidence of spine, hip, and other fractures.[25,27,36] In a large (N = 3,270) controlled trial of healthy, elderly Frenchwomen (mean age, 84 years) who had low calcium intake and low vitamin D levels, women who received supplemental calcium (1,200 mg/day) and vitamin D (800 IU/day) for 18 months had significantly fewer nonvertebral fractures (32%) and hip fractures (43%) than placebo recipients.[36] Another well-controlled (3-year, double-blind, placebo-controlled) trial in older postmenopausal women (aged 65 years and older) found that 500 mg/day of calcium plus 700 IU/day of vitamin D for 3 years significantly reduced the relative risk (RR) of any first nonvertebral fracture (RR, 0.4; 95% CI, 0.2-0.8).[27] A reduction in vertebral fracture rate was also seen in a study of 93 vitamin D–replete elderly women (mean age, 72.1 years) given calcium supplementation (800 mg/day).[25]

Some recent large randomized trials did not show significant efficacy of daily oral calcium supplements in preventing fracture. Three studies of calcium and vitamin D[37-39] and one study on calcium alone[40] concluded no efficacy in reducing fracture risk using prespecified intent-to-treat analysis. However, in two of the studies, baseline calcium intake was already at or close to the response threshold, and calcium intake for the other two was not reported. Because calcium is a threshold nutrient (like iron), response to augmented intake would not be expected if most of the supplemented individuals had intakes already at or above the level that produces bone effects. Additionally, treatment adherence was poor (in the range of 35%-55%) in two of the studies reporting this information, and in both, when analysis was confined to treatment-adherent participants, significant reductions in fracture risk were found.

The recently published NAMS osteoporosis position statement,[23] which reached the conclusion that primary analysis (intent to treat) of the effect of calcium intake on fractures did not show efficacy, did conclude that secondary evidence (patient compliance) revealed benefit.

Calcium appears to potentiate the effect of exercise on BMD in postmenopausal women. In a review of 17 trials evaluating the benefits of exercise (eg, resistance training, low- to high-impact exercises) and calcium intake on bone,[41] adding calcium supplementation to the exercise groups significantly improved BMD. The benefits of exercise were observed primarily in those with a daily calcium intake of more than 1,000 mg.

Calcium plus antiresorptive or anabolic skeletal agents

Calcium, either alone or with vitamin D, is not as effective as pharmacotherapy with either estrogen alone (ET) or estrogen combined with a progestogen (EPT), calcitonin, a selective estrogen-receptor modulator (SERM), or a bisphosphonate.[23] However, supplemental calcium substantially improves the efficacy of these agents in reducing menopause-related bone loss.

A 1998 review of 31 trials[42] found that calcium potentiates both the bone-sparing and antifracture efficacy of ET/EPT and nasal calcitonin. Annual BMD gains at the hip were significantly greater for estrogen plus calcium (2.4%) than for estrogen alone (0.9%). Similar results were observed in the trials evaluating the effects of calcium supplementation with calcitonin. In these studies, lumbar spine BMD increased 2.1% with calcitonin (200 IU/day) plus calcium (1,466 mg/day), compared with a decline of 0.2% with calcitonin without calcium.

Because of the well-established need for adequate calcium intake, all key clinical trials with either a SERM or a bisphosphonate have provided supplemental calcium to both treatment and placebo arms.[43-51] Although it is likely that calcium potentiates the positive BMD effects of SERMs and bisphosphonates, as it does for ET/EPT, this conclusion can only be surmised.

COLORECTAL CANCER

The third most common malignancy in US women is colorectal cancer, and the risk increases with age. The incidence is 4.4 times higher in women aged 65 years and older than in women aged 40 to 64 years.[52]

Low calcium intake is one of the risk factors associated with an increased incidence of colorectal cancer. The principal mechanism seems to be binding by unabsorbed calcium of cancer-promoting substances in the colon contents (eg, unabsorbed fatty acids and bile acids). A high calcium intake is needed to neutralize these potentially harmful residues of the digestive process.

A review published in 2000 of epidemiologic studies concluded that high calcium intake appears to decrease

proliferation of colorectal epithelial cells (shown in animal studies to be associated with tumor formation) and lower the risk of colorectal adenoma.[53] Calcium (up to 1,200 mg/day from either diet or supplementation) reduced colorectal mucosal turnover in high-intake groups.[54-56] The largest trial (N = 193) found that calcium supplementation (1,000 or 2,000 mg/day) normalized the distribution of proliferating cells in the colorectal mucosa without affecting the proliferation rate.[57] However, two randomized trials using 1,200 mg/day of calcium did not find reduced epithelial cell proliferation.[58,59]

In studies of calcium and colorectal adenoma development, most findings support an inverse association between high calcium intake and cancer risk, although statistical significance has been reached in only a few of the studies.[53] In the largest controlled study (930 men and women with a recent history of colorectal adenomas),[60] 1,200 mg/day of calcium significantly reduced the risk of recurrent colorectal adenomas (RR, 0.85; 95% CI, 0.74-0.98). A similar positive effect, although not statistically significant, has been observed in other prospective trials.[61-63] A prospective cohort study of nearly 90,000 women free of colorectal cancer at study entry also found an association, again not statistically significant, between calcium intake and decreased risk of colorectal cancer.[64]

Considerable research on animals has clearly established the protective role of calcium in colon carcinogenesis.[65] Although the human studies have not all been positive, their findings are consistent with the animal data.

The controlled trials of calcium supplementation and colon cancer in humans have typically used calcium carbonate as the calcium source, based on the assumption that one calcium source is much the same as another. However, calcium phosphate has been shown to bind bile acids more efficiently than calcium carbonate and has worked better in the animal models than has the carbonate salt. Furthermore, diets high in milk content, in which the calcium source is effectively calcium phosphate, yield a colonic residue less irritating to mucosal cells than do diets in which supplements of the carbonate salt are used.[66] More research is needed to clarify the difference, if any, between various calcium salts and their role in colorectal cancer prevention.

An apparently negative finding in the Women's Health Initiative (WHI) study with respect to colon cancer prevention is best explained by the fact that there was, effectively, no low-calcium control group. Once the quantity of calcium in the digestive residue has bound the irritant substances left over from digestion, consuming more calcium provides no further benefit. The mean intake in the so-called control group in WHI was already close to, or perhaps even above, the response threshold.[67]

HYPERTENSION

Overall, an estimated 37.8% of women have hypertension. The prevalence rises with age. Before age 45, a higher percentage of men than women have hypertension. Between ages 45 and 55, the percentage of women becomes greater. After age 55, the percentage is substantially higher in women.[68]

Although data on the association between calcium and hypertension are inconsistent, considerable epidemiologic and clinical trial data have reported that a higher intake of calcium tends to lower blood pressure.

Analyses of pooled data from calcium intervention trials in hypertensive women[69-72] have concluded that supplemental calcium intake significantly lowers blood pressure (systolic, −0.15 mm Hg per 100 mg/day of calcium; diastolic, −0.051 mm Hg per 100 mg/day of calcium).[70] Because of the heterogeneity of hypertension, calcium intake did not have an effect on all active-treatment cohorts, although some subsets did show efficacy.

In both hypertensive and normotensive women and men, trials have found that high calcium intake from supplements produced small (2-5 mm Hg), but statistically significant, decreases in blood pressure. Dietary sources for calcium have produced similar effects. In a study of the Dietary Approaches to Stop Hypertension (DASH) diet,[73] which used low-fat dairy products as the primary source of calcium along with intakes of fruits and vegetables, blood pressure decreases of 3.0 mm Hg (diastolic) and 5.5 mm Hg (systolic) were observed. In an analysis of the relationship between dairy consumption and hypertension among 4,797 participants by the National Heart, Lung, and Blood Institute Family Heart Study,[74] consuming dairy products containing 1,200 mg calcium/day was also associated with a systolic, but not diastolic, decrease in blood pressure, mainly among individuals consuming less saturated fat.

In a statement addressing dietary approaches to managing hypertension,[75] the American Heart Association commented that the evidence documenting the effect of calcium supplementation on hypertension is limited but equivocal.

A Cochrane review[76] of 13 randomized, controlled trials (N = 485) with 8- and 15-week follow-ups

found that calcium supplementation resulted in a statistically significant reduction in systolic blood pressure (mean difference, −2.5 mm Hg; 95% CI, −4.5 to −0.6), but not diastolic blood pressure. The review concluded, however, that most trials were of poor quality, so their results may not be reliable.

Larger, longer, and better-quality trials are needed to clarify whether calcium supplementation can lower high blood pressure.

NEPHROLITHIASIS

Another condition, nephrolithiasis, is relatively common among both women and men. Although some concern has been expressed that high intake of calcium may increase the risk of developing renal calculi, several lines of evidence suggest that increasing calcium consumption up to or beyond 1,500 mg/day actually reduces the risk. However, in the recent WHI study of calcium plus vitamin D,[39] in which the daily calcium intake averaged 2,150 mg, a 17% increase in renal calculi was observed; the factors contributing to this increase are under investigation.

The most convincing evidence that calcium intake decreases renal calculi risk comes from the standard use of calcium carbonate to treat the syndrome of intestinal hyperoxalosis. Low calcium intake predisposes men and women to a higher risk of calculi, primarily because there is insufficient unabsorbed calcium in the intestine to bind to oxalic acid and prevent its absorption. Oxalic acid is a more potent risk factor for stone formation than is calcium.

Evidence also comes from a randomized, controlled trial[77] that showed a 50% reduction in stone recurrence in men with recurrent calcium oxalate stones and hypercalciuria who were assigned to a calcium diet of approximately 1,200 mg/day as compared with those ingesting a low-calcium diet of approximately 400 mg/day. At 5 years, the unadjusted RR of calculi recurrence was 0.49 (95% CI, 0.24-0.98) for the higher calcium diet.

Data from the Nurses' Health Study, an observational study of 91,731 women followed for 12 years,[78] showed that women with dietary calcium intake of more than 1,000 mg/day had a lower risk of developing an initial renal calculus than did women with dietary calcium intake of less than 500 mg/day (RR, 0.65; 95% CI, 0.50-0.83).

Women with renal calculi or renal disease should be advised to consume adequate calcium but not to exceed the age-appropriate daily recommended allowance, at least until the cause of their stone formation has been discovered. Furthermore, women at high risk of renal calculi should avoid dehydration and foods that are high in oxalate, in particular spinach.

OBESITY

According to data from the National Health and Nutrition Examination Survey (NHANES III), approximately 65% of women aged 40 to 59 years are either overweight or obese, a percentage that increases to approximately 68% in women older than 60.[79]

A potential link between an increased risk of obesity and low calcium intake has only recently become apparent. The association is based mainly on observational data showing that children and adolescents with high milk intake weighed less and had less body fat than those with low milk intake.[80] This conclusion is supported by an analysis of the NHANES III database that found a highly significant stepwise, inverse correlation between dietary calcium intake and the risk of obesity.[81] Other databases, including the Continuing Survey of Food Intakes by Individuals[82] and the Quebec Family Study,[83] show a similar inverse relationship between calcium intake and both body mass index (BMI) and the risk of being obese. In a reanalysis of three calcium intake trials,[84] investigators found a similar inverse relationship between BMI and calcium intake in two studies of perimenopausal women as well as significant weight loss in a controlled trial of calcium supplementation in older women.

OPTIMAL INTAKE

The primary factor influencing the amount of calcium absorbed is the amount of calcium ingested. Vitamin D is also essential.

Calcium

Adequate intake requirements for nutrients have been established by the US Institute of Medicine (IOM). In 1997, the IOM published revised calcium requirements for North American residents.[85] The National Institutes of Health and the Osteoporosis Society of Canada have also published calcium intake guidelines.[20,86] Recommendations related to peri- and postmenopausal women are presented in Table 1.

The report from the 2005 Dietary Guidelines Advisory Committee states that 2 or 3 cups of milk or milk products, the major sources of calcium in US diets, will meet the daily goal for calcium intake in adults.[87]

Calcium intake is based on the total calcium content of food consumed. To achieve maximum

TABLE 1. *Recommended daily elemental calcium intake for peri- and postmenopausal women*

Institute of Medicine	
Aged 31-50	1,000 mg
Aged 51 and older	1,200 mg
National Institutes of Health	
Premenopausal women aged 25-50	1,000 mg
Postmenopausal women younger than age 65 and using estrogen therapy	1,000 mg
Postmenopausal women not using estrogen therapy	1,500 mg
All women aged 65 and older	1,500 mg
Osteoporosis Society of Canada	
Menopausal women	1,500 mg

Adapted from the Institute of Medicine,[85] the National Institutes of Health,[20] and the Osteoporosis Society of Canada.[86]

calcium absorption, food selection decisions should reflect the food's calcium bioavailability and the presence in the meal of foods that may inhibit calcium absorption.

In general, postmenopausal women in the United States and Canada have low calcium intake (median intake approximately 600 mg/day).[88] The probability of calcium adequacy in the American diet is approximately 46% for women.[89] Specific populations of postmenopausal women at extra risk of inadequate calcium intake include women who are lactose intolerant, follow a pure vegetarian diet (vegan), or have poor eating habits. This low probability of adequacy led the 2005 Dietary Guidelines Advisory Committee to classify calcium as a "shortfall" nutrient.[87]

The side effect profile from recommended levels of calcium intake is insignificant. Calcium intervention trials have not reported any serious adverse events. Nevertheless, some women have difficulty swallowing the large tablet or have gastrointestinal (GI) adverse effects (ie, gaseousness, constipation). Tolerability can be addressed by getting most or all of the requirement from food or by switching the type of calcium or reducing the dose. GI adverse effects are often related to a woman's taking more calcium than required, not dividing doses, or perhaps confusing supplemental intake with recommended total daily intake.

Calcium intake greater than the IOM recommendations produces no currently recognized health benefits in women, and adverse events might be more likely to occur. Intake of more than 2,500 mg/day (the upper limit for healthy adults set by the IOM) can increase the risk of hypercalcemia, which, in extreme cases, can lead to kidney damage. It is not necessary to measure urine calcium excretion before increasing calcium intake to recommended levels in women who have not had a renal calculus. But a woman diagnosed with renal calculi should not consume calcium supplements above the level recommended for her age until the specific cause has been determined.

Vitamin D

The nutrient vitamin D is essential for the efficient intestinal absorption of calcium. In women with a vitamin D gross deficiency, no more than 10% to 15% of dietary calcium is absorbed.

The recommended adequate dietary intake for vitamin D is 400 IU/day for women aged 51 to 70 years and 600 IU/day for women older than age 70 years.[85] NAMS and the National Osteoporosis Foundation recommend an intake of up to 800 IU/day for women at risk of deficiency because of inadequate sunlight exposure, such as elderly, chronically ill, housebound, and institutionalized women or those who live in northern latitudes.[90,91] In Canada, the recommended vitamin D intake for women younger than 50 years is 400 IU/day and 800 IU/day for women over 50 years.[86]

The safe upper limit of vitamin D is 2,000 IU/day.[85] Higher doses may cause vitamin D intoxication and increased risk of hypercalciuria and hypercalcemia. Doses greater than 10,000 IU/day should be avoided.[92]

Sources of vitamin D include sunlight exposure, vitamin D–fortified foods (eg, milk, some yogurts and cheeses, some orange juices, some breads, oily fish), and vitamin supplements.[93]

Sun exposure is the major source of vitamin D. The amount of exposure time varies depending on time of day, season, latitude, and degree of skin pigmentation. For the typical white individual living in the northeast, sunlight exposure of 5 to 15 minutes on the arms and legs between the hours of 10 AM and 3 PM two to three times per week is often adequate.[94] Women with dark-colored skin may require as much as 5 to 10 times longer skin exposure because their darker skin pigment markedly reduces vitamin D production from sunlight. Wearing a sunscreen with a sun protection factor of 8 or more reduces the skin's ability to produce vitamin D by 95%.[95] In the absence of sunlight, most experts agree that at least 800 IU and preferably 1,000 IU of vitamin D per day is needed to maintain a healthy serum level of 25-hydroxyvitamin D [25(OH)D] of at least 30 ng/mL.[96] Canadian guidelines recommend intake of vitamin D_3, not reliance on sun exposure.[86]

There are few foods that contain vitamin D. Those that do include oily fish, such as salmon, mackerel,

and herring, as well as sun-dried mushrooms. In milk and orange juice fortified with vitamin D, 100 IU of vitamin D is provided per 8 oz. A fortified serving of yogurt may contain 100 IU of vitamin D. Some cereals and breads are also fortified with vitamin D.

Current daily requirements can usually be met with an oral multivitamin supplement plus moderate sun exposure. However, older women (>65 years) who have little or no sun exposure and rely on diet alone for vitamin D intake may have suboptimal 25(OH)D levels.[97] Because vitamin D must be metabolized before it is biologically active, taking vitamin D at the same time as a calcium supplement is not necessary. However, some calcium supplements contain vitamin D, providing the convenience of obtaining adequate levels of both nutrients.

A typical multivitamin contains 400 IU of vitamin D, although many multivitamin supplements contain vitamin D_2 (ergocalciferol), which is from one third to one ninth as effective as vitamin D_3 (cholecalciferol) in maintaining serum levels of 25(OH)D; thus, if a multivitamin contains 400 IU of vitamin D_2, it is equivalent to taking 130 IU of vitamin D_3. Vitamin D supplements of 400, 800, and 1,000 IU are also available, either as D_2 or D_3.

ASSESSMENT OF DEFICIENCY

No single laboratory test can accurately detect calcium deficiency. Tests for serum calcium and urine calcium, as well as those for bone density, have been used; however, each has limitations in clinical utility. Serum calcium levels are maintained within normal ranges even with extreme dietary calcium deficiency, the use of urine calcium is limited by the large range of normal values, and bone density is influenced by many factors other than diet.

In the absence of specific laboratory tests for calcium deficiency, an assessment of dietary calcium intake is often utilized. However, such an assessment usually relies on the woman's recall of her food intake and serving sizes, which are often inaccurate. Moreover, inadequate dietary intake is only one aspect of calcium insufficiency. Other aspects include inefficient absorption and excessive or obligatory losses, neither of which is readily measurable in clinical practice.

Women with low 25(OH)D levels are unlikely to absorb calcium optimally.[98] Given this inference that low serum vitamin D levels are linked to calcium deficiency, laboratory tests for vitamin D are being used more often in lieu of specific tests for calcium deficiency. When investigating vitamin D status, measurement of 25(OH)D is most useful, whereas measurement of the active form (1,25-dihydroxyvitamin D) is of little value. As part of a workup for osteoporosis, the 25(OH)D level should be determined.

Currently, there is no worldwide consensus on criteria for acceptable serum 25(OH)D values. However, there is consensus that 25(OH)D levels below 20 ng/mL indicate vitamin D deficiency and that a level above 30 ng/mL is the median threshold needed to reduce fracture risk.[99] Parathyroid hormone concentration tends to be inversely correlated with 25(OH)D status. It has also been observed that if a 25(OH)D level is greater than 32 ng/mL, then intestinal absorption of dietary calcium is at its maximum.[98]

CALCIUM SOURCES

There are three categories of calcium sources: foods, calcium-fortified foods, and supplements.

Foods and fortified foods

Dietary sources are the preferred means of obtaining adequate calcium intake because there are other essential nutrients found in high-calcium foods. For most US residents, dairy products (eg, milk, cheese, yogurt, ice cream) are the major contributors of dietary calcium, providing approximately 70% of the total calcium intake of postmenopausal women aged 60 years and older.[100] Dairy products offer the benefits of high calcium content, high calcium bioavailability, and relatively low cost. Reduced-fat or low-fat products contain at least as much calcium per serving as high-fat dairy products (Table 2), and they offer an alternative for women concerned about body weight and lipid profiles.

Nondairy food sources of calcium include leafy green vegetables, a few types of nuts (eg, almonds), and some beans; however, the content is less concentrated than in dairy products, and the calcium in some foods (eg, spinach) is not well absorbed. Other foods containing high levels of calcium include canned salmon and sardines, but only if eaten with bones.

Many calcium-fortified foods are available, including orange and other fruit juices, cereals, bread, breakfast/nutrition bars, and selected soy products (which, if liquid, must be shaken to redistribute the calcium settled at the bottom of the container). Although some of these foods have been shown to exhibit good bioavailability for their added calcium, most have not been formally tested.

An estimated 25% of the US population and 70% of the world's population exhibit some degree of lactase nonpersistence (ie, inability to metabolize

TABLE 2. *Calcium content of foods*

Food	Serving size	Approximate calcium per serving (mg)
Milk		
Whole or skim	1 cup (8 oz)	290-315
Chocolate, whole, low-fat	1 cup	280-285
Powdered nonfat	1 tsp	50
Ice cream, soft, hardened	½ cup	90-100
Cheese		
American	1 oz	175
Cheddar	1 oz	200
Cottage	½ cup	70
Cream	2 tbsp	20-40
Mozzarella, part-skim	1 oz	210
Parmesan	1 tbsp	70
Ricotta, part-skim	4 oz	335
Yogurt[a]		
Whole-milk, plain	1 cup	295
Low-fat, plain, fruit	1 cup	340-450
Frozen, flavored	1 cup	160-240
Fish, shellfish		
Sardines in oil (with bones)	3 oz	370
Salmon, canned (with bones)	3 oz	170-210
Vegetables, nuts		
Almonds, dry roasted	¼ cup	100
Beans, kidney	1 cup	50
Beans, baked, canned	1 cup	130
Beans, refried, canned	1 cup	190
Bok choy, raw	1 cup	160-250
Broccoli, fresh, cooked	1 cup	120-180
Cabbage, fresh, cooked	1 cup	50
Collards, fresh, cooked	1 cup	300-350
Figs, dried	10 figs	270
Soybeans, cooked	1 cup	175
Soybean curd (tofu)[b]	4 oz	30-155
Turnip greens	1 cup	200
Fortified foods[c]		
Calcium-fortified milk	1 cup	500
Calcium-fortified soy milk product	1 cup	80-300
Cereal with added calcium (without milk)	1 cup	100-1,000
Fruit juice with added calcium	1 cup	225-300
Breakfast bars	1 bar	200-500

[a]Yogurt varies in serving size, fat, and calcium content. Check labels for calcium content and calories.
[b]The calcium content of tofu processed with calcium salts can be as much as 300 mg/4 oz. The label should provide specific information.
[c]Unfortified breads and cereals are relatively low sources of calcium but still contribute substantially to calcium intake because these foods constitute a large part of the diet.
Adapted from USDA National Nutrient Database for Standard Reference, 2005.[101]

lactose in dairy products),[102] which in some individuals may produce diarrhea, bloating, and gas when dairy products are consumed (ie, lactose intolerance). Lactase nonpersistence is more common among people of Asian, African, and South American descent. Other GI problems (eg, celiac disease, irritable bowel syndrome, Crohn's disease, GI infection), or their treatment with intestinal antibiotics, can cause lactose intolerance, either temporary or chronic.[103]

Many women with lactase nonpersistence can tolerate milk normally if they have never stopped drinking it since youth or if they increase intake gradually, thereby conditioning their intestinal flora to produce lactase.[104] Those few who remain intolerant may substitute yogurt and lactase-treated milk. True milk intolerance or allergy is rare. Calcium supplements or calcium-fortified foods should be considered if dietary preferences or lactase nonpersistence restricts consumption of dairy foods.

Supplements

Calcium supplements offer a convenient alternative to women unable to consume enough calcium from diet alone. They vary in type of calcium salt (and, hence, calcium content), formulation, price, and, to some extent, absorbability.

The two most often used calcium supplement types contain either calcium carbonate or calcium citrate, but a wide variety of calcium salts is found in calcium supplements, including calcium acetate, calcium citrate malate, calcium gluconate, calcium lactate, calcium lactogluconate, and calcium phosphate (a collective term that describes supplements consisting of either the monobasic, dibasic, or tribasic phosphate salt of calcium). Calcium is also available in bone meal (basically calcium phosphate) as well as dolomite or oyster shell (both basically calcium carbonate) supplements. In the past, some of these have contained toxic contaminants, especially lead[105]; however, a more recent analysis of the most commonly used brands did not reveal toxic levels of contaminants.[106]

Recommended calcium levels (either reference values or dietary recommended intakes) refer to "elemental calcium." Different calcium salts may contain different percentages of elemental calcium. Calcium carbonate provides the highest percentage (40%); thus, 1,250 mg of calcium carbonate provides 500 mg of elemental calcium. Calcium citrate (tetrahydrated form) contains 21% elemental calcium; 2,385 mg of calcium citrate provides 500 mg of elemental calcium. All marketed calcium supplements list the elemental calcium content.

Various formulations of calcium supplements are available, including oral tablets, chewable tablets, dissolvable oral tablets, and liquid. Another formulation

for individuals with difficulty swallowing is an effervescent calcium supplement, typically calcium carbonate combined with materials such as citric acid that facilitate dissolving in water or orange juice.

Calcium supplements also vary by price. Calcium carbonate products are typically less expensive than most other types of calcium supplements.

Absorbability is also a concern. Contrary to popular belief, calcium carbonate and calcium citrate are equally well absorbed if taken with meals, the normal way of assimilating any nutrient.[107] Calcium citrate malate is highly bioavailable, as are supplements containing calcium that is chelated to an amino acid (eg, bisglycinocalcium), but both of these lesser used supplements are typically more expensive than calcium carbonate. Studies comparing various commonly used calcium compounds found few differences in their bioavailability when supplements were taken with food.[108] To maximize absorption, calcium supplements should be taken in doses of 500 mg elemental calcium or less throughout the day and usually with meals. Consumption of calcium supplements with meals can also minimize the potential for rare GI side effects.

Pharmaceutical formulation of the supplement (ie, the other ingredients in the tablet and how they are packed together) actually makes more of a difference in absorbability than does the chemical nature of the calcium salt. Name-brand supplements are more predictably reliable than store-brand products.

MANAGEMENT

It is clear that adequate calcium intake has implications that encompass a woman's overall health. Based on the available evidence, a strong statement can be made regarding the importance of ensuring adequate calcium intake in all women, particularly peri- or postmenopausal women.

According to the US Surgeon General's report on bone health in the United States,[109] calcium consumption is a major public health concern because average consumption is far below the amount recommended for optimal bone health. Furthermore, a study of trends in osteoporosis management[110] found that many US healthcare providers do not recommend calcium supplements as part of pharmacotherapy. During the 1988 to 2003 study period, the percentage of prescription osteoporosis medication regimens that included calcium dropped from 39% to 24%.

Encouraging adequate intake of calcium should be a goal of all healthcare management plans for peri- and postmenopausal women. This begins with an assessment of a woman's estimated daily calcium intake to determine her individual needs.

When it is necessary to increase calcium intake, most experts recommend consuming 500 mg of calcium or less at one time to maximize absorption. A simple way to consume adequate amounts of calcium is to include foods containing calcium at each meal or snack. It should be stressed that food sources are the preferred way to ensure enough calcium because calcium-rich foods provide a variety of important nutrients that may not be present in supplements. If the woman is allergic to milk or follows a strict vegetarian diet, she can obtain enough calcium by choosing nondairy beverages with calcium added, although the fortification can be inconsistent, or by eating calcium-rich nondairy foods.

Many women will have questions and concerns regarding advice to modify their diets. For example, some women are concerned that they might consume too much calcium. They can be assured that it is considered safe for all healthy individuals to consume up to 2,500 mg/day of calcium from foods and/or supplements. The adverse effects of chronic calcium supplement intake in excess of 2,500 mg/day may include high blood calcium levels, renal function complications, and renal calculi formation. There are no recorded cases of calcium intoxication from food.

If a woman is unable to or chooses not to modify her dietary regimen, a calcium supplement should be recommended to fill the gap necessary to achieve the IOM recommended intake for calcium. It is important for women to determine the calcium content of supplements by checking the serving size to determine how many tablets or capsules provide the specified amount of elemental calcium.

A calcium supplement should be taken with a meal to enhance bioavailability (particularly with calcium carbonate) and as an aid to adherence.

The simplest message to women regarding calcium intake is that consuming a well-balanced diet that includes adequate calcium will help them achieve and maintain optimal bone health. Often, supplementing the diet is needed to achieve desired intake of these nutrients. For most healthy individuals, additional vitamins or minerals (such as magnesium, boron, vitamin K, selenium, or others) in the form of supplements are not required for healthy bones. In fact, many of these nutrients will be present in a wholesome diet that includes five or more servings of fruits and vegetables per day.

It is important to remind women of the importance of adequate vitamin D. There are only a few naturally occurring food sources of vitamin D, although some foods are fortified with vitamin D. Vitamin D can also be obtained from multivitamins (most contain 400 IU), in combination with some calcium supplements, or alone as a separate vitamin D supplement. Clinicians should be alert for women at higher risk of vitamin D deficiency, including individuals who are older than age 70, are homebound, have malabsorption syndromes, have liver or kidney disease, are obese, have an increase in skin pigmentation, or always wear sun protection outdoors.

Encouraging adherence to the treatment plan is perhaps the most important follow-up measure for clinicians. In counseling women on how to incorporate more calcium and vitamin D into their diet, there are behavior modification methods that have been effective. In separate studies, providing an estimation of a person's individual calcium intake helped to modify future calcium intake.[111-113] In one randomized trial,[113] providing women with an informational brochure on assessing dietary calcium intake effectively improved their estimates of calcium intake. Other studies have shown that increasing a woman's knowledge of the osteoporosis-calcium link is important for her to make a change in diet.[71,114] Viewing a video in the office has also been found to improve knowledge and to increase calcium and vitamin D intake in almost 25% of participants.[115] Educational programs that increase knowledge and self-efficacy of bone health behaviors and are accompanied by a personalized risk assessment, such as BMD testing or dietary calcium intake measurements, appear to motivate the most significant changes in calcium intake.[114,116] Repeated counseling has increased the calcium intake of women following an osteoporotic fracture.[117] Educational materials should be tailored to the specific audience regarding gender, age, race/ethnicity, and educational level.

Using a multidisciplinary approach that includes other health professionals (eg, nutritionists, nurses, dietitians) to help educate and reinforce bone-healthy messages can serve as a valuable, cost-effective means to improve calcium intake and to provide education about nutrition strategies for optimizing bone health.

SUMMARY

- Adequate calcium intake (in the presence of adequate vitamin D status) has been shown to reduce bone loss in peri- and postmenopausal women and reduce fractures in postmenopausal women older than age 60 with low calcium intakes. Calcium strongly enhances the bone-protective effects of ET/EPT in postmenopausal women. Adequate calcium is considered a key component of any treatment regimen for patients with established osteoporosis.
- A woman's calcium requirement increases at menopause (or whenever estrogen is lost). This is because calcium absorption efficiency and renal conservation are both estrogen dependent, and both deteriorate in the estrogen-deprived state.
- The target calcium intake for most postmenopausal women is 1,200 mg/day.
- Adequate vitamin D status, defined as serum 25(OH)D of 30 ng/mL or more, is required to achieve the nutritional benefits of calcium. This level is usually achieved with a daily oral intake of at least 400 to 600 IU.
- Foods should be the primary source of calcium intake. Dairy products are among the best sources of calcium based on their calcium content, absorption, content of other essential nutrients, and low cost relative to total nutritional value. Approximately 3 cups of dairy products daily provide the 1,200-mg target.
- Supplements and fortified foods are an alternative source for women not able to consume enough dietary calcium to reach the recommended daily intake. Calcium supplements are best taken with meals and in divided doses (typically 500 mg or less at one time) to maximize absorption. Because calcium bioavailability varies from product to product, name-brand supplements that have been tested to demonstrate consistent bioavailability are recommended.
- There are no reported cases of calcium intoxication from food sources, and cases associated with supplements are rare.
- Calcium, like most nutrients, has beneficial effects in many systems. In addition to protection of bone mass and reduction of excessive bone remodeling, calcium is associated with small reductions in the risk of colorectal cancer, hypertension, renal calculi, and obesity.
- Based on the generally consistent animal and human data, a case can be made that calcium intake greater than or equal to the current recommended calcium intake provides some chemoprotective properties against colorectal cancer.

- Trials have demonstrated that a calcium intake of at least 1,200 mg/day is associated with a beneficial effect on systolic blood pressure. However, further research is needed.
- Calcium intake of up to 1,500 mg/day has been found to reduce the risk of developing renal calculi, but one study has found a 17% increased risk at 2,150 mg/day. For women at high risk of developing renal calculi, foods may be the best sources of calcium. If calcium supplementation is needed, each dose must not exceed the age-appropriate allowance and should be taken with a large glass of water, as avoiding dehydration is an important practice for these patients.
- Although limited data suggest a statistically strong inverse correlation between the risk of obesity and dietary calcium intake, available studies indicate that calcium intake explains only a small portion of the variability in body weight in postmenopausal women. Nevertheless, ensuring an adequate calcium intake for skeletal purposes may confer small weight-control benefits as well.
- Because no accurate test to determine calcium deficiency exists, clinicians should focus instead on encouraging a woman to consume enough calcium to meet the recommended levels through diet and, when necessary, calcium supplements. Laboratory tests for serum vitamin D should be for 25(OH)D, which are useful in identifying women who are vitamin D deficient and therefore likely to be calcium deficient even when ingesting adequate amounts of calcium from diet and supplements.
- Average calcium consumption is far below the amount recommended for optimal bone health, and many US healthcare providers do not recommend calcium supplements as part of pharmacotherapy. Encouraging adequate intake of calcium should be a goal of all healthcare management of peri- and postmenopausal women.

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