Calcium Metabolism and Correcting Calcium Deficiencies

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KEYWORDS

• Calcium metabolism • Calcium absorption • Vitamin D • Osteoporosis
• Calcium requirements

KEY POINTS

- Calcium is the most abundant cation in the human body.
- Calcium contributes to the strength and rigidity of bone.
- Calcium absorption occurs through a process both active and passive, influenced by many factors.
- Large meta-analyses demonstrate a reduction in hip fractures with higher calcium and vitamin D ingestion, most consistently in a higher-risk population.
- It is difficult to separate out the individual contributions of calcium and vitamin D in these studies.
- The importance of concomitant protein and phosphorus ingestion may be underestimated.
- Dietary calcium may be the most reasonable approach to satisfy the body's calcium needs.

INTRODUCTION AND HISTORICAL PERSPECTIVE

Currently accepted tenets of biological theory suggest that current human dietary requirements have evolved over 200 million years, during the first 150 million years of which our ancestors were largely insectivorous and thus consumed a diet higher in calcium content than that of modern man. The average insect calcium content is 124 mg per 100 g portion, and thus much higher than wild game at 14.2 mg per 100 g. Approximately 50 million years ago, our ancestors were omnivorous and consumed a large amount of wild plants (133 mg calcium/100 g portion) in addition to wild game. During this late Paleolithic period, dietary calcium content has been calculated as 1798.9 mg/d.[1] Dietary calcium consumption during the Mesolithic and Neolithic periods decreased substantially to approximately 30% to 50% of the stone-age diet, despite there having been very little change in the genetic makeup

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of humans during this time period.[2] Human skeletal remains from the Mesolithic period revealed cortical thickness to be on average 17% greater than those of current whites and blacks.[3] Whether this was due to the increased calcium intake, more physical activity, and/or other dietary changes (more protein, micronutrients, and fiber with less sodium and fat) during the Mesolithic period compared with today is not clear.[1]

Because calcium is a threshold nutrient, would achieving a given threshold for each person be a reasonable goal, and should that level consider the higher calcium intake of our evolutionary ancestors? There is no consensus as to whether exceeding a "threshold" intake may be helpful or harmful to bone or other cellular systems in which calcium plays a significant role. Because fewer than 100 generations have elapsed since the time of calcium surfeit to the present, it is unlikely that adaptive mechanisms for the conservation of calcium would have evolved, thus generating an even more complex dilemma.[4] Modern man is living longer and reproducing successfully, suggesting some evolutionary success. Conversely, our longer life span (and longer postmenopausal interval) may play a major role in the apparent increase in osteoporosis we now see, rather than attributing it anthropologically to a lower calcium intake.

Without doubt we have come a long way in our understanding of the mechanisms of calcium absorption and its effects on bone. Despite this knowledge, a clear demonstration of its therapeutic efficacy in fracture prevention, independent of vitamin D, is lacking. Current evidence warns of the potential toxicity of excess calcium supplementation; however, well-designed clinical trials are necessary to validate these observations and also to define appropriate calcium dosing.[5–7]

DISTRIBUTION

Calcium is the most abundant cation in the human body, approximately 1000 g, of which 99% exists in the mineral phase of bone as hydroxyapatite crystals. One percent of the remaining calcium is contained in the extracellular fluid, blood, and soft tissues. The deposition of calcium into the organic matrix of bone contributes to the rigidity and strength of bone. Bone also functions as a reservoir of calcium, which is readily available for its roles in multiple physiologic and biochemical processes including neuromuscular functioning, coagulation, cell permeability, enzyme activation, hormone secretion and functioning.[8] The calcium required for the latter nonosseous functions is satisfied largely by intracellular stores of the mineral. Because only 5 g of bone contains more calcium than the entire extracellular fluid space of an adult, it would be inconceivable for the requirement of all of the body's cellular functions to ever deplete the bone's calcium reservoir.[4] Nonetheless, protracted periods of inadequate calcium intake require enhanced resorption of bone to satisfy rapidly changing extracellular calcium needs, likely resulting in the loss of key structural elements that could weaken bone. Although nutritional calcium intake may contribute to the mass of the remaining structural elements, there are no data suggesting the lost elements can be replaced.

ABSORPTION

Overview

The ingestion of calcium is the only route by which humans can acquire this important ion needed to serve our cellular functions. Calcium absorption is a multifaceted process, influenced by a large number of factors (**Table 1**) including age, genetics, dietary intake, disease states, race, and medications. Seasonal variations have also been