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STUDIES ON DIETARY CALCIUM – STRATEGIES TO OPTIMIZE INTAKE

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ABSTRACT

Calcium is an essential nutrient required for numerous biological functions. Studies have demonstrated an association between low calcium intake and chronic diseases, such as osteoporosis, colon cancer, hypertension, and obesity. However, most Brazilians do not meet the adequate intake for calcium. This review focuses on the endogenous (age, hormonal state) and exogenous (phytate, oxalate, sodium, bioactive compounds and vitamin D) factors that can influence calcium absorption. The main methods used for evaluating calcium absorption and bioavailability.

KEY WORDS : *calcium, absorption, bioavailability, intake, calcium salts.*

INTRODUCTION

The need for an adequate calcium intake has been the focus of a number of studies.1-3 Calcium is an essential nutrient needed in biological functions such as muscular contraction, mitosis, blood coagulation, nervous or synaptic impulse transmission, and structural support of the skeleton.4 Many studies have demonstrated that calcium intake prevents diseases like osteoporosis, hypertension, obesity, and colon cancer.1,3

Some studies try to explain the relation between the intake of calcium and chronic diseases. Zemel (2001) argues that the increase of calcium intake attenuates the sensitivity to salt and reduces the blood pressure, mainly in hypertensive individuals.5 The relation between calcium and obesity is explained by $1,25(OH)_2D_3$, which stimulates the inflow of calcium inside the adipocyte resulting in the increase of lipogenesis and inhibition of lipolysis. It is believed that the production of $1,25(OH)_2D_3$ varies inversely with the calcium intake, therefore the increase in calcium intake would lead to a reduction in fat mass.5 When it comes to cancer, evidences indicate that non-absorbed fatty acids and bile irritate the mucosa enabling the proliferation of cancerous cells. In this context, calcium can form complexes with fatty acids as well as with the bile, causing them to be harmless.6

The recommendations for calcium intake from several countries is shown in Table 1. Calcium requirements vary throughout an individual's life, with greater needs during the periods of rapid growth in childhood and adolescence (1,300 mg/day). In these periods, bone growth and increase of mineral deposit occur, until the peak of the bone mass is reached around the third decade of life. On adult age, the daily need of calcium is around 1,000 mg. In periods when intestinal absorption finds itself decreased or the bone reabsorption rate is increased, such as the menopause, the need of calcium raises once again (1,200 to 1,300 mg/day).7

Table 1. Recommendation for calcium intake in several countries (mg/day)

Country/ organization	Babies	Children	Adolescents		Adults		Elderly
			M	F	M	F	
Australia	300 550	700 800	1,000 1,200	800 1,000	800	800	800
European Community	400	450 550	1,000	800	700	700	700
FAO/WHO	300 400	600 700	1,300	1,300	1,000	1,000	1,300
Mexico	450 600	800	1,200	1,200	800	800	800
Venezuela	210 270	500 800	1,300	1,300	1,000	1,000	1,200
United Kingdon	525	350 550	1,000	1,000	700	700	700
Food Nutrition Board	210 270	500 800	1,300	1,300	1,000 1,200	1,000 1,200	1,200
Nordic Countries	360 540	600 700	900	900	800	800	800

M=male; F= female; FAO/WHO= Food and Agriculture Organization of the United Nations/ World Health Organization; Adapted from reference 7

According to food consumption data obtained by the BRAZOS (Brazilian Osteoporosis Study) research of 2007, 90% of the interviewed reached 1/3 (400 mg) of the calcium intake preconized by the *Dietary Reference Intakes* (DRI). The use of a calcium supplement was referred by only 6% of the individuals.8

Considering that large proportion of the Brazilian population fail to achieve the recommended calcium intake, a better understanding of the absorption, bioavailability and the factors which can influence them, as well as how to optimize the intake of this nutrient through food sources and supplements, it is important to develop strategies to increase calcium intake.

CALCIUM BIOAVAILABILITY AND ABSORPTION

Calcium is absorbed by the gastrointestinal tract via active transport, which occurs predominantly in the duodenum and the proximal jejunum, and passive diffusion, located mainly in the distal jejunum and the ileum.1,9

The active component is saturatable, stimulated by 1,25(OH)D_3 (calcitriol), regulated by dietary intake and by organ system needs. Calcitriol influences the active transport, increasing the permeability of the membrane, regulating the calcium migration through the intestinal cells, and increasing the level of calbindin (calcium transporting protein – CaBP).1,9 The fraction of absorbed calcium increases as its intake decreases. It is a partial adaptation to calcium restriction, resulting in the increase of the active transport mediated by calcitriol. Therefore, the active transport is characterized as the main mechanism of calcium absorption when the intake of this nutrient is low.10

As calcium intake increases (> 500 mg/day), passive diffusion presents a greater absorption of calcium.10 As a result, the passive process can become the predominant mechanism of absorption of great dosages of calcium, once the active transport is already saturated.1,9 Dietary nutrients such as milk proteins and lactose, which increase the solubility and osmolarity of calcium in the ileum, tend to stimulate the passive diffusion. On the other hand, other factors (phosphates, oxalates e phytates) turn insoluble calcium into neutral pH, causing passive absorption in the ileum to be more difficult.1

According to Bronner (1993), bioavailability is characterized by a sequence of metabolic events that include digestibility, solubility, absorption, retention, and use by the organ system, enzymatic transformation, secretion, and excretion.9

Calcium bioavailability, besides being influenced by exogenous components which interfere in its absorption and excretion, is also controlled by endogenous factors like age, physiological conditions and hormonal regulation.

Exogenous Factors that Interfere in Calcium Absorption and Bioavailability

Some food constituents, such as phytates (found in cereals and seeds), oxalates (spinach and nuts), and tannins (tea), can form insoluble complexes reducing calcium absorption. However, these components seem to affect the absorption only when the diet is unbalanced.1

Another factor that can influence calcium bioavailability is sodium, once the elevated intake of this nutrient results in an increase of renal excretion of calcium.11 According to predictive equations, it is believed that, to each 2 grams of sodium intake, the excretion of urinary calcium increases an average of 30 to 40 milligrams.1 However, if the sodium intake is below 2,400 mg/day, there won't be a negative impact over bone health.11

Nowadays, many studies demonstrate the benefic effects of bioactive compounds in different biological processes, including the increase of calcium absorption. The nondigestible oligosaccharides (inulin, fructans etc.) are resistant to hydrolysis of the food enzymes. Once they are not hydrolyzed and absorbed in the stomach and small intestine, these components suffer partial or total fermentation when they arrive to the large intestine.12-14 Fermentation leads to the production of short chain fatty acids, which results in the acidification of the intestine and consequent stimulation of calcium absorption.12,14

Vitamin D deficiency directly affects the absorption of calcium. Vitamin D3 (colecalciferol) is produced through cutaneous synthesis, and solar exposition is responsible for 80% to 90% of the stocks of vitamin D.15 Vitamin D can also be acquired by food intake sources sources of this nutrient, in the forms of vitamin D_2 (ergocolecalciferol) and vitamin D_3. Next, vitamin D, from both diet and solar exposition, has to pass through two hydroxylations to become functional in its primary biological part in the homeostasis of calcium and phosphorus. The first hydroxylation occurs in the liver, where it is metabolized into $25(OH)D_3$, which can be stored or released into circulation. When the physiological demand of calcium increases, circulating $25(OH)D_3$ is hydroxylized in the renal tubules to its active form $1,25\ (OH)_2D_3$.16,17 Therefore, the low intake of food sources of vitamin D and insufficient sun exposition can interfere in the absorption of calcium.

Endogenous Factors that Interfere in Calcium Absorption and Bioavailability

The efficiency of calcium absorption is influenced by age, genetics and hormonal state among other factors.18

Growth hormone (GH) can promote calcium absorption indirectly activating the renal 1α hydroxylase and elevating the serum concentration of $1,25(OH)_2D_3$.19 It is an important mechanism during the periods of rapid growth, in which the gain of bone mass is really fast (pubertal growth spurt).19,20 During gestation and lactation, the physiological demand increases in 200 to 300 mg of calcium per day.21 As a result, an increase of serum concentration of $1,25(OH)_2D_3$ occurs and, consequently, of calcium absorption, as a compensatory mechanism to the increase of the pregnant bone remodeling.22 During lactation, the absorption of calcium is not altered; however, there is a reduction in the excretion.19,22

Calcium absorption can be harmed during menopause due to the reduction of estrogen.19 There are evidences that this hormone presents a direct effect in calcium absorption.23 According to Gennari (1990), estrogen preserves the intestinal response to $1,25(OH)_2D_3$.24 Some studies suggest that its deficiency can reduce the number of vitamin D receptors (VDR).25,26 On the other hand, reduced levels of estrogen decrease the renal excretion of calcium.19

Additionally, calcium absorption declines with age and especially after 75 years old.27 Apparently this reduction is related to the sufficiency state of vitamin D which can be compromised due to the reduction of intestinal absorption of vitamin D, as well as the cutaneous synthesis and hepatic and renal hydroxylation of vitamin D.18,27,28

Methods Used to Evaluate Calcium Bioavailability

Calcium absorption, deriving from diet, fortified food or dietetic supplement, has been studied by various methods. Considering that calcium bioavailability is altered by diverse factors, the understanding of the available methods is a crucial factor. According to Heaney (1991), stating that a product is superior based on one of those methods requires the understanding of what is being measured and which are its requirements and its limitations.29 It is important to notice that there is not an ideal method to evaluate calcium bioavailability – the choosing of the method will depend on the goal of the study, time and available resources.

Metabolic Balance

It estimates the difference between calcium oral intake and fecal excretion.29 Therefore, it refers to the intestinal balance and not to the whole body balance.31 The metabolic balance is an imprecise, expensive, laborious and slow method.1,29,30 The validity of the obtained results depends on the accuracy of the parameters used to evaluate intake and excretion. Furthermore, this method supplies more satisfactory results in animal models than in humans.31 The main disadvantage is due to the fact that this method comprehends the calcium which was not absorbed in the gastrointestinal tract and the calcium which has already been absorbed and is resecreted with the gastric juice, also known as endogenous calcium fecal loss.29,32

Stable and Radioactive Isotopes

A stable calcium isotope is added to the food or supplement which will be tested. We start from the premise that the isotope is completely swapped with the intrinsic calcium of the food or supplement and it is absorbed and metabolized in the same proportions.30,33

The most accurate methods are: direct measurement of the radioisotope calcium retention of the whole body, which presents high precision and requires little effort from the participants; administration of two isotopes, an oral one and a parenteral one, in which calcium absorption is estimated from urine and blood. This method showed to be highly precise and reproducible.29,30,33

However, the main limitation is the marking of the isotope, which should be preferentially intrinsic. In addition, all atoms and molecules from the tested food should have the same probability of containing the isotope.30 The marking can also be performed extrinsically, but food such as vegetables, which contain phytates and oxalates, can't make the swap with the isotopes.1 Another limitation is the ionizing radiation, which should not be used in children, pregnants and lactants; in these cases, the stable isotope is the most indicated.33 The method with isotopes reveals the absolute quantity absorbed, the gross absorption, i.e., the unidirectional flow out of the lumen and into the circulation.30

Serum Calcium

The serum concentration of calcium is measured after the intake of a high dosage of such nutrient. So, the results reflect the instantaneous absorption. However, the observed increment tends to be small, once the homeostasis of calcium prevents from great changes. Therefore, this method presents a low sensitivity.30

Optimizing Calcium Intake

Calcium intake can be optimized by three ways: changes in alimentary behaviors, including the increase of food naturally rich in calcium intake; consumption of food fortified with calcium; or with the using of supplements.42

The priority should be given to adequate the calcium ingestion with food.4 Nevertheless, it is a challenge to make real changes in alimentary behavior in large populations. Some strategies can be taken, like increasing the information about the importance of calcium intake for the health as well as about the main calcium food sources (Table 2).4,42

To most people the main calcium food source is milk and dairy. In the United States it represents 72% of the total calcium ingested.43 The ingestion of four glasses (240 mL) of milk is enough to reach the recommendations for individuals above 50 years old. Yogurt and cheese are also good sources of calcium. Reduced-fat foods are usually recommended, and it is important to notice that there is little difference in the amount of calcium when compared to whole ones, the skimmed presenting a bit larger quantity.44 Dark green vegetables such as broccoli and cabbage are alternative calcium sources; however, the quantity and bioavailability of calcium in these foods are smaller when compared to milk and dairy.31

Parents present an important influence in children concerning choices and intake of food rich in calcium, and for this reason they should give the example of healthy alimentary habits.4 A study from Fisher *et al*. (2001) indicated that the intake of milk by mothers was a predictor of milk ingestion in their daughters.45

Considering the increasing tendency of eating away from home, it is important to develop strategies which help the consumers to make healthier choices, especially in calcium rich food.4

Table 2 Selected food sources of calcium – by consumed quantity46

Food	Portion	Weight (g)	Calcium (mg)
Milk enriched with calcium*	1 cup	240	384
Fresh cheese	2 slices	56	324
Skimmed milk	1 cup	240	322
Whole milk	1 cup	240	295
Baked sardines	2 units	50	219
Boiled spinach	1 cup	190	213
Mozzarella cheese*	1 slice	30	140
Yogurt with fruits	1 small pot	130	130
Boiled Brazilian pink beans	1 ½ serving spoon	160	109
Cream cheese	1 tablespoon	30	78
Sweet lime orange	1 unit	180	56
Tofu	2 slices	56	45
Cheese bread	2 average units	40	41
Soy-based beverage	1 cup	240	40

Adapted: Brazilian Table of Food Composition – TACO Version II, 2nd edition, 2006

* Information obtained by the manufacturers.

The messages on nutrition education aimed towards children and their parents should encourage the limitation of soda intake. Policies of restricting this beverage in schools should also be implemented, having the directives for the Promotion of Healthy Alimentation in schools and the directives of the National Program of Scholastic Alimentation as presupposition.47,48

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