Calcium Intake Trends and Health Consequences from Childhood through Adulthood

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Calcium Intake Trends and Health Consequences from Childhood through Adulthood

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Key words: children’s diets, calcium, dairy products, school meal participation, public policy

Issues involving low calcium intake and dairy product consumption are currently the focus of much debate and discussion at both the scientific and lay community levels. In this review, we examine the following major areas of interest: (1) the role of calcium intake and dairy product consumption in chronic diseases, (2) nutritional qualities of milk and other dairy products, (3) trends in calcium intake and dairy product consumption, (4) current status of calcium intakes and dairy product consumption in children, (5) tracking of calcium intake and dairy product consumption, (6) the impact of school meal participation on calcium intake and dairy product consumption, (7) concerns related to calcium-fortified foods and beverages and (8) factors influencing children’s milk consumption. To date, the findings indicate that calcium intake and dairy product consumption have beneficial roles in a variety of chronic diseases; dairy products provide an abundant source of vitamins and minerals; calcium intakes of children have increased over time, yet intakes are not meeting the current adequate intake (AI) calcium recommendations; dairy consumption has decreased, and soft drink consumption and, possibly, consumption of calcium-fortified products have increased; consumption of dairy products have a positive nutritional impact on diets of children, particularly from school meals, and there are many factors which influence children’s milk consumption, all of which need to be considered in our efforts to promote adequate calcium intakes by children. Based on this review, areas that need immediate attention and future research imperatives are summarized in an effort to further our understanding on what we already know and what we need to know to promote healthier eating habits early in life.

Key teaching points:

- Calcium intake and dairy products play an important role in prevention of several chronic diseases.
- Children’s dietary intakes fall short of current adequate intake calcium recommendations.
- Consumption of dairy products in school meals has a positive nutritional impact on diets of children.
- Children’s milk consumption is influenced by a number of factors which need to be addressed in our promotion efforts.

Calcium Intake, Dairy Product Consumption and Chronic Disease

During the past 25 years, research has demonstrated the potentially beneficial roles for calcium and/or dairy foods with regard to a variety of disorders. These disorders include osteoporosis [1–7], hypertension [8–17], colon cancer [18–23], breast cancer [23,24], kidney stones [25–27], polycystic ovary syndrome [28], ovarian cancer [29], premenstrual syndrome [30,31], insulin resistance syndrome [32], obesity [33–37] and lead poisoning [38–42].

Osteoporosis. In 1997, the National Osteoporosis Foundation published its first report on the prevalence of osteoporosis [43]. Osteoporosis and low bone mass are currently perceived major public health threats for an estimated 44 million U.S. women and men over the age of 50. It is projected that by the year 2010, an estimated 52 million women and men in the same
Calcium intake influences the risk of osteoporosis by affecting genetically determined peak bone mass, a state that is reached by age 30 or earlier [7,45,46–52]. Much of the genetically determined peak bone mass is accumulated during the first two decades of life; thus, childhood and adolescence are the critical times to optimize peak bone mass [50,53]. During adolescence, 45% or more of the body’s total skeletal mass is formed [50]. Children’s bodies need sufficient calcium to support an accelerated growth spurt during the preteen and teenage years. In addition, during this time period, children are laying the foundations of their peak bone mass, which will have a tremendous impact on their bone density during their older years. Young girls whose dietary calcium intake was provided primarily by dairy products had an increased rate of bone mineralization [54]. Sandler et al. [55] found that females 49 to 66 years of age who reported drinking milk with every meal during their childhood and adolescent years had significantly higher bone densities than females who reported lower intakes. It is therefore understandable that prevention begins in childhood and adolescence during growth and skeletal development. Increased calcium intake is not the only panacea for osteoporosis prevention. There are several other nutritional and lifestyle factors, such as the amount of protein in the diet, energy intake, body weight, alcohol consumption, Vitamin D intake, smoking, and exercise, which have been shown to play a potential role in affecting bone mass. However, the scientific reproducible evidence showing a connection between these factors and bone mass are not as convincing as the calcium connection. The consensus from several organizations [2,3,53,56] is that low calcium intake is a major player in the development of osteoporosis and the incorporation of dairy products into one’s eating lifestyle is one way to not only obtain adequate calcium but other essential vitamins and minerals.

Hypertension. Hypertension is present in an estimated 43 million Americans in the United States [53]. Twenty-three percent of Americans 20 to 74 years of age were diagnosed with hypertension from 1988 to 1994. It is more prevalent in African-Americans (AA); more than three-quarters of AA women 75 years of age and over have been diagnosed with hypertension [53].

After nearly 20 years of debate, there is now sufficient, reproducible evidence supporting a beneficial role for calcium or calcium-rich dairy foods in blood pressure regulation [8–17]. In the DASH (Dietary Approaches to Stop Hypertension) study [57,58] 549 people consumed a combination diet rich in fruits and vegetables and low-fat dairy products (~3 servings/day). The combination diet reduced their systolic blood pressure 5.5 mm Hg and diastolic blood pressure 3.0 mm Hg more than the control diet. Among those participants diagnosed with hypertension, the combination diet reduced systolic blood pressure by 11.4 mm Hg and diastolic pressure by 5.5 mm Hg more than the control diet [57,59]. African-Americans, who are at a disproportionately higher risk for hypertension, had twice the blood pressure lowering effect relative to Caucasians and none dropped out due to intolerance to dairy products [60]. These results from the initial DASH trial [57] were replicated in DASH sodium [61]. Research indicates that a calcium intake at the recommended level and a combination diet rich in fruits and vegetables and low-fat dairy products may be helpful in preventing and treating moderate hypertension [62].

Obesity. The prevalence of obesity in the United States and other developed countries has reached epidemic proportions [63–66]. Between 1980 and 1990, the prevalence of obesity in U.S. adults increased 40% [67] and continues to increase [65]. About 65% of American adults are now considered either overweight or obese [65]. Obesity contributes to five of the ten leading causes of death in the United States. It increases the risk for heart disease, stroke, high blood pressure, certain types of cancer, diabetes and many other health problems [68]. Direct and indirect costs associated with obesity exceed $99 billion annually [69,70].

The increasing prevalence of obesity in children parallels that of adults [66]. The prevalence of obesity among children 6 to 11 years of age increased 54% from 1960 to 1994, while prevalence of obesity among adolescents 12 to 17 year of age increased 40% [71] during the same time period. The increase in the prevalence of overweight between 1960 and 1994 was similar to that observed between 1988–1994 and 1999–2000 [66]. Currently, 10.4% of preschool children, 15.3% of school-age children and 15.5% of adolescents are overweight (BMI >95th percentile) [66].

Obesity tracks over time; that is, obese children, particularly obese adolescents, tend to become obese adults [72–74]. Overweight children tend to remain overweight during follow-up periods of up to 20 years [75–77] and, in general, have a 1.5 to twofold increased risk of being overweight as adults. Sixty-two percent of Bogalusa 10-year-olds in the upper quartile for BMI continued to be in the upper quartile when they were young adults. Children’s BMI at age 10 was significantly (p < 0.0001) correlated with BMI when they were young adults (r = 0.66) (data not shown).

Epidemiologic and experimental studies suggest that dairy products may have favorable effects on body weight in children [36,37] and adults [33,35,78,79]. Intracellular calcium has been shown to play a key role in metabolic disorders associated with obesity and insulin resistance [80–82]. Data from studies conducted by Zemel et al. [34] demonstrated that women with the highest calcium (1300 mg/day) and dairy food intake (3+ servings/day) had an 80% lower risk of being in the highest quartile of body fatness. A profound reduction in the odds of being in the highest quartile of adiposity was associated with increases in calcium and dairy product intake. The authors
showed that for any given level of energy intake and expenditure, low dietary intake of calcium favored increased efficiency of energy storage, and higher-calcium diets favored thermogenesis. In a study of adipose cells in transgenic mice [83], high-calcium, medium-dairy and high-dairy diets reduced lipogenesis, stimulated lipolysis and reduced body fat accumulation at equivalent levels of energy intake. Moreover, the dairy diets were more effective than the calcium supplemented diet. Another study of adipose cells from mice demonstrated that a high calcium, medium-dairy and high-dairy diet produced greater weight/fat loss in energy restricted diets compared to energy restriction alone [34]. These findings in animal studies were also shown in preschool children [36,37]; children with higher dairy intakes had lower body fat. These observations suggest that there may be a positive relationship between dietary calcium intake and the regulation of body fat-weight and that calcium intake explains only part of this effect.

In an exercise intervention study [79], higher calcium intakes were associated with weight loss, specifically loss of fat, in women 18 to 31 years of age. In a retrospective analysis of five earlier trials, a placebo-controlled calcium supplementation trial found significantly greater weight loss in elderly women supplemented with 1,200 mg of calcium/day compared to the control group [33]. Two studies have reported the effects of weight reduction diets with and without milk [84,85]. Both studies suggest that a high milk intake increases the effectiveness of a weight reduction program. However, in a multicenter, randomized controlled trial [86], adults assigned to the milk-supplemented group gained slightly more weight (0.6 kg) than the control group, although it was less than predicted, suggesting some compensation for the added energy from milk. Clearly, more research is needed to confirm the benefits of calcium and dairy foods for maintaining a healthy body weight.

Osteoporosis, hypertension and obesity begin developing early in life [35,55,87,88]. This fact suggests that prevention efforts should begin in childhood. Because eating habits developed in childhood set the stage for similar eating habits later in life, the adoption of healthier eating habits in childhood can reduce the risk of developing chronic diseases in later life.

**Nutritional Qualities of Milk and Other Dairy Products**

Milk and other dairy products are among the best natural sources of calcium. They offer high calcium bioavailability, have a high calcium content and may be obtained at low cost relative to their nutritional value [1,2,89–99]. Dairy products also provide an abundant food source of phosphorus, potassium, riboflavin, vitamins B12 and A, protein, magnesium and niacin (niacin equivalents) [93,94]. Additionally, most milk and some yogurt are fortified with vitamin D. Because milk and other dairy products are nutrient-dense foods, their intake improves the overall nutritional quality of children’s [100,101] and adolescents’ diets [102–107]. According to Healthy People 2010, “with current food selection practices, use of dairy products may constitute the difference between getting enough calcium in one’s diet or not” [108].

**Trends in Calcium Intake and Dairy Product Consumption**

The Bogalusa Heart Study, as well as epidemiologic investigation of the early natural history of heart disease, provides a unique opportunity to examine trends in food consumption over the past two decades (1973–1994). In the Bogalusa Heart Study, the percentage of 10-year-old children consuming milk declined while the percentage consuming cheese increased. The percentage consuming fruits/fruit juices increased and the percentage consuming sweetened beverages (e.g., soft drinks, tea and coffee with sugar, fruit flavored drinks) decreased. Mean gram consumption of sweetened beverages, cheese and fruit/fruit juices increased. However, the increase in mean gram consumption of sweetened beverages significantly increased in the moderate-to-high sweetened beverage consumers over time. Mean gram consumption of milk significantly decreased. Despite the increasing trend in cheese consumption, the decreasing trend in milk consumption resulted in an overall decrease in dairy product consumption in 1993–94. It is important to note that the increase in gram amount of cheese consumed was only 18 grams compared to a 64-gram decrease in milk consumption. Similar trends have been observed in other studies [102,104,109–111,115] and in the U.S. food supply [112]. Despite the trends observed in the percentage of children consuming dairy products and mean gram consumption of dairy products, total calcium intake significantly increased (p < 0.0001) and saturated fatty acid intake decreased [113] from 1973 to 1994 among 10-year-old children (Fig. 1). The data suggest that despite a reduction in the percentage of children consuming milk, calcium intake of the children was not compromised, indicating that the children obtained their calcium from other dairy products (e.g., cheese) and possibly from calcium-fortified foods. Although calcium intakes of children may have increased over the past two decades, the majority of children are not meeting current dietary or adequate intake (AI) recommendations for calcium [109].

Trends in beverage consumption among children and adolescents suggest that soft drinks may be replacing more nutritious beverages, such as milk and fruit juices [101,102]. A comparison between milk drinkers and soda drinkers showed that increased soda consumption had a negative impact on milk consumption and on intakes of many essential micronutrients [102]. This is a matter of concern because intake of these beverages and some of the nutrients contained in them, like calcium, is suboptimal for a substantial proportion of children in the United States. Data from national surveys indicate that, particularly in teenagers, the calcium intake is below the recommended dietary allowance. Findings from one study [114] indicated that children whose intake of calcium was less than...
the RDA consumed more soft drinks than milk and dairy products.

**Current Calcium Intakes of Children**

Current dietary recommendations for calcium are 800 mg/day for children 4 to 8 years of age, and 1,300 mg/day for children and adolescents 9 to 18 years of age [53]. At all ages, dietary calcium intake declines as children get older and females consume less calcium than males. Data from the 1994–1996 CSFII showed that the majority of children have a usual intake of calcium that is less than 100% of the calcium AI [109]. Seventy-one percent of girls and 62% of boys 6 to 11 years of age do not meet 100% of the AI for calcium [109]. Similar results were observed for 10-year-old children in Bogalusa, Louisiana, where 69% did not meet the dietary recommendation of 1300 mg/day; the percentage was higher among females (76%) than males (62%) (p < 0.001) (Table 1). In two young adult surveys, more females than males did not meet the calcium recommendation (Table 1). Among older females and males 12 to 19 years of age, 88% and 68%, respectively, did not meet the calcium recommendation [109]. That means nearly nine out of ten adolescent girls and seven out of ten adolescent boys failed to meet the AI for calcium. Caucasians and Hispanics had higher calcium intake levels than African-Americans and “others” [109,115,116]. Among young adults (19 to 28 years of age), 77% did not meet the AI for calcium, particularly females (82%) (Table 1).

**Food Sources of Calcium Intake.** Calcium is widely distributed in both plant and animal foods. In the United States, about 50% of total dietary calcium intake was supplied by milk and milk products [95,117]. Milk and cheese used as ingredients in meat, grain and vegetable mixtures contributed another 20% of dietary calcium. The remaining 30% of calcium was provided by grains, meat, fish, poultry, vegetables, fruits, eggs, legumes, nuts and seeds. Similarly, in Bogalusa 10-year-olds, a variety of foods contributed to calcium intake (Fig. 2), the majority of which came from milk products. The proportion of dietary calcium contributed by milk and milk products decreased with age; children between 1 and 2 years of age obtained 83% of calcium from milk and milk products, teenage girls 77% and adults between 65% and 72%.

**Comparison with Food Guide Pyramid.** Because of the health benefits of increased calcium consumption, national dietary guidelines recommend that Americans, including children 2 years and over, consume three to four servings of dairy

![Fig. 1. Mean Calcium Intake by 10-year-olds: 1973–1994. Source: The Bogalusa Heart Study.](image-url)
products daily [119]. Data from the 1994–1996 CSFII showed that on the average school-aged children were consuming daily 2.0 servings of dairy products, three-fourths of which were milk (1.5 servings), with cheese providing most of the remaining servings (0.5 servings) [110,115]. On average, children consumed twice as much low-fat and nonfat milk combined (0.8 servings) as whole milk (0.4 servings) [110,115]. Less than half of children 6 to 11 years of age (47% males, 36% females) consumed the recommended number of servings of dairy foods/day [110,115]. Among adolescents 12 to 19 years of age, only 28% of males and 11% of females consumed the recommended number of servings/day of dairy foods [110,115].

Dennison et al. [120] reported that 75% of children drank whole milk. The use of whole milk was associated with younger child age, Black race or Hispanic ethnicity. Dairy intake was found higher in whites than in Blacks [53], and whites tended to consume more reduced-fat dairy products than Blacks.

Children’s consumption of regular and diet soda and fruit-flavored drinks is high. On average, children consume nearly as much soda as they do milk on a given day [110,115]. The mean number of servings of regular and diet soda equals that for all servings of fruit consumed for the day, while the mean number of servings of soda and fruit drinks is more than half that for total servings of fruit consumed [110,115].

**Tracking of Calcium Intake and Dairy Product Consumption**

Epidemiologic studies show that chronic diseases have their origin during infancy and childhood and progress into adulthood [121–130]. Accordingly, the adoption of healthier eating lifestyles in early childhood may help prevent development of chronic diseases later in life. Previous studies of dietary tracking or consistency of diet have focused primarily on nutrients [122–126], food preferences [127] and more recently on intakes of fruit and vegetables and sugary foods [128]. There is an indication that consistency occurs in the diets of children [129], but intake may vary depending on the selected nutrient or food groups consumed [129].

It is well known that the transition from childhood to young adulthood consists of great behavioral and physiological changes [128,130]. For example, during childhood, eating patterns are greatly influenced by participation in school meals and parental control of foods served in the home. As children age, they become increasingly autonomous; there are decreased family influences on dietary habits, and children become increasingly reliant on fast-food sources [131,132]. One could reasonably hypothesize that with this transition from childhood to young adulthood, eating behaviors may change, resulting in inconsistent eating patterns across the age periods. In contrast, another hypothesis is that since food preferences are formed early in life [133,134] and food preferences predict food consumption [135,136], then the food consumption patterns in childhood would be similar to those of young adulthood.

One study showed that there were age differences in dairy product consumption patterns. Mean consumption of milk decreased, as children became young adults, while consumption of sweetened beverages and cheese increased [129]. Only 42% and 8% of the children who consumed milk or cheese, respectively, at age 10 consumed the same dairy products when they were young adults, based on one 24-hour dietary recall at each age period. When milk and cheese were combined into one dairy products group, only 62% of the children who consumed a dairy food/beverage at age 10 consumed the same dairy products when they were young adults.

Tracking of calcium intake and dairy product consumption has been reported in a number of studies [137,138]. In a cohort of 106 one-year-old children who were followed for 15 years,
there was significant tracking of calcium intake \( (r = 0.50–0.62) \) at various age intervals \( (p < 0.001) \) [137]. In another study of adolescents who were followed over a 15-year period [128], the degree of tracking for calcium intake was much lower \( (r = 0.43 \text{ males}, 0.38 \text{ females}) \). Thirty-three percent of males and females originally in the lowest quartile for calcium intake remained in the lowest quartile, and 41% of the subjects that began in the highest quartile remained in the highest quartile for calcium intake. Tracking coefficients for intake of cheese, milk, and milk products ranged from 0.22 to 0.54 depending on age. In the Bogalusa Heart Study, the correlation coefficients were even smaller for intakes of calcium (0.14), cheese \( (-0.003) \), milk (0.11) and total dairy (0.21) from childhood to young adulthood (data not shown). These very low correlations reflect the large number of children and young adults who did not consume dairy products in a 24-hour period.

Based on data from the Bogalusa Heart Study, a dramatic shift occurred in dietary quality from childhood to young adulthood [129]. Despite the increase in total gram amount of food consumed in a 24-hour period, the total gram amount of low-quality foods (i.e., fats/oils, candy, desserts, sweetened beverages, salty snacks) consumed increased twofold from childhood to young adulthood, with a 10% decrease in the total gram amount of high-quality foods (i.e., meats, fruits, vegetables, dairy, breads/grains) consumed. It was surprising to find that out of the total gram amount of food consumed in young adulthood, approximately 50% reflected low-quality foods and 50% high-quality foods. These data showed that children’s dietary quality decreased when they became young adults.

To assess adherence to the Food Guide Pyramid, one study [129] looked at the percentage of individuals who consumed at least one food from the five high-quality food groups during childhood and young adulthood [129]. At age 10, only 50% of the children consumed a food from each of the five high-quality food groups; this decreased to only 19% by young adulthood. Although the data reflected one 24-hour dietary recall at each time period, it indicated that an alarming percentage of individuals were not consuming a food from each of the five high-quality food groups [129] on a daily basis in both childhood and young adulthood. The food groups that were not being consumed in childhood were fruit/fruit juices or vegetables; in young adulthood, the food groups missing were fruit/fruit juices or dairy. There were strikingly high percentages of individuals who consumed a food item from at least three of the low-quality food groups (representing the apex of the Food Guide Pyramid) in childhood (92%) and young adulthood (67%).

These results have important implications for intervention research targeting children and young adults. Results suggest that efforts are needed to promote daily consumption of foods from the major high-quality food groups in the Food Guide Pyramid for a healthy eating pattern in an attempt to prevent or delay the onset of chronic diet-related diseases later in life. Moreover, consuming foods from the low-quality foods in moderation, coupled with increased consumption of fruits, vegetables and dairy, may be one approach to meeting the Food Guide Pyramid recommendations.

**Impact of School Meals on Calcium Intake and Dairy Product Consumption: National School Meals Programs**

As early as 1972, it was reported [139] that school lunches provided significantly more protein, calcium, vitamin A, thiamin, riboflavin, niacin and ascorbic acid than bag lunches brought from home. These results were later confirmed in 1995 [140] and 2001 [115] showing that students consuming school lunches had higher intakes of vitamin A, riboflavin, vitamin B-12, calcium, magnesium, phosphorus, and zinc compared to nonparticipants [115,141]. The nutrient density of vitamin D, vitamin B12 and calcium in NSLP lunches was relatively high [115,141]. National School Lunch Program (NSLP) participation was associated with an increase in the percentage meeting the calcium standard (54%) compared to nonparticipants (42%) [115]. NSLP participants consumed substantially more fluid milk, meats, grain-based mixtures containing meat or cheese, and vegetables at lunch than nonparticipants. NSLP participants consumed significantly larger amounts of whole milk and low fat milk [115]. This, together with higher intake of unspecified types of milk, resulted in much higher overall mean milk consumption specifically, four times as large as that of nonparticipants (0.8 servings versus 0.2 servings). The higher consumption of fluid milk by NSLP participants resulted in higher lunchtime intakes of vitamin A, calcium, and magnesium [141].

On average, participants consumed larger amounts of cheese (0.3 servings) than nonparticipants (0.2 servings). For overall dairy consumption at lunch meals, participants consumed more servings (1.1 servings) than nonparticipants [115] (0.4 servings). It appeared that the nonparticipants were more likely to consume soda (0.4 servings) and/or fruit drinks (0.3 servings) in greater quantities than the participants (0.2 and 0.1 servings, respectively). These significant differences in calcium intake and dairy product consumption based on NSLP participation were similar to those found in overall 24-hour intake [115].

Students who participated in the School Breakfast Program (SBP) had higher intakes of food energy, protein, thiamin, riboflavin, calcium, phosphorus and magnesium than individuals who did not [140]. SBP participants consumed 100% of the calcium AI and 152% of the phosphorus RDA compared to 83% and 132%, respectively, for nonparticipants. SBP participants obtained more calcium and magnesium at breakfast than nonparticipants, largely because they drank more milk [115,141]. At breakfast, participants’ mean milk intake was 1.0 servings compared to 0.6 servings among nonparticipants. This difference in milk consumption was due primarily to a difference in the consumption of low-fat milk. Thus, the higher milk intake of SBP participants did not result in significantly higher fat intake among the group. Similar findings were observed in

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utilization of iron, zinc and magnesium [53,164]. The nutrient is some concern that fortifying foods with large quantities of ability in calcium-fortified breads and cereals [164,165]. There tionally, phytic acid can significantly reduce calcium bioavail-
dairy products.

Overall 24-hour dietary intake of calcium and dairy products [115]. For those individuals who participated both in the SBP and NSLP, the differences in calcium intake were striking. Mean calcium intake among participants in both meal programs was 75% of the AI compared to 37% among nonparticipants. For overall 24-hour dietary intake of calcium, participants met 109% of the AI compared to 73% among nonparticipants.

Participants consumed 1.9 servings of milk from the two meals compared with 0.7 servings among nonparticipants. In stead of milk, nonparticipants consumed more soda and fruit drinks for breakfast and lunch (average of 0.9 servings for nonparticipants versus 0.2 servings for participants). For total amount of dairy products consumed, participants consumed 2.2 servings compared to 0.9 servings for nonparticipants. Similar differences were observed in overall 24-hour dietary intake of dairy products.

Concerns Related to Calcium-Fortified Food and Beverages

Fortification of foods has contributed substantially to nutrient intakes [151–160] and reduced risk for disease and nutrient deficiencies [53,161,162]. Calcium-fortified foods can be a reasonable option to help some high-risk people increase their low calcium intakes [161]. However, it is generally agreed that choosing calcium-fortified foods, particularly at the expense of foods naturally containing calcium, is not the best way to meet calcium recommendations. Several concerns have been raised regarding the use of calcium-fortified foods and beverages [52,163]. These concerns are valid ones and center on the risk of calcium excess [52,160], unknown calcium bioavailability [163–165] and the potentially negative effects of excessively high calcium diets on other nutrients such as trace minerals [53,164,166]. Substitution of calcium-fortified orange juice, calcium-fortified breakfast cereal and calcium-fortified mineral water for their traditional counterparts doubled calcium intake [52]. Thus, calcium intake above the upper limit of 2500 mg could result if calcium-fortified foods are added to a diet already containing calcium dense foods [160]. Calcium bioavailability from calcium-fortified foods may vary, depending on the food [167]. In a study of 16 healthy men, the calcium from soy beverages was absorbed at only 75% the efficiency of calcium from cow’s milk [168]; thus, more servings of non-dairy foods high in calcium or fortified with calcium may be needed to meet calcium recommendations. For example, one would need to consume eight cups of spinach, nearly five cups of red beans or 2½ cups of broccoli to obtain the same amount of calcium absorbed from one cup of milk [164,165]. Additionally, phytic acid can significantly reduce calcium bioavailability in calcium-fortified breads and cereals [164,165]. There is some concern that fortifying foods with large quantities of calcium, especially over the long term, may adversely affect the utilization of iron, zinc and magnesium [53,164]. The nutrient profile of calcium-fortified foods compared to milk can vary considerably [169]. For example, the amount of phosphorus in eight ounces of 2% milk meets 23% RDI compared to <5% RDI for eight ounces of calcium-enriched orange juice or one slice of calcium-enriched bread. Similar variations are found in the amount of magnesium (8% RDI), vitamin A (14% RDI), vitamin B (25% RDI) and riboflavin (24% RDI) in 2% milk compared to calcium-enriched orange juice (7%, 5%, 0%, 4% RDI, respectively) and calcium-enriched bread (2%, 0%, 0%, 6% RDI, respectively). Consumption of milk and other dairy products appear to be an excellent way, not only to achieve more calcium, but to reap the benefits of the other nutrients they provide compared to calcium-fortified products. With regard to low-nutrient-dense foods, the FDA discourages fortification of those foods because of the risk that consumers consuming such fortified products will ignore the rest of their diet, resulting in nutrient deficiencies and imbalances [170].

Factors Influencing Children’s Milk Drinking Behavior

Availability of Competitive Foods. In addition to the school breakfast and lunch programs, many schools also offer foods and beverages a la carte during breakfast or lunch, and in after-school programs, school stores or snack bars, vending machines, and concession stands. Students at nearly all senior high schools, most middle/junior high schools, and more than one-fourth of elementary schools have access to foods and beverages at school through vending machines [171–173]. More than 40% of elementary schools allowed students to purchase food and beverages through either vending machines or a school store, canteen or snack bar [171]. Eighty-seven percent of high schools had vending machines and almost one-third had a school store [171]. The majority of the vending machines in high schools offered juice drinks, carbonated beverages and foods of minimal nutritional value [171]. Only 6% of the vending machines offered a milk beverage [171]. Items sold in school stores were snacks of low nutrient density and high in fat and sodium, and drinks that were high in energy and added sugars [174]. Forty percent of beverages consumed by students consisted of soft drinks [171,172,174]. Furthermore, nearly half of the school stores were open during lunch hours, competing with the school lunch program [172]. More than two-thirds (68.4%) of schools allowed students to buy soft drinks, sport drinks or fruit drinks that were not 100% juice during the lunch period [171], thereby providing an obvious disincentive for consuming milk provided by the school lunch program. About half of all districts and schools had contracts that allowed companies to sell soft drinks at schools [175].

In addition to the SBP and NSLP, many schools offered foods and beverages a la carte [176,177]. Ninety-six percent of 55 schools surveyed had an a la carte line [171]. Foods in a la carte menus varied greatly in their nutritional value, ranging
from extra servings of reimbursable meal components to high-energy, high fat choices [176,177]. One study showed that 24% of the a la carte food items in junior and senior high schools were snacks, 16% were nondairy drink items, 13% were dessert items and 12% were entree items [176]. Sales data indicated that, on the average, 34% of the students purchased one or more a la carte food items daily [176]. Although more than three-fourths of the schools sold milk, the best-selling a la carte beverages were fruit juice and juice drinks [176]. School Nutrition Dietary Assessment Study II (SNDA II) found that weekly a la carte revenue was inversely related to overall NSLP participation, while another study found an inverse association between soft drink consumption and milk/fruit juice consumption [173].

There has been a movement to eliminate competitive foods in schools [178], to create national policies [178] and/or develop nutrient standards for competitive foods [175]. Although these efforts appear reasonable, there is a concern among the public and scientific communities that limiting food options in schools to only those that reflect healthy eating recommendations or some nutrient standards may not be the most practical solution. Moreover, based on food preference studies, it has been shown that restricting children’s access to foods will in fact increase children’s preference and consumption of those restricted foods when they become available [179,180], so restricting the availability of less nutrient-dense foods may not result in an increased consumption of more nutrient-dense foods.

Eating away from Home. Over the past decade, there has been an increased popularity of eating meals/snacks away from home [181]. The greater numbers of meals/snacks consumed away from home (excluding school meals) have adversely affected the nutritional quality of the diet [181]. Away-from-home foods/beverages consumed by children were higher in fat and saturated fat, and lower in fiber and calcium [181]. Calcium density in home foods showed a general upward trend from 1977 to 1995, while in away-from-home foods, calcium density declined slightly [181]. The calcium density of school foods has always been considerably higher, from 1977 to 1995, than that of restaurant or fast foods, or even home foods [181]. In one study of adolescents in grades 7 and 10, students said that they rarely ordered milk when eating at fast-food establishments because milk was unavailable, not promoted or not as visible as other beverage options such as soft drinks [182]. Encouraging children to improve their away-from-home food choices and to eat more meals at home may increase their intake of dairy foods and improve the overall nutritional adequacy of their diets [183].

Concern about Body Weight. There is a misperception that milk and other dairy foods are fattening, which can lead children, particularly adolescent females, to limit their intake of dairy foods and calcium in an attempt to lose and/or maintain weight [182,184,185]. Frequent dieting was associated with inadequate consumption of dairy products among both males and females [182], with a high percentage of chronic dieters reporting inadequate intake. This association is of concern, given the high prevalence of low consumption of dairy products and high prevalence of dieting among adolescent females [182]. Studies in children and adolescents demonstrate that dairy foods can be consumed without increasing body weight or fat mass [184,186]. Moreover, it has been observed that higher dairy consumption is associated with a reduced risk of being overweight or obese [8,33,35–37,54,79]. More studies are needed to better understand the associations among dieting, calcium intake and dairy product consumption.

Nutritional Concerns with Reduced Fat Foods. Studies have shown that individuals who consumed less energy from fat had lower intakes of total energy, saturated fat, cholesterol and several micronutrients [187–190]. In contrast, others have shown that the vitamin and mineral content of the diet can potentially be improved when fat is reduced in the diet [191–193]. One study showed that the total fat intake of skim and low-fat milk drinkers was significantly lower than that of whole milk drinkers; males but not females compensated for energy by increasing carbohydrate intake, and reduced-fat-milk drinkers consumed more fruit and vegetables and less meat and sweets than whole milk drinkers [194]. Other studies have shown that children who reduced their total fat intake consumed fewer dairy foods and had lower calcium intakes than children with higher fat intakes [195,196]. Contrary to these findings, dietary calcium intakes can be increased to recommended levels with dairy foods without increasing total energy or fat intakes [54,186,197]. All types of dairy foods, regardless of fat content, can be incorporated into a healthy eating pattern that meets the current recommendations for total fat, specifically saturated fat [54,186].

Lactose Intolerance. It is estimated that 25% of the U.S. population and 75% of adults worldwide are reported to be lactose-intolerant. In the United States, the prevalence of lactose intolerance is lowest in Caucasians (15%), and highest in African-Americans (80%) and Asian-Americans (90%). A common fear or fallacy perceived by people with lactose intolerance is that they cannot consume dairy products because they will produce gastrointestinal symptoms [198,199]. As a result, milk and other dairy foods are often eliminated or restricted from the diet [200]. One study found that those with adequate lactase levels absorbed 92% of milk’s lactose while those with low lactase levels absorbed only 25% to 58% [198,199].

The majority of the incidence figures for lactose intolerance represent the proportion of people who are diagnosed with lactose malabsorption after consuming a challenge dose of lactose in water (50 grams). A much smaller number of people experience intolerance symptoms when they consumed usual amounts of milk (12 grams lactose). Current research findings show that the majority of individuals with low lactase levels can ingest at least eight ounces of milk with a meal and even 16
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ounces per day without distress [198–200]. Other studies conclude that most lactose maldigesters can consume small amounts of lactose as found in four ounces of milk or hard cheeses and that greater quantities can be tolerated if consumed with other foods [201–206]. Furthermore, habitually including milk and other dairy products in the diet can actually improve one’s tolerance to lactose [198,199]. Colonization adaptation to daily lactose feeding in lactose maldigesters reduces lactose intolerance [207]. Considering that lactose intolerance is reportedly high among African-Americans and they have a disproportional higher risk for calcium-related diseases, such as colon cancer, hypertension and obesity, it appears that African-Americans would greatly benefit from improved intake of calcium and dairy products [208].

An individual’s tolerance for dairy foods varies by type [198–200]. Whole milk appears to be better tolerated than lower-fat milks, chocolate milk better than unflavored milk, and cheeses and cultured/culture-containing dairy foods better than milk [198,200]. Calcium intake levels of most Americans are far below recommended levels [109,110], and lactose intolerant people are at particular risk of low calcium intakes; dairy products are important sources of calcium. Although lactose intolerance may partly explain the low calcium intakes due to reduced dairy product consumption by minority populations [208], culturally determined food preferences and dietary practices learned early in life may also play a role. Therefore, we need to educate people with lactose intolerance that dairy products can, in most cases, be gradually added to their everyday eating lifestyles [209].

Breakfast Consumption. Eating breakfast has a positive impact on milk intake [115,210]. Eating breakfast increases calcium intakes [210–214]. In one study, children 6 to 19 years of age consumed 23% to 30% of their daily calcium intake at breakfast [110]. Unfortunately, 25% of adolescent girls and 22% of adolescent boys were found to skip breakfast [110]. Ready-to-eat (RTE) cereals have traditionally been considered breakfast foods. A positive effect of RTE cereal consumption was the usual (92%) addition of milk [210]. In the Bogalusa Heart Study [210], 96% of 10-year-old children who consumed RTE cereals also consumed an item from the milk group, whereas only 83% of the non-cereal eaters consumed milk. The difference was more striking in young adults: 74% of those who ate cereal also consumed a milk product, whereas only 31% of non-cereal-eaters did so.

Another important observation is that the nutrient contribution of the breakfast meal varied by source, (i.e., home compared with school) [213]. The percentage of 10-year-old children not meeting two-thirds of the RDA for calcium was significantly higher among children consuming a home breakfast compared to children consuming a school breakfast. A larger percentage of children consumed sweetened beverages at home for breakfast than those who consumed school breakfast. Of the children who drank milk for breakfast, whole milk was generally consumed with breakfast at home, versus low-fat chocolate milk at school.

Parents. Parents, particularly mothers, can influence their children’s intake of milk by drinking it themselves and by making it readily available [215]. A recent study of 180 mothers and their five-year-old daughters demonstrated that the mothers’ own beverage consumption patterns determined the extent to which their daughters’ intake of milk was displaced by soft drinks [215]. Mothers, by serving as role models, can shape their daughters’ beverage choices, calcium intake and risk for osteoporosis in later life. For both mothers and daughters, intake of soft drinks was negatively associated with both milk and calcium intake.

Taste. Taste is an important factor influencing children’s and adolescent’s food choices, including their decision to consume milk [54,182,184]. Milk’s flavor affects children’s milk-drinking behavior. A recent study of elementary school children found that children preferred chocolate milk [215] and adolescents preferred flavored milk over plain milk [184]. Children who consumed flavored milk had lower intakes of soft drinks and fruit drinks and higher calcium intakes than children who did not consume the flavored milk [100].

Lack of Knowledge. Lack of knowledge about how much calcium is needed and dietary sources of this nutrient is another factor that can influence children’s consumption of dairy foods and calcium intake. A survey of 1,117 adolescents found that those who were knowledgeable about calcium consumed more of this nutrient than adolescents who were less aware of calcium [216,217]. Only 19% knew how many dairy foods they should consume, and only 10% knew the calcium content of various dairy foods, while 45% were knowledgeable about nondairy sources of calcium [216,217].

Other Factors Related to Milk Consumption by Children. Asian adolescents reported that the important motivators of consuming calcium-rich foods were parental encouragement, taste, type of food accompanying the calcium-rich food and the media [218]. Key barriers were certain locations, cost, hot weather and inconvenience [218]. Several of these factors varied in importance by gender and age [218]. Family connectedness, low socioeconomic status and average or below-average school grades were also associated with low consumption of milk and dairy products [218]. Others [120] have shown that behavioral modeling of milk consumption and perceptions of others’ opinions were factors associated with calcium intakes and dairy product consumption. A recent pilot study found that some adolescents rarely consumed meals with their families and that many watched television during meals [219]. Watching television while eating was associated with increased intake of soft drinks and other foods of low nutritional value [219].

More recently, focus groups were conducted among Asian, Hispanic and Caucasian preadolescent and adolescent females in ten states to understand influences on adolescents’ consumption of calcium-rich foods [220]. A barrier to milk consumption was the limited expectation within families for drinking milk,
particularly among older girls and Asians. Little role modeling by parents was indicated. A large percentage of the participants indicated that they controlled their own beverage selection at home, and a variety of beverage options were available. Caucasian girls had the most positive comments relative to the taste of milk and Hispanic girls had the most negative comments. All ethnic groups positively associated milk with health, both general and bone specifically. Milk was also associated with breakfast, school lunches, cereal and desserts. Another interesting finding was that Hispanic girls were more likely to consume milk in milk shakes, whereas Asian girls liked warm, sweetened milk or in combination with tea.

A national study showed that school milk had some negative physical and imagery characteristics and associations for many students [221]. Students reported eight key reasons for not drinking milk which included: (1) they preferred to drink something else; (2) the milk was sometimes warm or “bad” (poor product quality); (3) there was an absence of the preferred type of milk (e.g., skim, flavored); (4) insufficient portions were offered; (5) a negative association was made with school food; (6) the milk was given unattractive and juvenile packaging; (7) the containers were hard to open/drink from, and (8) there was a perceived value of “free” milk versus other beverages costing money. In comparison with soda, students’ image of soda was rated “good” based on being sweet, coming in a variety of flavors, having bubbles and caffeine, coming in “neat” packaging and coming in teen-size portions [221]. Based on these findings, a school milk pilot test was conducted with roughly 100,000 students from 146 schools in nine states [221]. At a majority of sites, a single new flavor of milk was offered (e.g., strawberry, vanilla, caramel, orange, mocha, cappuccino and coffee) free or at a reduced price in addition to white and chocolate milk on the serving line. The containers were more attractively packaged (8- or 10-ounce resealable plastic); other aspects of product quality and presentation were enhanced including refrigeration, display, freshness and merchandising. In some test schools where value-added milk products were not part of the school milk bid program, 16-ounce flavored milk in plastic resealable bottles were offered as la carte selections and/or from vending machines, were physically located in close proximity to the serving line and were priced competitively with non-milk beverage selections. Results showed the children reported the plastic resealable bottle to be more appealing than the traditional carton and that the container was easier to open and to drink from. With an improved milk offering at lunch time, particularly when a third flavor and a 10-ounce serving was offered, more children bought and drank more milk. Moreover, those students were more likely to take two or more milk servings. The initial increase in milk consumption continued to increase throughout the study; resulting in decreased milk waste. More studies are needed to confirm these findings and to examine potential impact on average daily participation in school lunch and dietary intakes of children.

Call For Action

Based on these findings several areas need immediate attention:

1. Reauthorization of the school meals program.
2. Increasing or maintaining participation in school meals.
3. Encouraging breakfast consumption.
5. Decreasing plate waste of school meals by increasing meal flexibility, expanding the use of self-service and regulating options for customizing portion sizes to children’s grade level, offering a variety of milk options, improving the quality, appearance and/or acceptability of foods, and promoting consumption of healthier food choices.
6. Balancing nutritional and financial considerations with regard to the sale of competitive foods in schools.
7. Offering some healthy competitive food options rather than eliminating less nutrient-dense foods/beverages altogether.
8. Integrating behavior-focused nutrition education into the curriculum.
9. Increasing the public’s knowledge and awareness through effective media and marketing messages about how much calcium is needed, as well as dietary sources of calcium.

Future Research Imperatives

1. Determine whether or not high intakes of calcium result in calcium-mineral interactions that affect the mineral status of vulnerable populations.
2. Determine the impact of calcium-fortified foods on overall nutritional adequacy of the diet.
3. Determine the impact of competitive foods in schools on food consumption and dietary intakes.
4. Conduct further studies to determine whether a reduction in sweetened beverage consumption results in increased milk consumption.
5. Develop effective behavioral interventions designed to increase calcium intake with milk and other dairy products.
6. Confirm whether there is a positive relationship between dairy consumption and weight loss, and further validate the mechanism for this relationship.

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