PERSPECTIVE

Perspective: School Meal Programs Require Higher Vitamin D Fortification Levels in Milk Products and Plant-Based Alternatives—Evidence from the National Health and Nutrition Examination Surveys (NHANES 2001–2018)

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ABSTRACT

Poor vitamin D status impairs bone growth and immune defense in school-aged children and adolescents, particularly in minorities. Vitamin D insufficiency/deficiency increases the risk of acute viral respiratory infection, underscoring the need for adequate vitamin D intakes during school sessions when viral exposure may be greatest. We studied available vitamin D–related survey data and published findings based on NHANES (2001–2018) to assess the dependency of vitamin D status {25-hydroxyvitamin D [25(OH)D]; in nmol/L} on vitamin D intake (μg/d) in elementary school–aged children (4–8 y), middle school children (9–13 y), and high school adolescents (14–18 y). We sought evidence supporting the need for school programs to facilitate vitamin D adequacy. Usual vitamin D intakes from food and beverages by children/adolescents (NHANES 2015–2018) examined at the 50th percentile intake by race/ethnicity (non-Hispanic White, non-Hispanic Black, Hispanic) showed all age groups consumed less than half of the Estimated Average Requirement (EAR) for vitamin D (10 μg/d), independent of race/ethnicity. NHANES (2001–2010) analyses show evidence of lower vitamin D status in school-aged children that is linked to lower intakes of fortified milk varying over race/ethnicity and age. Adolescents had lower vitamin D status and milk intake than younger children. A total of 22–44% of vitamin D intakes occurred away from home, with larger percentages of total intakes at breakfast and lunch, at times consistent with school meals. Ever-present inadequate vitamin D intakes with a large percentage consumed away from home together with well-established benefits to growth, bone, and immune defense from enriched vitamin D–fortified milk in school intervention trials provide strong justification to require enriched vitamin D–fortified foods in school meals. An easy to implement plan for improving vitamin D intakes is possible through the FDA's amendment allowing higher vitamin D fortification levels of dairy and plant-based milk alternatives that could increase vitamin D intakes beyond the EAR with just 2 daily servings. *Adv Nutr* 2022;13:1440–1449.

Statement of Significance: We demonstrate that there is strong justification to require newly approved, enriched vitamin D–fortified foods in school meals, as school-aged children in America have inadequate vitamin D status.

Keywords: 25-hydroxyvitamin D, vitamin D deficiency, vitamin D insufficiency, NHANES, school-aged children/adolescents, vitamin D-fortified milk, vitamin D-enriched milk, plant-based milk intended as milk alternatives, USDA school meal program

Introduction

In 2002, the first nationally representative report on vitamin D status of Americans based on circulating total 25-hydroxyvitamin D [25(OH)D] concentrations used data from the NHANES 1984–1994 (1). After 1999, the NHANES surveys continued in 2-y cycles and these surveys over the last 2 decades have been critical in establishing that vitamin D intakes and status vary by age, sex, race/ethnicity, and income in adults. However, despite the important functions that vitamin D plays in growth, bone health, and the immune response (2), much less is known about how these differences affect school-aged children and adolescents. From the first report, the risk of vitamin D deficiency in the healthy US population has remained low and stable, while the risk of insufficiency was higher but has slightly declined over consecutive cycles for the overall population (3, 4). Early on, focus on specific population groups showed a higher prevalence of vitamin D insufficiency and deficiency in

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younger individuals and in specific races/ethnicities (5–8). This raises public health concern due to the increasing awareness of vitamin D's role in reducing chronic and acute disease risk. There is an ever-growing number of studies reporting the association between poor vitamin D status and the incidence and disease severity of respiratory infections in school-aged children and adolescents, including those from common cold viruses, acute upper and lower viral influenza, and bacterial respiratory infections (9–15); otitis media (16); allergic asthma (17–20); and of recent concern, association with coronavirus disease 2019 (COVID-19) transmissibility, severity of infection, and the COVID-19–associated hyperinflammatory condition, Multisystem Inflammatory Syndrome in Children (MIS-C) (21, 22).

To date, NHANES cycles have consistently shown a higher prevalence of vitamin D deficiency and insufficiency in non-Hispanic Blacks (NHBs) and Hispanics (HIS) compared with their non-Hispanic White (NHW) counterparts (3–5, 7, 8) and lower vitamin D dietary intakes (4, 6, 8). Greater skin pigmentation impairing the natural synthesis of vitamin D with UV light exposure does not fully explain these racial/ethnic differences in vitamin D status, while growing evidence suggests that significant differences in the consumption of dietary sources of vitamin D may play a greater role than previously realized (4, 6, 8). The aim of this Perspective is to assess the dependency of vitamin D status [25(OH)D; in nmol/L] on vitamin D intakes in elementary school–aged children (4–8 y), middle school children (9–13 y), and high school adolescents (14–18 y) using publicly available data and analyses from the published literature that is based on survey findings from the NHANES cycles conducted over the last 2 decades (2001–2018). These data may give insight into practical strategies and potential national policies that could improve adequate vitamin D status among students of different ages and races/ethnicities.

NHANES Vitamin D Data Sources

Vitamin D content of foods in NHANES

Vitamin D intake data from NHANES cycles were available from What We Eat in America (23) and the USDA Food Nutrient Database for Dietary Studies (FNDDS) (24), which provide vitamin D dietary intake data from all foods (including beverages and dietary supplements) reported since the 2007–2008 cycle. The FNDDS is specific for each wave and is based on the USDA Standard Release (SR) for that cycle. The FNDDS is updated periodically to include new foods, which increases the total number of vitamin D–containing foods over each cycle. SR-28 for the 2013–2014/2015–2016 cycles contained close to 9000 foods listing vitamin D content.

Mean and median usual intake data and percent less than the Estimated Average Requirement

The USDA Automated Multiple-Pass method (25) was used in the NHANES surveys to estimate 24-h dietary intake of vitamin D in children and adolescents in three 2-y cycles of the continuous NHANES: 2013–2014, 2015–2016, and 2017–2018 (26–28). These data along with a second 24-h intake serve as the basis for estimating usual vitamin D intake, which was recently computed for age, sex, and race/ethnicity for the combined NHANES 2015–2018 (29–31). The usual intake of a nutrient differs from a single 24-h dietary recall estimate in that it reflects the typical intake by adjusting for day-to-day variation in nutrient intake.

The usual mean intakes of vitamin D in 4–8-, 9–13-, and 14–18-y-old boys and girls in all 3 race/ethnicity groups are shown in **Table 1**. For all ages, sexes, and races/ethnicities, the usual intakes of vitamin D were less than half the Estimated Average Requirement (EAR) of 10 μg/d and far less than the RDA of 15 μg/d. The intakes in girls were always lower than those of boys, independent of age or race/ethnicity. One notable observation is that adolescents had lower intakes than their younger counterparts, which was most obvious in NHBs, with the lowest intakes. Most problematic is the gap in daily vitamin D intake between the usual intake and the EAR of 10 μg/d, which is in the range of 4–7 μg/d for all ages, sexes, and races/ethnicities. Various government agencies now recognize that vitamin D is a significant underconsumed, disease-related nutrient, with limited intakes in all younger age groups that have been repeatedly shown in the continuous NHANES surveys. Table 1 shows the percentage of boys and girls in the three age groups with vitamin D intakes below the EAR which is a measure of the prevalence of inadequacy. The range for boys across race/ethnicity is 89% to >97%, whereas the range for girls is 93% to >97%—clear evidence that school-aged boys and girls of all race/ethnicities significantly underconsume this critical nutrient in situations of low-UVB-radiation exposure.

Twenty-four-hour dietary intake data and vitamin D intakes.

Shown in **Table 2** are the % of the estimated 24-h vitamin D intakes that were consumed away from home for the 2013–2014, 2015–2016, and 2017–2018 cycles (26–28). When averaged over the 3 cycles, for the 6–11-y groups, NHW, NHB, and HIS children consumed 31%, 44%, and 35% away from home, respectively. These data indicate that younger NHB children were more likely to get a higher percentage of vitamin D away from home than NHW and HIS children. For those aged 12–19 y, approximately 26%, 22%, and 25% of their vitamin D intake was consumed away from home,

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Abbreviations used: COVID-19, coronavirus disease 2019; DV, Daily Value; EAR, Estimated Average Requirement; FNDDS, Food Nutrient Database for Dietary Studies; HIS, Hispanic; NHB, Non-Hispanic Black; NHW, Non-Hispanic White; SR, Standard Release; UL, Tolerable Upper Intake Level; 25(OH)D, 25-hydroxyyvitamin D.

TABLE 1 Mean and 50th percentile estimates of usual vitamin D intake from food and beverages in children and adolescents from combined cycles (NHANES 2015–2018) and the percentage of group with intakes below the EAR by age, sex, and race/ethnicity[1]

NHANES 2-y-cycle (2015–2018)	NHW: 4–8 y[2]	NHB: 4–8 y[2]	Hispanic: 4–8 y[2]	NHW: 9–13 y	NHB: 9–13 y	Hispanic: 9–13 y	NHW: 14–18 y	NHB: 14–18 y	Hispanic: 14–18 y
Boys, *n*	465	325	424	225	159	225	219	162	189
Mean (SE), μg/d	5.3 (0.2)	4.4 (0.2)	5.6 (0.2)	5.7 (0.4)	4.8 (0.3)	6.0 (0.3)	5.2 (0.4)	4.4 (0.3)	5.3 (0.3)
50th Percentile intake (SE), μg/d	5.0 (0.2)	4.1 (0.2)	5.3 (0.2)	5.2 (0.4)	4.3 (0.3)	5.4 (0.3)	4.6 (0.4)	3.8 (0.3)	4.8 (0.3)
% Below EAR (SE)[3]	>97 (~)	>97 (~)	96[4] (1.1)	90 (2.4)	95[4] (1.4)	89 (1.7)	93[4] (2.1)	96[4] (1.0)	93[4] (1.3)
Girls, *n*	465	325	424	222	184	246	202	165	217
Mean (SE), μg/d	5.3 (0.2)	4.4 (0.2)	5.6 (0,2)	5.1 (0.3)	4.3 (0.3)	5.2 (0.4)	3.7 (0.3)	3.1 (0.2)	3.8 (0.2)
50th Percentile intake (SE), μg/d	5.0 (0.2)	4.1 (0.2)	5.3 (0.2)	4.5 (0.3)	3.8 (0.3)	4.6 (0.3)	3.2 (0.3)	2.6 (0.2)	3.3 (0.2)
% Below EAR (SE)[3]	>97 (~)	>97 (~)	96[4] (1.1)	94[4] (1.6)	>97 (~)	93[4] (2.1)	>97 (~)	>97 (~)	>97 (~)

[1] Data from references 29–31. EAR, Estimated Average Requirement; NHB, non-Hispanic Black; NHW, non-Hispanic White.

[2] Male and female data combined for children aged 4–8 y old.

[3] When given as >97% below the EAR, (~) indicates no SE measure is available for populations >97% below the EAR for vitamin D intake.

[4] Estimate may be less reliable due to the small sample size and/or large relative SE.

respectively. Overall, the younger children likely consumed more away from home due to eating more meals at school than older youth; yet, this does not tell us what the meal distribution of vitamin D intake was. We then explored the NHANES data to determine the percentage of total vitamin D that was consumed at breakfast and at lunch. The contribution at breakfast (range: 37–48% of total vitamin D) and at lunch (range: 15–26%) varied with race/ethnicity for both meals. Again, only younger but not older NHB children were more likely to get a higher percentage of vitamin D away from home at these meals. Further, NHB and HIS children consumed almost half of their daily vitamin D (∼45%) at breakfast. Lunch contributed about one-quarter of daily vitamin D intake, with the remaining one-quarter at dinner (data not shown).

Vitamin D status of children and adolescents.

Karalius et al. (32) surveyed 2877 children and adolescents aged 6–18 y participating in NHANES 2003–2006 and reported their assay drift-adjusted prevalence of 25(OH)D deficiency as percentage <30 nmol/L (<12 ng/mL), risk of inadequacy as percentage <40 nmol/L (<16 ng/mL), and adequacy as percentage >50 nmol/L (>20 ng/mL) (32). Based on these widely accepted cutoff guidelines, 4.6% of 6–18-y-olds were at increased risk of deficiency (US population estimates: 2.5 million) and approximately 10.3% were at risk of inadequacy (population estimate: 5.5 million). Herrick et al. (4) surveyed NHANES 2011–2014 participants and reported 1.4% prevalence of at-risk for deficiency in 6–11-y-old children and 12.3% at risk of inadequacy using the same cutoffs. They reported 4.8% risk of deficiency and 22.7% at risk for inadequacy in 12–19-y-old adolescents (4). These 2 studies (4, 32) differed in age groupings; yet, both describe measurable (close to 5% in older children) deficiency and approximately 10% to 20% risk of insufficiency. The higher prevalence of risk for poor vitamin D status in adolescents is consistent with their lower vitamin D intakes shown for high school–aged adolescents in the section above. Adjustment for age and season for everyone aged 1 y and over assessed in NHANES 2011-2014 revealed that 17.5% of NHBs were at risk of deficiency and 35.8% were at risk of inadequacy (4). It is not clear if risk in adolescence for poor vitamin D status influences vitamin D status in adulthood and possibly greater susceptibility to disease; however, this is a fertile area for prospective studies.

Evidence of Efficacy of Vitamin D Food Fortification for Children/Adolescents

Types of major food sources of vitamin D in children and adolescents

The long-held principle guiding the justification for the fortification of foods with vitamin D requires timely documentation of vitamin D dietary inadequacy (33). Based on intake data from NHANES 2003–2006, food sources with only fortified (added) vitamin D contributed over 93% of total vitamin D intake in children 2–8 y old and

TABLE 2 Percentage of total vitamin D intake contributed by food and beverages consumed away from home by race/ethnicity in children and adolescents and of total vitamin D consumed at breakfast and at lunch, by race/ethnicity in children and adolescents estimated from 24-h day-1 data in NHANES 2013–2014, 2015–2016, and 2017–2018[1]

	NHW: 6–11 y	NHB: 6–11 y	Hispanic: 6–11 y	NHW: 12–18 y	NHB: 12–18 y	Hispanic: 12–18 y
Away from home,[2,3] % (SE) [% (SE)]						
2013–2014, Vit D intake away from home Total reporting	36 (3.9) [82% (3.6)]	48 (4.6) [75% (3.2)]	31 (2.8) [80% (2.7)]	24 (2.4) [70% (2.7)]	26 (4.5) [63% (3.4)]	24 (2.2) [71% (2.8)
2015–2016 Vit D intake away from home Total reporting	32 (2.6) [82% (2.2)]	49 (5.0) [75% (1.9)]	34 (2.8) [76% (2.8)]	32 (3.0) [78% (3.0)]	17 (3.4) [50% (3.3)]	26 (3.9) [67% (2.6)
2017–2018 Vit D intake away from home Total reporting	25 (2.9) [76% (3.40]	35 (3.8) [64% (3.7)]	40 (4.5) [83% (2.9)]	24 (47) [73% (3.9)]	22 (4.1) [62% (5.5)]	24 (2.2) [71% (3.2)]
Breakfast,[3,4] % (SE) [% (SE)]						
2013–2014 At breakfast Total reporting	37 (1.5) [92% (1.6)]	43 (2.7) [83% (3.2)]	46 (2.4) [87% (3.3)]	39 (3.2) [76% (3.8)]	38 (3.1) [61% (3.3)]	43 (2.0) [80% (2.6)
2015–2016 At breakfast Total reporting	39 (2.4) [87% (2.8)]	41 (1.9) [84% (3.4)]	46 (2.8) [86% (3.0)]	41 (3.2) [76% (3.0)]	46 (4.0) [69% (3.1)]	39 (2.7) [72% (2.3)]
2017–2018 At breakfast Total reporting	41 (2.8) [90% (25)]	48 (3.2) [86% (4.0)]	44 (2.0) [91% (2.5)]	41 (4.5) [75% (3.2)]	42 (3.9) [65% (3.6)]	46 (4.6) [74% (2.8)]
Mean (SE)	39 (2.2)	44 (2.6)	45 (2.7)	40 (3.6)	42 (3.7)	43 (3.1)
Lunch,[3,4] % (SE) [% (SE)]						
2013–2014 At lunch Total reporting	26 (3.0) [92% (2.5)]	29 (3.2) [86% (3.1)]	23 (2.6) [85% (2.9)]	19 (1.3) [88% (2.4)]	20 (2.3) [78% (3.3)]	20 (2.4) [76% (3.7)]
2015–2016 At lunch Total reporting	27 (1.9) [94% (2.4)]	33 (2.2) [88% (2.1)]	18 (1.8) [77% (3.5)]	20 (2.5) [80% (3.3)]	15 (3.0) [75% (2.4)]	22 (2.4) [77% (2.5)]
2017–2018 At lunch Total reporting	19 (2.2) [93% (1.6)]	25 (2.4) [81% (4.7)]	18 (1.8) [78% (3.8)]	18 (2.1) [86% (2.8)]	22 (3.1) [76% (3.7)]	19 (3.6) [75% (4.0)]
Mean (SE)	24 (2.4)	29 (2.5)	20 (2.1)	19 (2.0)	19 (2.8)	20 (2.8)

[1] NHB, non-Hispanic Black; NHW, non-Hispanic White; Vit, vitamin.

[2] The percentage (% SE) of total vitamin D intake contributed by food and beverages consumed away from home by individuals in race/ethnic and age groups who reported consuming at least 1 item away from home. Away from home includes any location other than home. Home is defined as an individual's dwelling unit and the surrounding areas that are used solely by the occupants of that dwelling unit.

[3] The percentage [% (SE)] of Total number of individuals reporting in each race/ethnic group of children aged 6–11 y and 12–18 y the food and beverages consumed away from home and at breakfast and lunch for all locations of meal consumption in 3 cycles of NHANES: 2013–2014 (26), 2015–2016 (27), and 2017–2018 (28).

[4] The percentage (% SE) of total vitamin D intake contributed by food and beverages consumed by individuals in race/ethnic and age groups who reported consuming at least 1 item at breakfast or lunch (meal occasions at all locations where consumed) in 3 cycles of NHANES: 2013–2014 (26), 2015–2016 (27), and 2017–2018 (28).

TABLE 3 (A) Estimated mean (SE) dietary vitamin D intake from all types of milks by age and race/ethnicity using NHANES 2001–2010 day-1 dietary data and (B) circulating mean (SE) serum 25(OH)D concentrations by nonconsumers and by consumers at the highest level of milk intake (tertile 3) in race/ethnic population and 2 age groups: NHANES 2001–2010[1]

	Mexican American (*n* = 7827)	Other Hispanic (*n* = 2994)	Non-Hispanic White (*n* = 14,525)	Non-Hispanic Black (*n* = 7739)	Other (*n* = 1487)
(A) Age group, μg/d from milks					
2–8 y old	4.81 (0.13)	5.47 (0.31)	4.47 (0.12)	3.29 (0.12)	4.22 (0.17)
9–18 y old	3.03 (0.13)	2.90 (0.21)	3.71 (0.14)	2.13 (0.07	2.57 (0.23)
(B) 25(OH)D, nmol/L					
2–8 y Nonconsumers	63.5 ± 1.3	64.8 ± 2.0	78.1 ± 2.6	59.7 ± 1.6	65.5 ± 3.1
2–8 y Tertile 3 milk consumers	69.6 ± 1.1[*,#]	72.2 ± 1.9[*,#]	80.3 ± 1.2	64.6 ± 1.3[*,#]	71.4 ± 2.1
9–18 y Nonconsumers	54.1 ± 1.0	58.2 ± 1.5	68.4 ± 0.7	43.9 ± 1.2	54.8 ± 2.1
9–18 y Tertile 3 milk consumers	61.0 ± 1.1[*,#]	64.2 ± 3.0	75.3 ± 1.2[*,#]	55.0 ± 1.2[*,#]	63.0 ± 2.2[*,#]

[1] Total population of 2–8-y-olds, *n* = 8700, and for 9–18-y-olds, *n* = 17457, and the total number surveyed in each race/ethnic group are shown (42).

[*] Significantly different from nonconsumers at $P < 0.05$.

[#] Significantly different from nonconsumers at $P < 0.05$ after additionally adjusting data for vitamin D intake from nonmilk sources, supplements, and seafood (data from reference 42). 25(OH)D, 25-hydroxyvitamin D.

over 93% of total vitamin D intake in adolescents 9–18 y old. For both age groups, fortified milk and milk products contributed over 80% of vitamin D intake (33). Consistent with these earlier surveys, NHANES 2009–2012 vitamin D intake estimates revealed that over 90% and 80% of children 2–8 y and 9–18 y, respectively, were below the EAR (34). In a recent meta-analysis, randomized clinical trials that used milk as the fortification vehicle showed greater benefit for higher 25(OH)D than fortification with juice, cereal, or yogurt/cheese, and the effect was higher among preschool- and school-aged children compared with 5–12-y-old children (35).

Vitamin D fortification of fluid milk effects on vitamin D status in children.

Globally, in countries with fortification policies for fluid milk products, they contribute 28–63% of vitamin D intake and intakes are much lower in countries with no vitamin D fortification policies (36). Vitamin D–fortified milk products contribute to individual intake and circulating 25(OH)D concentrations worldwide, but the positive impact of vitamin D fortification at the population level is dependent on whether the regulation of the fortification process is a mandatory or voluntary-based policy (36). Unlike Canada, vitamin D fortification of milk products in the United States is largely optional or voluntary; thus, unfortified choices are also available and vitamin D fortification of milk cannot always be assumed, especially if it is labeled organic.

Findings from small community studies focusing on low-income NHB and HIS children in Atlanta (37) or northern inner-city minority infants and children with reported clinical rickets (38) validate the benefits of fortified milk and infant formulas in correcting deficient vitamin D intakes and suboptimal and deficient vitamin D status. Use of vitamin D supplements in minority children and adolescents is effective in correcting vitamin D deficiency (39) but not feasible in a school setting, leaving a food-based strategy in the context of breakfast and/or lunch programs more practical. Further, the nature of the milk, whether dairy or plant-based milks intended as alternatives to milk, despite differences in overall nutritional quality (40), can all be used to reach even school-aged children and adolescents who require nondairy sources of vitamin D due to religious or lifestyle dietary preferences and/or serious dairy intolerances or allergies. Moreover, in the United States, 22.8% of households in a recent survey were found to consume only plant-based beverages, thus making this choice necessary (41).

Estimates of milk consumption in the United States from NHANES 2001–2010 when most market available milk was fortified at the level of 400 IU/quart (10 μg/quart, where 1 quart equals 946 mL) were 57–80% of children and were shown to be positively associated with serum vitamin D status and a 31–42% higher probability of meeting adequate serum 25(OH)D concentrations greater than 50 nmol/L (20 ng/mL) (42). Estimated mean usual dietary vitamin D intakes from all types of milk assumed to be fortified are shown for different race/ethnic groups of children and adolescents in **Table 3**A. All ages and races/ethnicities consumed less vitamin D than the EAR and again, across race/ethnicity, older adolescents consumed less vitamin D shown in these data from earlier NHANES cycles. The authors also reported the circulating 25(OH)D concentrations of the children and adolescents in the highest tertile of fluid milk consumption; both age groups of Mexican Americans and other HIS and older NHWs had significantly higher ($P < 0.05$) serum concentrations compared with their non–milk-consuming counterparts (Table 3B). Importantly, mean 25(OH)D concentrations were well above 50 nmol/L in all young and older milk consumers in the highest tertile, independent of race/ethnicity. In more recent NHANES cycles (2011–2014), milk is the top-ranked food source for calcium and potassium as well as vitamin D (43).

Success of milk fortified with vitamin D provided in school meal programs.

School-aged children in New Zealand, India, China, and Morocco (44–48) participating in school milk intervention trials showed improved serum 25(OH)D concentrations in winter, but some (44, 46, 47) were only mildly or insufficiently improved. These studies varied with the age of the students, initial vitamin D status, duration, dose, and form used, making it difficult to draw firm conclusions as to the benefit of fortified milk in schools outside the United States.

Despite the accessibility of fortified milk to millions of US schoolchildren, total consumption of all milk types declined in US schools by 14.2% from 2008 to 2017 and the percentage of children participating in school lunch programs also declined during this pre-pandemic period (49). School meal programs in the United States feed over 30 million children daily and account for much of their milk intake and thus their vitamin D intake (50). Recent changes in the USDA School Meal Nutrition Standards starting in the 2022–2023 school year may help to reverse this decline by expanding the choices of milk types offered to include flavored low-fat milk and other non- and low-fat milk options (51). The USDA has also received approval for an increase in national school lunch program funding needed to increase rates for school lunch budgets, and this $750 million increase in available funding will help with school reimbursement funds for the cost of sourcing, purchasing, and preparing food (52).

Adequacy of current vitamin D fortification level to offset seasonal decline.

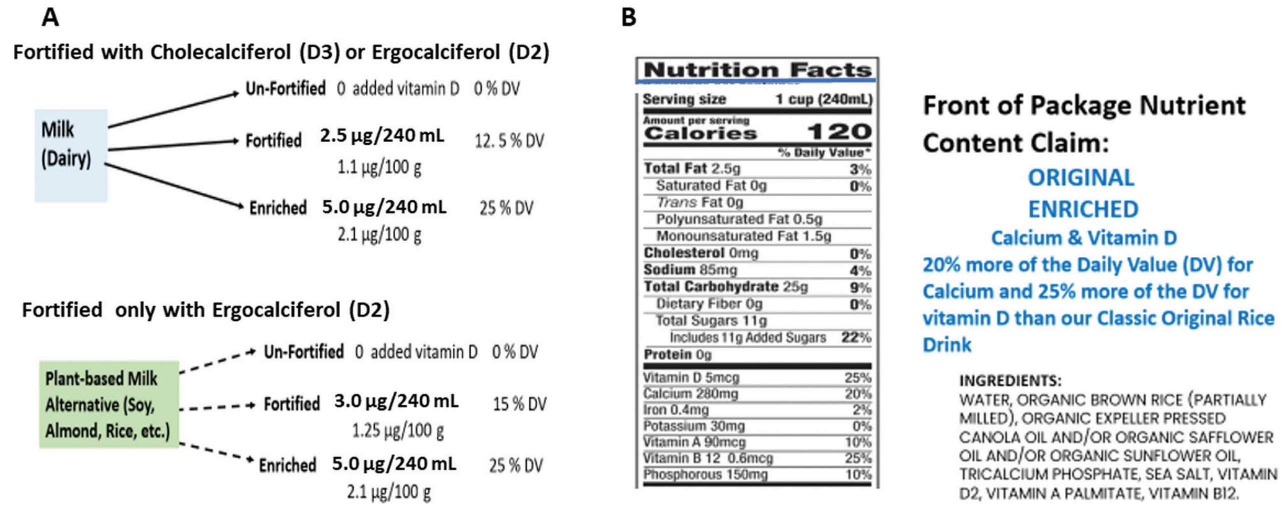
Vitamin D status may be improved with supplements and/or fortified foods frequently consumed such as milk; however, adequacy to improve vitamin D status is, in part, dependent on the dose. The level of vitamin D in fortified milk that was set at the current level of Adequate Intake in a New Zealand study (5 μg/d) was not enough to prevent the winter decline in 25(OH)D in young-adult women (53). In Canada, where fortification of milk is mandatory, serum 25(OH)D is positively associated with milk intake; yet, in winter, a sharp seasonal decline is evident in Canadians, suggesting this level of fortification is inadequate to maintain vitamin D status (54). As well, there has been a decrease in milk consumption and its alternatives from 2004 to 2015, which supports Canada's planned doubling of fortification levels by 2023 (55).

A recent systematic review and meta-regression study in children showed that food fortification improved 25(OH)D concentration, with a mean increase of 3 nmol/L for every 100 IU (2.5 μg) of vitamin D when adjusted for baseline 25(OH)D and country latitude (35). Clearly, vitamin D fortification of food is an effective way to improve 25(OH)D concentration, the key indicator of vitamin D nutritional status, but what about the impact of food fortification on a functional biomarker indicating immune status in children? Brett et al. (56) examined the relation between vitamin D from fortified foods and ex vivo biomarkers of immune function in children using 25(OH)D cutoffs different from that of the Institute of Medicine, which reflect status of skeletal health. Rather, Brett and co-investigators appropriately used cutoff values reflecting immune function—that is, vitamin D sufficient (>75 nmol/L) and insufficient (<50 nmol/L) for immune response. In Canadian children consuming 400 IU/d or 600 IU/d over 12 wk, those with higher intakes of vitamin D had significantly lower ex vivo IL-6 production by mononuclear cells stimulated with Concavalin A compared with controls. In this study, children with 25(OH)D >75 nmol/L had higher systemic concentrations of IL-6, TNF-α, and C-reactive protein (CRP), which raises a question about the need to establish a specific vitamin D status cutoff for immune response outcomes (56), as has been done for bone health outcomes with a severe deficiency cutoff of <30 nmol/L associated with rickets.

Provision of free school milk: potential benefits to growing students.

Early evidence of the benefits to bone health and to immunity of offering vitamin D–fortified milk during winter school sessions involved low- to middle-income countries with a high prevalence of vitamin D deficiency. Bone health outcomes, including bone biomarkers, bone mineral content and density (45, 46, 57), and follow-up studies relating to risk of osteoporosis in adulthood (58), have been used to evaluate the effectiveness of school-based vitamin D–fortified milk interventions to promote calcium and vitamin D intake for bone health. In a recent review, Nguyen (57) presented evidence for studies providing vitamin D–fortified milk during school, showing there was both an increased consumption of milk and an improvement in bone health when it was measured. Only recently have school-based vitamin D nutrition intervention trials focused on immune response, largely due to the lack of appropriate outcome measures (biomarkers) of immune status other than illness or infection, which can be influenced by many different factors in addition to diet. When vitamin D–fortified milk was provided to Mongolian schoolchildren during the winter at the level of 300 IU/d compared with children in the control group fed unfortified milk daily, there was a significant decrease in the number of acute respiratory infections (59).

Fortified milk is an important part of a nutritionally adequate breakfast, the meal where NHANES participant children and adolescents consumed much of their vitamin D. Access to school breakfast programs has been shown to modestly improve educational engagement and performance, with universally free breakfast associated with higher attendance and test scores in elementary schoolchildren (60). There is a serious gap in knowledge about the effects vitamin D–fortified milk provides in US school meals and its potential benefit to improve serum 25(OH)D in racial/ethnically diverse urban schoolchildren with the greatest need during the winter (61). Consideration of the specific health benefits of providing free vitamin D–fortified milk or plant-based milks intended as alternatives to milk to minority students stems from a study in northeastern urban HIS and White children who did not meet the EAR for vitamin D intake, who were vitamin D deficient, but whose dietary vitamin D intake did not explain differences in 25(OH)D between the NHW and HIS children (62). Notably, when vitamin D intake



Nutrition Facts

Serving size	1 cup (240mL)
Amount per serving Calories	120
	% Daily Value*
Total Fat 2.5g	3%
Saturated Fat 0g	0%
Trans Fat 0g	
Polyunsaturated Fat 0.5g	
Monounsaturated Fat 1.5g	
Cholesterol 0mg	0%
Sodium 85mg	4%
Total Carbohydrate 25g	9%
Dietary Fiber 0g	0%
Total Sugars 11g	
Includes 11g Added Sugars	22%
Protein 0g	
Vitamin D 5mcg	25%
Calcium 280mg	20%
Iron 0.4mg	2%
Potassium 30mg	0%
Vitamin A 90mcg	10%
Vitamin B 12 0.6mcg	25%
Phosphorous 150mg	10%

Front of Package Nutrient Content Claim:
ORIGINAL
ENRICHED
Calcium & Vitamin D
20% more of the Daily Value (DV) for Calcium and 25% more of the DV for vitamin D than our Classic Original Rice Drink

INGREDIENTS:
WATER, ORGANIC BROWN RICE (PARTIALLY MILLED), ORGANIC EXPELLER PRESSED CANOLA OIL AND/OR ORGANIC SAFFLOWER OIL AND/OR ORGANIC SUNFLOWER OIL, TRICALCIUM PHOSPHATE, SEA SALT, VITAMIN D2, VITAMIN A PALMITATE, VITAMIN B12.

FIGURE 1 (A) Different levels of vitamin D in fortified cow milk and plant-based milk alternatives that are currently available in the US marketplace are shown. For each level of fortification allowed, the maximum amount of ergocalciferol (vitamin D_2) or cholecalciferol (vitamin D_3) that can be added and the % of the DV of 20 μg/d are shown. (B) The Nutrition Facts label shown here is from a rice-based milk-alternative drink that is fortified with the higher level of vitamin D. Products that have higher levels of vitamin D are now considered "enriched" or "high vitamin D" and must adhere to FDA labeling requirements as shown in this example. The Ingredients list shows that ergocalciferol (vitamin D_2) was added to the plant-based milk alternative consistent with FDA's new regulation. DV, Daily Value.

is very low, variation in serum 25(OH)D concentrations between racial/ethnic groups may be explained by skin color, especially at latitudes where winter sun exposure is limited. Swedish researchers determined that children with fair skin require less vitamin D (14 μg/d or 560 IU/d) compared with darker-skinned children who required 28 μg/d or 1120 IU/d to maintain circulating 25(OH)D $\geq$50 nmol/L in winter (63). Higher childhood vitamin D status was associated with vitamin D supplement use and higher dietary vitamin D intakes, and these likely influenced differences in vitamin D status between NHW and NHB children (64). The evidence provided by the NHANES surveys demonstrating low intakes in all school-aged races/ethnicities during different seasons and at varying latitudes points to the need for even higher vitamin D fortification levels in milk and plant-based alternatives offered in school meals if it is to be an effective intervention addressing the racial/ethnic differences in vitamin D status early in life needed to attenuate the risk of bone disease and other associated adverse health outcomes later in life, especially immune defense.

FDA Update of the Label Guide for Vitamin D Intake (Daily Value) and Amount Added to Dairy and Plant Milks and Yogurts

The US FDA updated the more than 20-y-old Nutrition Facts label required on packaged foods and beverages to help convey new scientific information and nutrition research findings to the American public (65). Important additions to the new label reflect recent scientific findings concerning the importance of vitamin D to both chronic and acute disease risk, morbidity, and mortality. These changes include a large increase in the % Daily Value (DV) for vitamin D from 400 to 800 IU/d (10 to 20 μg/d), and the regulatory requirement to list vitamin D content in micrograms per serving and % DV. The % DV enables consumers to know how much of a specific nutrient in a serving of food contributes to their total daily consumption. Another change in the new Nutrition Facts label is the definition for a food to be labeled with a content claim indicating that it is high in a specific nutrient. The content guide for a "high" label is 20% DV or more; so for a product to have a high vitamin D content claim, a serving would need to have $\geq$4 μg (160 IU) vitamin D. Further, the FDA now requires vitamin D to always be listed on the Nutrition Facts label, evidence that the FDA recognizes that Americans do not always consume the recommended amounts of vitamin D and the importance of this nutrient intake to reduce disease risk.

Except for infant formulas and evaporated milk, all vitamin D fortification of eligible foods in the United States is optional or voluntary and up to the discretion of the manufacturer (66); therefore, the marketplace may feature milk and milk alternatives and yogurts that are not fortified with vitamin D, fortified at the current level, or doubly fortified at the new higher level that the FDA terms "enriched" (**Figure 1**A). In 2016, the FDA approved the voluntary increase in the amount of vitamin D that may be added to milk (all fluid milks), as well as beverages that serve as alternatives to animal milk and yogurts that are made from edible plants (soy, almond, coconut, rice, and others) (67). The FDA recently amended the existing vitamin D additive regulations to now allow manufacturers the option of adding up to 84 IU/100 g to milk or plant-based milk-alternative beverages as either vitamin D_3 (cholecalciferol) or vitamin D_2 (ergocalciferol) and 89 IU vitamin D_2/100 g to plant-based yogurt alternatives (67). The FDA amended §172.379 to allow edible plant-based beverages intended as milk alternatives to be fortified with vitamin D_2 (ergocalciferol) at maximum levels not to exceed 84 IU/100 g (2.1 μg/100 g) (as served) and edible plant-based yogurt alternatives fortified at maximum levels of 89 IU (2.2 μg) vitamin D_2/100 (as served). Section §172.380 was amended to allow levels of vitamin D_3 not to exceed 84 IU/100 g or 800 IU/quart in milk that already contained more than 42 IU vitamin D_3 (cholecalciferol) per 100 g (400 IU/quart, the existing fortification level). The amendment further requires that "the foods meet the requirements for foods named by use of a nutrient content claim and a standardized term in accordance with §130.10" (67). Plainly stated, this means that if manufacturers choose to fortify a food to the new higher levels of vitamin D, then it must be identified in the product name using standardized terms such as "enriched," "more," "extra," and others and/or use of a nutrient content claim such as "high in vitamin D," if a serving contains at least 20% of the DV (160 IU or 4 μg). An example of these labeling requirements is shown in Figure 1B. In the case of a "good source" nutrient content claim, then it needs to contain 10% to 19% of the DV for vitamin D or 80 to 152 IU vitamin D/serving (2 to 3.8 μg). Figure 1A shows the maximum levels of vitamin D that can be added to the various dairy and plant-based alternative milks and yogurts that are currently in the US marketplace; their identification requires reading their labels.

Safety and benefits of vitamin D–fortified milks

Vitamin D can be toxic if consumed in excess, requiring the FDA to conduct an in-depth safety evaluation of the cumulative exposure to vitamin D from all food sources, including the newly proposed uses and dietary supplements, using NHANES 2003–2008. The FDA estimated dietary exposure to vitamin D_2 (ergocalciferol), vitamin D_3 (cholecalciferol), and the intermediate metabolite 25(OH)D naturally found in animal foods. For the US population aged 1 y and older, the FDA estimated exposure to vitamin D to be 2000 IU/d per person at the 90th percentile of intake (67). This exposure is well below the Tolerable Upper Intake Level (UL) of 4000 IU/d per person. The UL is a regulatory guide defined by the Institute of Medicine as the highest mean daily intake level of a nutrient that poses no risk of adverse effects when the nutrient is consumed over long periods of time (67). The FDA concluded that dietary intakes from vitamin D_2 (ergocalciferol) used as a nutrient addition in edible plant-based beverages intended as milk alternatives, edible plant-based yogurt alternatives, and the proposed (now allowable) increased maximum permitted level of vitamin D_3 (cholecalciferol) in milk are safe (67). With the FDA amendments allowing greater vitamin D levels added to either cow milk or plant products intended as milk alternatives, these beverages can be transformed to excellent sources of calcium and vitamin D, as shown in Figure 1B.

Conclusions

The goal of this Perspective was to develop a compelling evidence-based policy position supporting mandatory higher vitamin D fortification of milk and plant-based foods intended as alternatives to milk and yogurt to optimize vitamin D intake benefiting growth, bone health, and enabling a robust immune defense in primary and secondary schoolchildren and adolescents. Data from the nationally representative, cross-sectional NHANES surveys conducted over the last 2 decades document evidence of usual vitamin D intakes significantly below the EAR in school-aged children and adolescents across the 3 main races/ethnicities surveyed in NHANES. NHB and HIS youth have lower vitamin D status than NHW youth, and NHB adolescents have the lowest intakes and vitamin D status. Fluid milk is the most widely consumed vitamin D fortified food by 4–18-y-olds in the United States; recent trials demonstrate strong associations between vitamin D insufficiency and adequate dietary intake gained from vitamin D–fortified milk provided when schools are in session. School intervention trials also provide evidence of increased milk consumption when fortified milk is offered at no cost, as well as better attendance, test scores, bone growth, and resistance to viral infection. We show evidence supporting darker-skinned students' need for higher vitamin D fortification levels than previous FDA regulations allowed for milk; however, recent regulatory amendments now allow higher maximum levels in cow milk and plant-based milks and yogurts intended as alternatives to dairy products that could provide 10 μg/d (400 IU/d) of vitamin D, the EAR, in just 2 servings. A daily dietary increase of 100 IU (2.5 μg) vitamin D is estimated to increase 25(OH)D by 3 nmol/L in children (35); thus, higher vitamin D fortification of milk offered in school meals could attenuate the winter decline in vitamin D status in children and adolescents, especially in NHB and HIS inner-city youths. Given the voluntary nature of the FDA's vitamin D fortification policy in the United States, success of the new vitamin D–enriched milk program for school meals can only be achieved if the new milk enrichment is mandatory for this specific use, like the FDA policy for vitamin D fortification of infant formulas.

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