Public Health Strategies to Overcome Barriers to Optimal Vitamin D Status in Populations with Special Needs

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ABSTRACT In North America, there is increasing public health awareness of the importance of adequate vitamin D intake to the maintenance of optimal vitamin D status and overall health. Experts now define this as circulating levels of 25-hydroxyvitamin D of 75–80 nmol/L. This serum level and high levels of dietary intake have been associated with significantly reduced risk of chronic diseases, such as osteoporosis, cardiovascular disease, diabetes, and some cancers. All of these diseases are more prevalent in the elderly of all races, and some are more prevalent and of greater severity among blacks than whites. Our objective is to review recent actions to increase public awareness of the health importance of maintaining optimal circulating 25(OH)D and potential strategies to increase vitamin D intake. Clinicians and educators are encouraged to promote improved vitamin D intake and status, particularly among the elderly and blacks. This will largely depend on combined efforts to judiciously fortify our food supply and to develop individual supplementation protocols for supplements or controlled use of UV light exposure to maintain optimal serum 25(OH)D, especially in high-risk groups. Growing evidence supports a low risk of toxicity with vitamin D use in fortification or supplementation, despite its past reputation of potential toxicity in excess. The cost to fortify food or supplements with vitamin D is relatively inexpensive compared with developing drugs used to treat or prevent chronic diseases; moreover, there is significant potential for broad health benefits in the reduced risk and prevention of multiple chronic diseases. J. Nutr. 136: 1135–1139, 2006.

KEY WORDS: • vitamin D • fortification • supplementation

Importance of optimal vitamin D status to health. Recent studies have revealed the importance of adequate levels of circulating 25-hydroxyvitamin D [25(OH)D] in preventing chronic diseases associated with significant morbidity and mortality in the U.S. and Canadian populations (1). In the general population of North America, the majority of circulating 25(OH)D originates from cutaneous synthesis upon exposure to sunlight; however, seasonal changes, living at high latitudes or low-pollution altitudes, dark skin pigmentation, and aging are among the many factors that can impede this process, requiring periodic reliance on dietary sources to supply the precursor to 25(OH)D (2,3). Prevalence of low circulating levels of 25(OH)D are higher than anticipated in North America, despite the required fortification of milk (4,5); further, this prevalence is much higher than previously thought, year around, in dark-skinned young and old adults (6). The groups at greatest risk for vitamin D insufficiency and deficiency include African American men, women, and children living in northern latitudes, but all race or ethnic groups with darker skin face some risk during all seasons. Moreover, African Americans and Mexican Americans have a much higher incidence and mortality of specific types of cancers and autoimmune diseases, including diabetes, that cannot be attributed entirely to socioeconomic differences or disparities in health care (4,7).

These populations at risk for low-circulating 25(OH)D or vitamin D insufficiency or deficiency also face unique barriers to
achieving adequate intakes of vitamin D, as addressed by Drs. Harris (7) and Heaney (8) in this issue. Our goals in this article are to review the current guidelines and health policies demonstrating awareness of the importance of maintaining optimal levels of circulating 25(OH)D and adequate levels of vitamin D intake, and to evaluate the specific public health strategies currently in place or proposed that individuals may use to help optimize vitamin D status, especially in the high-risk groups.

Cross-sectional and local studies in North America reveal a significant disparity between amount of vitamin D actually consumed and the amount needed to maintain healthy circulating levels of 25(OH)D. We know, from the nationally representative National Health and Nutrition Examination Surveys (NHANES) conducted in 1988–1994 and 1999–2000 (6,7,9,10), that there has been little change in vitamin D intake over the last decade in the U.S., and that few age, race, and gender groups meet the dietary intake guidelines (Figs. 1 and 2). Moreover, based on median usual intake estimates from NHANES III, even fewer older men and women of all racial and ethnic groups meet the dietary needs demonstrated by Heaney in this symposium (8) that are necessary to maintain serum 25(OH)D at optimal levels (2). In Canada, longitudinal studies in young and primarily white women revealed that consumption of vitamin D at the dietary guideline (5μg) was not effective in maintaining vitamin D status at the 80 nmol level in winter, when cutaneous synthesis of vitamin D is reduced even in younger women (11).

This growing awareness of the need for greater consumption of vitamin D, particularly in the elderly, was conveyed to the public as a key recommendation in the 2005 Dietary Guidelines for Americans (12), which is aimed at older adults, people with dark skin, and people exposed to insufficient ultraviolet band radiation (i.e., sunlight) who are advised to consume extra vitamin D from D-fortified foods and/or supplements. In Canada, the main effort to increase public awareness about the need for vitamin D is through the Osteoporosis Health Claim appearing on eligible food products. This health claim recognizes the importance of both calcium and vitamin D to osteoporosis prevention: “A healthy diet with adequate calcium and vitamin D, and regular physical activity, help to achieve strong bones and may reduce the risk of osteoporosis” (13; p. 306). These initiatives will hopefully draw attention and action to this important dietary need, but such guidelines beg even more important questions: what public health strategies are in place or are proposed to help optimize vitamin D status in North America, and what are the inherent problems that we face with each?

Strategies to correct low dietary vitamin D intake. There are 3 different dietary approaches that could enable most of us to improve our vitamin D status without consulting a physician or participating in a new drug trial. All 3 approaches require educating the public and food manufacturers as to the needed adjustments in labeling or level of fortification. Consumers can improve and maintain vitamin D status through increased consumption of natural or fortified food sources or vitamin D-containing dietary supplements. Planned exposure to sunlight is an alternative approach but beyond the scope of this article. Each approach by itself, or in any combination, could be effective in maintaining 25(OH)D levels. Below, we discuss strategies to overcome the barriers to optimal vitamin D intake associated with natural food sources, fortification of foods, and dietary supplement use.

Natural food sources. There are very few foods that are naturally rich in vitamin D, and most of these are not frequently consumed and are subject to large seasonal variation in vitamin D content (14). Fatty fish, such as salmon, are the richest natural source of vitamin D that is frequently consumed in North America. Frequent fish consumption can be a very effective way to maintain desirable circulating levels of 25(OH)D, as observed in elderly Japanese women (15). Nakamura et al. (15) reported significantly higher mean serum 25(OH)D levels in older women consuming fish more than 4 times/wk relative to those who ate fish less frequently or not at all. Frequent fish eaters were able to maintain desired serum 25(OH)D levels even during the winter.

Other natural vitamin D–rich foods include organ meats, such as liver, but many people do not consume these sources because of the high cholesterol content. A largely unrecognized food source of vitamin D includes all the edible mushrooms, wild and domestic. Wild mushrooms naturally contain small amounts of vitamin D2, but all edible mushrooms make abundant amounts of ergosterol, which, when irradiated with sunlight or UVB light, is converted to vitamin D3 (16–21).
metabolized to 25-hydroxyvitamin D, and functional in promoting bone mineralization in rodent models [20,21]. Depending on the type of mushroom and the duration of UVB exposure, vitamin D2 content may reach as high as 25 μg/g of dried shitake [19]; thus, irradiated cultivated mushrooms are a potential important alternative for fatty fish or other natural food sources of vitamin D and is of particular importance to vegans and vegetarians whose diet is otherwise extremely limited in vitamin D [6].

One common barrier to improving vitamin D intake that is characteristic of all natural food sources, whether of animal or plant origin, is the lack of vitamin D content information on the label. Examination of many different frozen or canned fish products in our respective local marketplace revealed that only the Canadian products were labeled with the vitamin D content, and this important labeling information was highly variable, with its presence being the exception rather than the rule. Similarly, none of the Nutrition Facts panels of any of the mushroom products contained vitamin D content information. The addition of vitamin D content information to the labels is a relatively easy barrier to overcome and would facilitate educating the public about natural sources of vitamin D.

**Fortification.** U.S. and Canadian populations are most reliant on fortified foods to meet their vitamin D needs during the winter months (Fig. 3). Fortified foods constitute the largest contributor (65–87%) to dietary vitamin D intake as calculated from the ongoing NHANES (1999–2000) [10]. Although vitamin D fortification is clearly effective in reaching the general population and is the greatest source of vitamin D for all age, gender, and racial groups, it is apparent that the current level of fortification in the U.S. (4,6) and in Canada (11) is not effective in reaching the needed levels for vitamin D intake. Consideration needs to be given to the level of fortification, especially in countries like Canada, where only 2 food staples, milk and margarine, are required to be fortified, while fortifying other staples with vitamin D is not allowed (2,14). Milk is the major fortified staple in the U.S. and Canada, but as shown by Vieth et al. [11], the amount of vitamin D added to milk (1 μg/100g fluid milk) is not adequate to produce the desired increase or maintenance of circulating 25(OH)D, while fortification at higher levels (10 μg/50g powdered milk) has been shown to be effective in improving vitamin D status and bone mineralization in older women [22].

Another drawback to limiting fortification to only a few staples is the inability to reach vulnerable populations with different dietary preferences or aversions to specific foods such as milk. In the U.S., the 2 major contributors to vitamin D intake observed in both NHANES were from fluid milk products and ready-to-eat cereals (10,14). Significant racial differences in vitamin D intake from these 2 fortified food sources are shown in Table 1 of the introduction to this issue [23]. Because of a higher prevalence of lactose intolerance and low milk consumption in African-Americans, there are marked differences in food consumption patterns between whites and blacks that affect vitamin D intake. Selective fortification of these 2 staples is a major barrier to optimal vitamin D status in African Americans who are at greatest risk of poor vitamin D status.

Unlike Canada, where vitamin D fortification is mandatory for milk and margarine, the addition of vitamin D to eligible foods in the U.S. is optional, with the exception of fortified milk (14). If the label declares that the milk is fortified, then it must contain added vitamin D. Although many categories of foods are eligible for controlled levels of vitamin D fortification in the U.S., there is a large discrepancy between the number of eligible foods and the number and variety of vitamin D–fortified foods currently observed in the U.S. marketplace (14).

By encouraging manufacturers to utilize these fortification options, the vitamin D intake of groups at risk could be significantly improved. To illustrate this point, we used the recommended daily amount of food from each of 6 food categories in the 2005 USDA My Pyramid food intake patterns guidelines (http://www.MyPyramid.gov). We used the 2000 calories/day level as the basis for estimating potential contributions to vitamin D intake if foods in this category were fortified to the maximum optional fortification levels (14). Under current U.S. regulations, food components of 4 of these general food categories are eligible for optional fortification: fruits (calcium-fortified 100% fruit juice), grains, milk, and oils (margarine) (14,24). The maximum allowed fortification of each food in common household units and 100-g equivalents, and the total amount of vitamin D that would be available if the eligible food was fortified to the maximum allowed level, is shown in Table 1. This hypothetical exercise illustrates that considerable amounts of vitamin D could be obtained through mandatory fortification of staples, such as grain products, at levels not to exceed what is currently allowed (14). Cereal grain products include pasta, bread, and other baked goods that are frequently consumed by the general population and could reach specific target populations, such as the elderly. Consideration should be given to fortifying them at levels of 25 μg/100g.

**TABLE 1.** Hypothetical contributions to vitamin D intake in the United States through universal fortification of eligible foods at the maximum level currently allowed

<table>
<thead>
<tr>
<th>Food category</th>
<th>Daily suggested amount consumed</th>
<th>Maximum allowed addition of vitamin D</th>
<th>Potential amount of vitamin D from fortification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruits</td>
<td>2 cups (474)</td>
<td>100 (RACC)</td>
<td>5.0 (200)</td>
</tr>
<tr>
<td>Grains</td>
<td>6 oz (168)</td>
<td>90 (100 g)</td>
<td>3.7 (153)</td>
</tr>
<tr>
<td>Milk</td>
<td>3 cups (711)</td>
<td>42 (100 g)</td>
<td>7.5 (302)</td>
</tr>
<tr>
<td>Oils (margarine)</td>
<td>6 tsp (30)</td>
<td>331 (100 g)</td>
<td>2.5 (99.3)</td>
</tr>
</tbody>
</table>

1. Food patterns obtained from the USDA MyPyramid guidelines for the amount of food in each category recommended to be consumed as a healthy eating pattern for a 2000 kcal daily intake.

2. Maximal level of vitamin D that can be added in accordance with the Code of Federal Regulations governing the addition of vitamin D 21 CFR 184.1 (b) (2) for this category of food.

3. RACC, reference amount customarily consumed, or the USFDA regulatory serving size.
given to a proposed shift from optional to mandatory fortification for eligible food staples frequently consumed by the entire population as a potentially viable and effective strategy to meet vitamin D needs of target groups. The safety and efficacy of the recently proposed mandatory fortification of cereal and grain products (25) clearly merits further study.

Supplementation. Dietary supplement use is another option for improving vitamin D status. The NHANES (2,10,26) show that supplement use can significantly increase vitamin D intake across all age, race, ethnic, and gender groups. However, as observed in NHANES III, the benefit of supplement use was gained more in persons whose intakes were already above the median intake and less gain was observed in individuals with low vitamin D intake from food (2). Supplement use varies among race or ethnic groups, with African Americans consuming the lowest amount from supplements. Furthermore, there are significant racial differences in the effect of daily intake of supplements containing >400 IU (10 μg) vitamin D (Fig. 4). Nesby-O'Dell et al. (26) showed that the prevalence of vitamin D insufficiency is markedly higher in African Americans compared with Caucasian women, even when both consume >10 μg/d (400 IU/d). Harris et al. (27,28) show similar differences in older African American and Caucasian women consuming vitamin D supplements at or above the recommended intake guidelines. In a recent study, African American women (15–49 y) were given daily vitamin D supplements (400 IU, 10 μg) in addition to their usual food sources of vitamin D, but 11% of these subjects had serum 25(OH)D levels <37.5 nmol/L, a conservative cutoff point for vitamin D insufficiency (29). These findings suggest the need for race- or age-specific dietary supplements with higher vitamin D content that reflects the specific needs of the group.

As discussed by Heaney in this symposium (8), many experts now believe that intakes of 25–65 μg/d (1000–2600 IU/d) are needed for many people to achieve 75–80 nmol/L circulating concentrations of 25(OH)D (30,31). For the elderly and dark skinned, this suggests the need for dietary supplements with higher vitamin D levels than what is currently available without prescription.

The vitamin D content of dietary supplements for daily use in the U.S. ranges from 200 to 400 IU/tablet (5–10 μg/tablet), while those in Canada contain 400–1000 IU (10–25 μg/tablet). Dietary supplements are allowed to contain up to the tolerable upper limit (2000 IU or 50μg) as designated by the 1997 Dietary Reference Intakes (32). Although manufacturers of daily use, multiple, or single-nutrient supplements in the U.S. have not yet responded to the growing public demand for greater vitamin D potency, others have. Several novel products have entered the marketplace in the U.S. and Canada that are food-like in many respects, but are clearly identified as dietary or vitamin supplements. In Canada, there are a number of fruit drinks that are fortified with a variety of nutrients, but the vitamin D content is only ~70 IU or <2 μg. The Nutrition Facts panel of a recent FDA-approved dietary supplement, now available in the U.S., is shown in Figure 5. This chocolate candy, or dietary supplement, contains 2000 IU (50 μg) of vitamin D and represents the most potent supplement source of vitamin D sold over the counter in the U.S. The introduction of this novel dietary supplement product lowers the barrier to obtaining adequate vitamin D intake for many individuals and suggests a new approach to providing products that are custom designed to the tastes and needs of a specific target population.

Conclusion. With each of the 3 public health strategies discussed here, there is a need for both safety- and efficacy-testing of any changes introduced, such as a shift from optional to mandatory fortification of cereal grain products. At minimum, this would entail monitoring the circulating levels of 25(OH)D, parathyroid hormone, and other select endpoints that would reflect improved vitamin D status or potential toxicity. In this issue, Vieth (33) discusses the growing evidence that supports a low risk of toxicity from vitamin D use in fortification or supplementation. The development of natural food sources with higher vitamin D content, the shift to mandatory fortification of cereal grain staples, or the development of high-potency–food-based vitamin D supplements...
are all potentially safe and effective mechanisms for overcoming the barriers to optimal vitamin D status, and they each merit further study. The cost to fortify food with vitamin D or to increase supplement potency is relatively inexpensive compared with the cost of developing drug treatments for the many chronic diseases strongly associated with vitamin D insufficiency. In the case of maintaining optimal vitamin D status, an ounce of prevention may very well be worth a pound of cure.

LITERATURE CITED


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