

D-FENCE AGAINST THE CANADIAN WINTER: MAKING INSUFFICIENT VITAMIN D LEVELS A HIGHER PRIORITY FOR PUBLIC HEALTH[†]

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SUMMARY

With most of the country situated above the latitude of the 42nd parallel north, there is a significant portion of the Canadian population that is not getting enough of the sunshine vitamin during the winter. Vitamin D is naturally produced when skin is exposed to sunlight, however during the winter months in Canada the sun is too low in the sky for this to occur. A full quarter of the Canadian population is estimated to have vitamin D levels so low as to be considered insufficient or deficient by Health Canada guidelines.

Increasing vitamin D intake should be considered a public health priority. Vitamin D deficiency is known to be linked to rickets in children and osteomalacia in adults (bone softening and malformation) as well as osteoporosis (loss of bone density, increasing susceptibility to fractures). However a growing body of evidence also suggests that vitamin D may have a role in the prevention of chronic diseases such as heart disease, high blood pressure, diabetes, cancer, cognitive decline, Parkinson's disease, multiple sclerosis and arthritis.

There is, of course, no way to change Canada's proximity to the equator. But there are ways to help Canadians get more vitamin D through dietary intake. Improving the vitamin D status of the Canadian population through food fortification and dietary supplements represents an inexpensive intervention that can improve the health of the population, but debate remains over how much vitamin D the Canadian population needs and how to ensure the population adheres to whatever recommendations are made.

Food fortification has already demonstrated its effectiveness in improving vitamin D levels (as it has for other public health priorities, such as with iodized salt). Decades ago, the prevalence of rickets in Canadian children led health professionals to lobby for, and win, legislation making vitamin D fortification mandatory for milk. Other foods, such as orange juice, milk of plant origin and margarine are sometimes also fortified with vitamin D. However many Canadians do not consume milk or the other fortified foods or do not take dietary supplements at the current recommended levels, increasing their risk of vitamin D insufficiency.

It is clear there is a need to gain a better understanding of the benefits and the costs of strategies associated with vitamin D intake in the general population. There have been longstanding concerns about the risk of people consuming too much vitamin D (leading to hypercalcemia). More recently there has emerged great disagreement in the scientific and regulatory communities over what constitutes an excessive dosage of vitamin D, and even what constitutes the optimal blood-serum level for vitamin D. The inability to settle on firm guidelines is paralyzing any movement towards increasing vitamin D intake in the Canadian population.

Fortification and public health strategies are needed to ensure current vitamin D targets are met. Health Canada's proposal to allow greater levels of vitamins and minerals to be added to foods, to meet consumer demand (within maximum limits), has been on the table since 2005. A decade later, the Canadian winters have grown no shorter, and the solar zenith angle has not changed. It is becoming an increasingly urgent matter of public health to reach a consensus on updated guidelines for vitamin D intake levels and limits, to better inform Canadians.

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INTRODUCTION

Are Canadians getting enough vitamin D? Virtually all Canadians live above the latitude of the 42nd parallel north (only the southernmost tip of Ontario lies south of it), so between October and March they experience what has been referred to as a “vitamin D winter.” That is, Canadians have too little ultraviolet B (UVB) light exposure from the sun to maintain appropriate levels of vitamin D in their bloodstreams (as measured by 25(OH)D serum levels). With few natural dietary sources of vitamin D, food fortification and dietary supplements have been important strategies for ensuring that Canadians acquire the vitamin D that they need. While the health benefits of vitamin D are most commonly associated with clinical conditions arising from vitamin D deficiency, such as rickets in children and osteomalacia in adults (bone softening and malformations), or osteoporosis in adults (loss of bone density that makes bones more susceptible to fractures), with increased understanding of the full extent of the biological mechanisms of vitamin D, there has been a dramatic increase in studies suggesting that vitamin D may have positive health benefits beyond bone health, including the prevention of chronic diseases. The discussion about vitamin D has shifted from a question of deficiency, as indicated by clinical conditions, to one of insufficiency in terms of increased risk of adverse health outcomes and chronic diseases. For many researchers, these projected health benefits are associated with higher intakes of vitamin D than are currently recommended through Health Canada’s dietary guidance. For others, higher intakes raise concerns over risks of vitamin D toxicity without strong enough evidence of the health benefits to justify the increased health risks.

There is a growing body of associative evidence suggesting a connection between vitamin D deficiency and non-skeletal chronic diseases¹ including cancer (Lappe et al. 2007), cardiovascular disease (Giovannucci et al. 2008, Wang et al. 2008), metabolic disorders (Pittas et al. 2007), infectious disease (Yamshchikov et al. 2009), autoimmune disease (Cutolo et al. 2007, Myhr 2009) and mortality (Melamed et al. 2008).² These associations could be of great importance to public health if found to be causal, particularly in the Canadian population residing at a high latitude. A recent burden-of-disease study in the United States estimates that 26 per cent of deaths and 14 per cent of disability-adjusted life years in the U.S. are attributed to dietary risk factors, even without counting the impact of obesity (US Burden of Disease Collaborators 2013). A study estimating the economic burden in Canada attributable to low vitamin D status projected that increasing the mean serum level to 105 nmol/L could reduce annual death rates by 16.1 per cent (37,000 deaths/year) and ultimately reduce the chronic disease burden in Canada by \$14.4 billion (6.9 per cent), less the cost of the program (Grant et al. 2010). Given that raising vitamin D levels with supplements in Canada costs as little as \$15–20 per person per year, there is potentially an economic case to be made for the large reductions in chronic-disease burdens that have been associated with higher vitamin D status. However, conditions of what qualifies as necessary and sufficient evidence of health benefit must first be met.

Given the relatively low cost of vitamin D supplements and food-fortification strategies, and the potentially sizeable benefits for health, there is value in investigating what the physiological normal and safe range of 25(OH)D serum levels are in order to determine what level of supplementation the population needs to improve the well-being of Canadians and contribute to the sustainability of Canada’s

¹ Data obtained from several organ systems suggest that, in addition to the established endocrine actions of vitamin D, there are autocrine actions (activity of vitamin D that may occur from 1,25(OH)₂D synthesized within those cells), and/or paracrine actions (1,25(OH)₂D is synthesized in one cell type and acts within adjacent cells) as well. This new paradigm provides a plausible explanation for the observational data that optimal health outcomes are associated with higher levels of serum 25(OH)D than previously considered. However, the evidence is currently based on in vitro studies in pathological situations and more in vivo evidence in the normal circulatory system is needed (Plum and DeLuca 2010).

² The basis for the non-skeletal chronic-disease health benefits of vitamin D intake is rooted in the presence of vitamin D receptors in an array of tissues (Holick 2007).

publicly funded health-care system.³ Vitamin D supplementation recommendations are made as a means to make up for the deficiency in skin synthesis, due to the lifestyle of Canadians and the latitude at which they reside. This is similar to other nutrition regulatory strategies for public health, such as adding iodine to salt or other nutrients to food.

In any policy-making framework there are multidimensional considerations that influence public health nutrition policy, including the science (as an institution and process), the scientific community, the policy-making process and its institutions/actors, and wider contextual elements (Timotijevic et al. 2013). Conceptually, the role of nutrition policy is to choose the policy options that maximize the likelihood of the target population achieving a desired health outcome from vitamin D, which in this case is optimal health through prevention of nutrient deficiency. Any policy recommendations require consideration of what constitutes necessary and sufficient evidence for health benefits and, analogously, absence of harms to health. The debate should focus on what evidence and levels of evidence are sufficient to inform policy recommendations in the best interest of the public. In this report we first summarize some relevant background on vitamin D, and strategies to increase vitamin D intake, and then identify two policy challenges that have emerged with respect to vitamin D intake. The first involves how to get the population to achieve whatever level of intake is chosen, and the second concerns the challenges for determining the biologically normal and safe levels of vitamin D intake that would be necessary for optimal health.

WHAT IS THE ISSUE?

Vitamin D is important for health

Vitamin D has a clear role in the regulation of calcium absorption, which is important for bone health and facilitating muscle function. The benefits of vitamin D may go beyond bone health, playing a role in suppression, and perhaps treatment, of a large number of diseases. Obtaining sufficient vitamin D to achieve these health benefits can be a challenge. Vitamin D can be obtained from either dietary sources (through natural or fortified foods or supplementation) or it can be produced endogenously through UVB exposure of the skin, all sources being equally effective in the human body.⁴ Vitamin D is biologically inactive and is converted in the liver to calcidiol (25-hydroxyvitamin D₃ (25(OH)D)). It is 25(OH)D that is measured in blood serum to determine a patient's vitamin D level because it more accurately reflects all vitamin D loading from dietary intake and sunlight exposure, as well as the conversion of vitamin D from fat stores in the liver (Institute of Medicine 2010).

Canadians are at risk of deficiency

With virtually all Canadians living above the latitude of the 42nd parallel north, vitamin D deficiency is a concern in Canada, where residents experience a “vitamin D winter” between October and March, characterized as reduced skin synthesis of vitamin D from UVB light exposure. Sunlight⁵ is the main source for obtaining vitamin D naturally (typically constituting about 40 to 50 per cent), with the remainder obtained through dietary sources (Rosen 2011). The advantage of obtaining vitamin

³ Grant et al. calculate that raising vitamin D levels to 100 nmol/L in Canada through the use of supplements would cost as little as \$15–20 per person per year and has the potential to reduce the chronic-disease burden in Canada by \$14.4 billion (6.9 per cent), less the cost of the program (Grant et al. 2010).

⁴ Vitamin D has two chemical forms: D₃ is the form made in animals from UVB irradiation, and D₂ is the form made by yeasts and fungi after UVB irradiation.

⁵ UVB radiation with a wavelength of 290 to 315 nm.

D through sunlight exposure is that there is no risk of toxicity from prolonged exposure since excess previtamin D or vitamin D is destroyed by sunlight. However, increased UVB exposure can result in an increased risk of skin cancer.

There are several physiological, environmental, social and cultural factors that affect vitamin D synthesis from sun exposure and result in reduced vitamin D production in the skin. Physiological factors such as skin pigmentation, body size and aging impact the synthesis of vitamin D in the skin. Environmental factors that impact the UVB radiation of the skin include solar zenith angle (season and time of day), cloud cover, ozone-layer thickness, surface reflection, altitude, windows, and sunscreen usage. Social and cultural factors, such as an individual's living and workplace environment, wearing concealing clothing, cultural practices, and sun-exposure preferences can also impact cutaneous exposure to UVB radiation. For a complete review of these factors see Whiting and Calvo (2011).

WHAT IS ENOUGH VITAMIN D?

Current recommendations

Since 2010, Health Canada's Dietary Reference Intake (DRI) for vitamin D recommends that Canadians consume 600 International Units (IU) per day to achieve a level where 97.5 per cent of the Canadian population would have a serum 25(OH)D level of 50 nmol/L or higher, the threshold established by the Institute of Medicine as sufficient for health. To avoid unnecessary health risks associated with vitamin D toxicity or long-term intake, Health Canada recommends an upper tolerable limit for daily intake of 4,000 IU/day.

Dietary Reference Intake (DRI) values were first introduced in the mid-1990s as dietary intake recommendations for nutrients. DRI is an umbrella term that describes four types of reference values including the Estimated Average Requirement (EAR), Recommended Dietary Allowance (RDA), Adequate Intake (AI) and Tolerable Upper Intake Level (UL) (Table 1). In the initial DRI values in the mid-1990s, only vitamin D AI values were established, as there was not sufficient evidence to estimate RDA and EAR values.

The realization that sun exposure in North America is inadequate to meet vitamin D needs caused the Canadian and U.S. governments to task the Institute of Medicine (IOM) of the U.S. National Academy of Sciences with developing new DRI values in 2010. The IOM's process for the review of data on vitamin D included a risk-assessment approach, where potential health-outcome indicators were identified to establish the DRIs. Data have emerged that allow a requirement distribution to be simulated for vitamin D and these updated guidelines are three times higher than DRI values established in the 1990s. The IOM developed these reference values (Table 1) based on background information on the metabolism and physiology of calcium and vitamin D.⁶

From a policy perspective, the DRI reference values are important for nutrition policy. At a minimum, a policy focus should be targeted at increasing the serum 25(OH)D levels within the population to achieve the recommended vitamin D status either via sunlight exposure, diet, and/or supplementation. The goal of assessing the dietary data of vitamin D is to determine if the population is meeting its needs for a particular nutrient. The purpose of assessing the usual intakes is to determine the prevalence of

⁶ It is important to note that the RDA is a recommended intake that is expected to result in 97.5 per cent of the population having a 25(OH)D of 50 nmol/L or higher (97.5 per cent probability intake is adequate). Research from Taylor and colleagues found that, when analyzing the prevalence of inadequacy using blood status, a statistical-probability method using an EAR-type value would be appropriate and can also be more accurate compared to using a high-end RDA-type cut-off value (Taylor et al. 2013).

inadequacy of a particular group.⁷ The IOM expert committee suggests that, with respect to bone health, people are at risk of vitamin D deficiency at serum 25(OH)D concentrations less than 30 nmol/L. Some people are potentially at risk for inadequacy at levels ranging from 30–50 nmol/L, and practically all people are sufficient at levels greater than or equal to 50 nmol/L. The guidelines suggest that there may be reason to be concerned about increased health risks at serum concentrations greater than 125 nmol/L (Institute of Medicine 2010).

The DRI guidelines that emerged in 2010 from the IOM serve as the official nutrient-intake guidelines for North America, used by both the general public and health professionals. Health Canada uses the DRI in policies and programs that benefit the health and safety of Canadians. Policy-makers use the DRIs to evaluate and improve food supplies to meet national needs, and health workers use the DRI to provide nutrition education, such as the “per cent daily value” (% DV) labels on food. DRIs are also used for nutritional recommendations and in institutions to plan healthful diets for schools, prisons, hospitals and nursing homes, as well as in industry to develop new food products. The IOM guidelines are recommendations for a healthy population and are distinct from recommendations for high-risk subpopulations and disease states.

With the new recommendations provided in 2010, the challenge became translating these quantitative reference-nutrient values into food-based recommendations for the healthy Canadian population. Health Canada and the Canadian Food Inspection Agency (CFIA) oversee the regulatory process of food labelling in Canada.⁸ The current RDA is not used to inform the “% DV” printed on food labels in Canada. The “% DV” is currently based on the RDA of 200 IU for vitamin D — the RDA established in the 1990s and identified as too low by the IOM in 2010. With the change to the RDA values, to make the same claim regarding the “% DV,” more vitamin D needs to be added to supplemented foods. Health Canada is working on updating the “% DVs” to better reflect the more recent IOM-recommended DRI values.⁹

The “% DVs” for vitamins and mineral nutrients are derived based on the “population coverage” principle of choosing the highest recommended intake values for ages two years and above, omitting supplemental needs for pregnancy and lactation¹⁰ (Health Canada 2014). To limit confusion with the new reference values developed for different demographics, Health Canada is proposing to use the population-weighted RDA of 600 IU as the revised “% DV.” The proposed value would allow Health Canada to monitor vitamin D status of Canadians and decide later whether further increasing the “% DV” to 800 IU is warranted. Nutrition labelling is designed to allow consumers to rapidly and efficiently understand how a particular food fits in the context of a healthy diet. The “% DV” is based on a caloric intake of 2,000 calories for adults and children four years of age and older.

As noted above, the IOM guidelines are recommendations for a healthy population and are distinct from recommendations for high-risk subpopulations and disease states. Providing a single intake-recommendation value is difficult because things such as sunlight exposure, age-related changes in cutaneous vitamin D formation, BMI, skin pigmentation and availability of food containing vitamin D all affect vitamin D status. Separate recommendations for supplementation to achieve 25(OH)D targets specific for normal weight, overweight and obese individuals are needed. Supplementation may need to be two to three times higher for obese subjects and 1.5 times higher for overweight subjects relative

⁷ The proportion of usual nutrient intakes less than the EAR is equivalent to the proportion of a group with intakes below requirements.

⁸ Health Canada is responsible for setting health and safety standards and for developing food-labelling policies related to health and nutrition under the Food and Drugs Act. The Canada Food Inspection Agency (CFIA) is responsible for administering other food-labelling policies and enforcing all food-labelling regulations.

⁹ See Health Canada (2014) for Health Canada’s Proposed Changes to the Daily Values for Use in Nutrition Labelling.

¹⁰ The “% DV” is printed on nutrition-facts labels in the U.S. and Canada with the “per cent daily value” being the amount of nutrient per serving divided by the daily value of a nutrient multiplied by 100 (Health Canada 2014).

to normal-weight subjects, depending on an individual's baseline (Ekwaru et al. 2014). Breastfeeding mothers or pregnant women are other examples of individuals who may need higher vitamin D intake. A mother needs vitamin D in her blood to get it into her milk.¹¹ The concern is that North American breastfeeding mothers can't provide enough vitamin D to their babies through their breast milk, resulting in infants not consuming adequate intakes of vitamin D (Perrine et al. 2010). According to the IOM, the effect of vitamin D on pregnancy and lactation is presently unclear (Institute of Medicine 2010). Existing evidence from the DRI report suggests that vitamin D intake from food does not appear to affect bone resorption in mothers during lactation, nor its restoration during the post-lactation period. However, a recent study suggests that a maternal intake over 4,000 IU/d could achieve substantial progress toward improving both maternal and neonatal nutritional vitamin D status (Oberhelman et al. 2013). A better understanding of the impact of vitamin D intake in obese or pregnant/breastfeeding subpopulations is needed to inform clinical guidelines.

TABLE 1 DIETARY REFERENCE INTAKE COMPONENTS

Dietary Reference Intake Components	Description and serum 25(OH)D reference value	Supplement reference value IU/day	Application	Issues
Estimated Average Requirement (EAR)	Reference value: 40 nmol/L. Estimated population median requirement where half of the population meets its needs for a nutrient (50 per cent probability that intake is adequate (Taylor 2008)).	400 IU for people between one and 70 years of age.	Reference point for assessing the adequacy of intake for groups.	Need to ensure there is adequate data to allow a reasonable approximation of variability in the requirement and the resulting distribution among individuals.
Recommended Dietary Allowance (RDA)	Reference value: 50 nmol/L Two standard deviations ¹ from the EAR, reflecting the variability around the median (Taylor 2008) and meets or exceeds the requirement for 97.5 per cent of the population.	600 IU for people from one to 70 years of age. 800 IU for elderly over 70 years of age.	Reference value that is above the intake required for 97.5 per cent of the population and is not a target intended to be met by all individuals.	Based on the assumption that the distribution of the nutrient requirements in the population is a normal Gaussian distribution; however there is concern that this is not the case with vitamin D.
Tolerable Upper Intake Level (UL)	Reference value: (no target serum level given). The highest average daily intake that is likely to pose no risk of adverse effects to almost all individuals in the general population.	1,000 IU: infants zero to six months. 1,500 IU: infants seven to 12 months. 2,500 IU: children one to three years. 3,000 IU: children four to eight years. 4,000 IU: people over nine years.	Top dose where there is no risk of adverse health effects. Doses over the UL are treated as a drug intervention that, in theory, should have medical supervision.	Determining this level is difficult and largely depends on experimental animal data and observational studies. There is controversy over what level of evidence should be used (Institute of Medicine 2010).
Adequate Intake (AI)	Reference value: (no target serum level given). Average intake level based on observed or experimental intakes, used when an EAR/RDA cannot be developed.	400 IU per day from birth to 12 months of age.	Developed to address the uncertainties associated with specifying requirements for infants, however obtaining adequate information for infants is a challenge.	Criticized for not fitting into the probability assumptions for DRI use, because it is determined based on experimentally determined estimates of a specific group with adequate nutritional state (Taylor 2008).

1. In the case of vitamin D, the variance is not precisely known from data to calculate the SD, so the assumption is that a 10 per cent coefficient of variation (CV) should be used. For this reason, some are critical of the RDA value because it is not a scientifically derived value based on an assumption of the variance.

¹¹ Continuous intake is required because 25(OH)D doesn't transfer to the infant in breast milk and there is a 24-hour half-life of vitamin D in the blood.

HOW DO WE GET ALL CANADIANS TO THE CURRENTLY RECOMMENDED LEVEL OF VITAMIN D?

It is clear that there remains a significant portion of the Canadian population deficient in vitamin D. An estimated 25 and 66 per cent of Canadians have serum 25(OH)D levels below 50 nmol/L and 75 nmol/L respectively¹² (Whiting et al. 2011). Supplement non-users tend to have lower serum levels than do supplement users. Data also suggest that some subpopulations are particularly at risk of vitamin D deficiency.

Dietary sources of vitamin D include natural food sources, fortified foods and supplementation. Foods that naturally contain vitamin D are oily fish (such as salmon, sardines, mackerel, tuna and cod liver oil) for D₃; shiitake mushrooms for D₂; and egg yolk for small amounts of D₂ (when fed UV-irradiated yeast) or D₃ (Holick 2007). With few dietary sources of vitamin D, food fortification and dietary supplements have been important strategies for ensuring Canadians acquire the vitamin D that they need. To improve the vitamin D status of the Canadian population, food fortification, dietary supplementation and public education all need to be considered as practical strategies to be pursued.

Food fortification to increase vitamin D intake

Some believe that food fortification represents the best opportunity to increase the vitamin D supply to the population (Kiely and Black 2012). Food fortification is an approach used for correcting nutritional insufficiencies in the general population.¹³ In Canada, some types of commonly consumed foods are required to be fortified with vitamin D, with around 60 per cent of the dietary intake of vitamin D thought to be from fortified foods (Calvo and Whiting 2013a). Mandatory vitamin D fortification includes cow's milk, margarine and infant formula. Cheese and yogurt can be made with vitamin D-fortified milk. Other foods can be fortified with vitamin D on a voluntary basis, including milk of plant origin (soy, rice and other grains), goat's milk, some foods for special dietary uses (such as nutritional supplements and meal replacements), and calcium-fortified orange and tangerine juices (Health Canada 2006). Bread and cream of mushroom soup can be made with vitamin D-enhanced yeast and mushrooms (Health Canada 2011).

The adequacy of fortified foods for meeting the needs of the Canadian population are under question (Vatanparast et al. 2010). Since its inception in the 1930s to reduce death from rickets due to malnutrition, food fortification in Canada has been cautiously limited due to concerns of over-fortification (Calvo and Whiting 2013b). Historically, foods such as fruit drinks, biscuits, cereals, milk and margarine could be fortified with vitamin D at levels of 400 IU in 1942 and then 800 IU in 1949. In the 1960s there was concern that this fortification was contributing to excess vitamin D in some children, although no reports of resulting adverse effects were reported. These concerns resulted in the Canadian government limiting voluntary fortification to standardized food staples including milk and margarine (Calvo and Whiting 2013b). Due to the continued occurrence of new cases of rickets in Canada, health professionals lobbied for, and were successful in getting legislation making vitamin D fortification of milk mandatory in 1975. A study by Whiting et al. (2011) suggests that current food choices alone are insufficient to maintain recommended 25(OH)D concentrations (50 nmol/L) in many Canadians, especially in winter. There are concerns about this method, as food preferences vary widely and there are questions about the effectiveness of reaching vulnerable populations with food

¹² Note that the EAR 40 nmol/L should be used to assess prevalence of inadequacy in a population.

¹³ For a complete listing of the regulated addition of vitamin D fortification to food in Canada, see Table 21.3 in Calvo and Whiting (2013b).

fortification. An example of this is that many Canadians don't consume milk (and other fortified foods) at the current recommendation levels, meaning that vulnerable subgroups, such as those with low milk consumption for a variety of cultural and other reasons, are at risk of vitamin D deficiency.

Given that a majority of Canadians consume less than the currently recommended intake of vitamin D from food (Vatanparast et al. 2010), consideration should be given to strategies to improve vitamin D intake among Canadians by increasing both the amount of vitamin D added to foods and the range of foods eligible for fortification. Given the low vitamin D intake from food, new regulations for allowing the addition of vitamins and minerals to Canadian foods have been proposed.¹⁴ This proposed policy would allow voluntary fortification from the manufacturer to meet market demand (within defined limits set by Health Canada for voluntary fortification). This is an avenue that needs careful consideration to ensure that food is fortified in a way that has the most benefit to Canadians, as voluntary fortification can have some of the same risks as mandatory fortification in exceeding the upper tolerable limit for safe intake (Calvo and Whiting 2013b). However, allowing the option to provide foods (such as orange juice) with and without fortification gives the consumer a choice and the ability to mitigate some of this risk. There is concern that consumption of foods slated for discretionary fortification would ultimately be associated with lower nutrient intakes and suboptimal food-intake patterns. If adding nutrients to these foods reinforces their consumption, discretionary fortification might function to discourage healthier eating patterns (Sacco and Tarasuk 2011).

Increasing vitamin D fortification of dairy products is another strategy that can lead to increased intake for Canadians without a risk of excess (Shakur, Lou, and L'Abbe 2014). However some suggest that to achieve better vitamin D adequacy in the Canadian population, strategies that fortify foods other than milk and milk products may need to be employed simply because a significant number of North Americans don't drink milk (Calvo and Whiting 2003). Recent information that animal-based foods contain 25(OH)D¹⁵ may mean that these are another source of vitamin D that should be considered in intake estimates (Taylor et al. 2014). Vitamin D enrichment of foods through "biofortification" is yet another potential source for fortification. This involves post-harvest or pre-processing manipulation of foods that result in high vitamin D content¹⁶ (Calvo and Whiting 2013a).

An important limitation on the use of food fortification to raise blood-serum levels of vitamin D is the current low upper-limit levels in the IOM guidelines, particularly for children with a UL of 1,500 IU/day. From a policy perspective, the UL value is a barrier to increased fortification of food with vitamin D, as all food fortification must account for the UL set for children. There is a trade-off between adding enough vitamin D to prevent vitamin D deficiency in people with low levels who consume few fortified foods, and preventing excessive intakes in people with high vitamin D levels (and therefore do not benefit from vitamin D fortification). If the UL is artificially low for children, this affects food fortification for all demographics.

Supplementation and public education to increase vitamin D intake

Supplementation of vitamin D is another approach that can be used to address the lack of natural sources of dietary vitamin D. The DRI values established by the IOM determined that 600 IU of vitamin D for those under 70 years of age (800 IU for those over 70 years of age), meets the needs of almost everyone

¹⁴ Proposed policy outlined in "Addition of Vitamins and Minerals to Food 2005: Health Canada's Proposed Policy and Implementations Plans."

¹⁵ A metabolite of vitamin D that is not currently factored into estimates of vitamin D intake.

¹⁶ An example is post-harvest exposure of edible mushrooms to ultraviolet light to enhance their vitamin D (Calvo et al. 2013). These mushrooms are available in the marketplace as a source of vitamin D enrichment in specific brands of mushroom soup.

in North America. These values were established based on dietary intake assuming minimal sun exposure. Dietary supplements may be the only approach for some individuals with poor nutrient status. Conceptually, supplementation is a method that has the advantage of facilitating correct dosage and adjustment for specific needs of vulnerable populations or target groups. Education strategies for health-care professionals and the general public are important to ensure all Canadians meet the DRI value for vitamin D.

It is important that health-care professionals know the facts about vitamin D. It has been reported that 75 per cent of Canadian medical professionals are open to receiving more education about vitamin D (Jaglal et al. 2003) and establishing clear clinical guidelines is important in this respect. It is clear that health-care professionals know that vitamin D nutrition is important, but they need to seek further education about current recommendations and follow these recommendations carefully.

Public education of the health benefits associated with vitamin D levels at 50 nmol/L would help to reduce the prevalence of 25(OH)D below these levels, particularly education targeted at vulnerable populations that may have inadequate intake through their diet. A 2005 Kaiser Family Foundation survey reported that 40 per cent of respondents got their health information from media, compared to the 20 and 14 per cent getting information from health professionals and family members respectively (Henry J. Kaiser Foundation 2005). An evaluation of high-circulation U.S. and Canadian newspaper coverage of the latest IOM report on Dietary Reference Intakes for calcium and vitamin D suggest that newspaper articles did not consistently or comprehensively report the IOM recommendations (Hatfield et al. 2013). Informing the public is important, as it is the individual that regulates his or her own daily dietary vitamin D intake through food sources and supplements. Given that the public relies heavily on the news media to obtain an objective translation of dietary recommendations, better communication to the public about how to achieve the recommended intake of vitamin D (particularly in the winter) is needed.

THE DILEMMA CONTINUES: WHAT IS ENOUGH VITAMIN D?

The normative interpretation of a vitamin D insufficiency depends on evidence from the published literature and what decision-makers and researchers believe to be sufficient evidence of benefit. There is debate over what level of vitamin D supplementation should be recommended. It is well established that maintaining adequate vitamin D levels is important for bone health. A recent clinical-practice article in the *New England Journal of Medicine* suggests that, in the United States, 53 nmol/L is a level that does not require vitamin D supplementation, as this level is sufficient for bone health (Rosen 2011). However, some researchers and clinicians believe that the RDA based on evidence for bone health is too conservative to achieve serum levels that would result in benefits beyond bone health.¹⁷ Clinical-practice guidelines set by physicians tend to reflect recommendations for vitamin D intake higher than that suggested in the established DRI values. Examples of some of these alternate vitamin D guidelines are summarized in Table 2. The discrepancy is, in part, due to guidelines acknowledging and considering populations that may be in need of higher vitamin D intake (Hanley et al. 2010). For example, the Endocrine Society estimates that obese subjects should be given two to three times more vitamin D relative to normal-weight subjects (Holick et al. 2011, Ekwaru et al. 2014).

¹⁷ The hormonally active form of vitamin D (1,25(OH)₂D) binds the vitamin D receptor (VDR), which has been found in virtually every tissue in the body, some of which are not involved in calcium and phosphorus homeostasis (Bouillon et al. 2008). Some studies suggest that the vitamin D hormone is capable of modulating the expression of a very large number of genes, possibly up to 10 per cent of the genome (Morris and Anderson 2010). Investigations into non-skeletal chronic-disease health benefits are due to the many diverse actions of vitamin D through nuclear receptors present on tissues throughout the body. For a more comprehensive and detailed description of mechanism of action of 1,25(OH)₂D, see these reviews: Demay 2006 and Christakos et al. 2007.

An evolutionary biological perspective suggests that optimal 25(OH)D levels should reflect the over-100 nmol/L levels of our evolutionary ancestors who inhabited tropical, sunny environments (Vieth 2011, 2006; Barger-Lux and Heaney 2002). These levels of vitamin D are reflected in populations with ample sun exposure (i.e., outdoor workers in sunny environments). The “natural” range of 25(OH)D levels in a population with ample exposure to sun is anywhere from 100–200 nmol/L with little to no vitamin D supplementation (Vieth 2011, 2006; Barger-Lux and Heaney 2002). Vieth (2006) suggests that a serum concentration of 25(OH)D, for which our genome might have been effectively designed through evolution and natural selection (more than 100 nmol/L), should be considered the optimal level for human health.¹⁸

Those who advocate for intake of vitamin D above the RDA, point to emerging evidence that low 25(OH)D concentrations may be associated with non-skeletal disorders such as heart disease, high blood pressure, diabetes, cancer, cognitive decline, Parkinson’s disease, multiple sclerosis and arthritis. Many of these extra-skeletal effects of vitamin D are supported by biological plausibility and observational studies that suggest that at least greater than 75 nmol/L and even greater than 100 nmol/L may be a more suitable characterization for the “normal range” of serum 25(OH)D, based on achieving full health benefits from vitamin D (Bischoff-Ferrari et al. 2006; Vieth 2011). If the goal is to achieve serum target-levels for extra-skeletal health benefits, then the prevalence of vitamin D insufficiency could be interpreted as widespread. As noted earlier, an estimated 25 per cent of Canadians have serum 25(OH)D levels below 50 nmol/L¹⁹ and 66 per cent of Canadians have 25(OH)D levels below 75 nmol/L (Whiting et al. 2011).

The Health Canada guidelines are clear that all Canadians should achieve a minimum serum 25(OH)D level. For those suggesting that vitamin D intake in Canada should be higher to achieve health benefits beyond bone health, there is a need for clear messaging as to what criteria should be used to determine an appropriate target serum level. As seen in Table 2, the variability in guidelines around 25(OH)D target levels and recommended daily intake make it difficult for the average Canadian to determine what daily intake of vitamin D he or she should target. There is a particular need for clarification as to what level of intake is appropriate for Canadians at high risk of vitamin D deficiency.

TABLE 2 VITAMIN D GUIDELINES

	25(OH)D deficient serum level	25(OH)D insufficient serum level	25(OH)D target serum level	Recommended daily intake (adults)
Health Canada and IOM guidelines	30 nmol/L	30-50 nmol/L	50 nmol/L	600 IU per day
Endocrine Society guidelines (Maxmen 2011)	<50 nmol/L	50 nmol/L-72.5 nmol/L	75-150 nmol/L	1,500-2,000 IU
Osteoporosis Canada guidelines (Osteoporosis Canada 2013)	<50 nmol/L	<75 nmol/L	75-150 nmol/L	400-1,000 IU
Toward optimized practice (TOP) guidelines	N/A	N/A	N/A	800-2,000 IU
Laboratory reference range (Rosen 2011, Cianferotti and Marcocci 2012)	<25 nmol/L	25-75 nmol/L	75-185 nmol/L	N/A
The Vitamin D Society guidelines	N/A	<100 nmol/L	100-150 nmol/L	75 IU per kg/day (i.e., 5,625 IU for 75 kg)

¹⁸ This argument refers to the northern migration of heavily pigmented women, which resulted in — among other problems — low serum 25(OH)D thought to contribute to increased difficulty of childbirth and a higher incidence of rickets in children (clinically presenting as stunted growth and deformed skeletal extremities). This is hypothesized to be the reason why Neanderthals varied in pigmentation levels with some having pale skin and red hair, potentially on the scale observed in modern humans (Lalueza-Fox et al. 2007). Reduced pigmentation was likely an advantage in Europe, increasing sunlight-mediated vitamin D synthesis. This is demonstrated today in the skin pigmentation of indigenous peoples, which varies according to ambient solar UV doses (Jablonski and Chaplin 2000).

¹⁹ Note that 40 nmol/L should be used to assess prevalence of inadequacy in a population, according to the IOM.

WHAT LEVEL OF EVIDENCE IS NECESSARY AND SUFFICIENT FOR VITAMIN D POLICY?

The debate over what concentration of vitamin D is optimal is ongoing, and until it is resolved it paralyzes discussion around related guidelines for intake. The issue is that the projected health benefits of higher vitamin D levels are associated with higher intakes of vitamin D than are currently recommended through Health Canada's dietary guidance. These higher intakes raise concerns over risks of vitamin D toxicity. Ultimately, in order for DRI recommendations to change, a consensus needs to be found on what criteria for evidence can be used to answer nutrient-adequacy questions. Using the evidence-based medicine approach,²⁰ randomized control trials (RCTs) are a preferred means for defining policy recommendations about how the health benefits and risks of vitamin D can be changed (Bouillon 2011). Recent umbrella reviews of systematic reviews and meta-analyses looking at the breadth and validity of the claims associated with non-skeletal chronic-disease health benefits and the risk of cause-specific death, suggest a lack of convincing associations.²¹ However there are concerns that the adaptation of this evidence-based medicine approach is not best suited to the nutrition context.²² This is because there are innate complexities of nutrient actions and interactions, which can't be adequately addressed through any single research design, and therefore the totality of the available evidence must be evaluated. Here we discuss some of the key findings from these recent reviews in the context of the debate over the quality of evidence needed to inform intake guidelines.

Randomized control trials and the evidence-based medicine approach

Study design is a critical aspect in determining the quality of evidence for establishing a normal vitamin D level. Recent reviews of the evidence related to the non-skeletal chronic-disease health benefits of vitamin D, suggest that higher vitamin D intake could have limited benefits. However, conclusions from cohort studies can be problematic because there may be confounding variables, such as obesity and physical activity levels, that bias the interpretation (Scragg 2011). Some suggest that even probable associations holding promise for clinical translation, found from high-level RCT and systematic review evidence, can only pertain to specific populations rather than being useful for universal recommendations about daily intake (Theodoratou et al. 2014). This would mean that randomized trials may be needed mainly to inform the design of pivotal mega-trials of comprehensive nutrition-type interventions (Ioannidis 2013).

In an umbrella review of the existing evidence²³ looking at health outcomes associated with 25(OH) D levels, only 10 of 137 different health outcomes reported to be connected to vitamin D were tested thoroughly in clinical trials (Theodoratou et al. 2014). Of these 10, one study²⁴ was found to have

²⁰ In the evidence-based medicine approach, used by the IOM and most other regulatory bodies, there is a hierarchy of evidence with regards to interpretation on causation; as you move up the pyramid, the amount of available literature decreases, the relevance to the clinical setting increases, and the probable benefit of positive findings increases. Animal studies and laboratory research are at the fundamental level, where ideas are formed and then tested. Case-control sectional studies show correlation and are the lowest level of clinical evidence due to the bias that can occur with the disease process. Cohort studies are considered to not be as reliable as RCTs because measurement often precedes disease onset, meaning there may be other confounding variables influencing the findings. The RCTs provide strong evidence because randomization and blinding reduce the bias that occurs in other studies when comparing intervention and control groups (Scragg 2011). Systematic reviews and meta-analyses are at the top of the evidence pyramid because they critically review and synthesize existing literature with sound methodology, although these are not primary literature sources and should be interpreted in this light.

²¹ For greater detail see: Theodoratou et al. (2014) and Chowdhury et al. (2014).

²² This argument is well summarized in Blumberg et al. (2010).

²³ Two-hundred-sixty-eight literature reviews and meta-analyses of observational studies and clinical trials

²⁴ Birth weight was linked to a mother's vitamin D level in late pregnancy.

“convincing” evidence of benefit²⁵ and four other studies²⁶ were found to have “probable” evidence of benefit.²⁷ Overall, this umbrella review agreed with the earlier IOM report that evidence for the benefits of higher levels of vitamin D intake at the population level is weak, finding a lack of convincing associations and a relative dearth of probable associations (Theodoratou et al. 2014). Another umbrella review²⁸ looking at the association between low-circulating vitamin D and risk of mortality found an inverse association of circulating 25(OH)D with risks of death due to cardiovascular disease, cancer, and other causes (Chowdhury et al. 2014). Supplementation with vitamin D₃ (but not vitamin D₂) was also found to significantly reduce overall mortality among older adults. The overall conclusions of these umbrella reviews were that policy recommendations from these studies are not possible because more studies, larger studies and better-designed trials are needed to establish the optimal dose and duration.

The authors of these type of umbrella reviews argue that observational data should be used cautiously, suggesting that new trial data should “focus on potential risks as well as benefits” (Kmietowicz 2014). Those arguing for the necessity of RCT evidence identify that research on vitamin D may produce the same safety and effectiveness concerns in clinical trials as was seen previously for vitamin A and E.²⁹ Observational findings do need to be interpreted with caution; however there are some fundamental distinctions between vitamin D and vitamins A and E. Unlike vitamin A and E, vitamin D levels being recommended are only at physiological levels, in contrast to the higher-than-physiological levels seen in the studies of concern for vitamins A and E. Notably, vitamin D supplementation is recommended as a means to make up for the deficiency in skin synthesis due to lifestyle and population latitude.

Is the adaptation of evidence-based medicine best suited to the nutrition context?

Critics of the existing approach that requires RCT and systematic-review evidence to inform policy are concerned that, in the nutrition context, RCTs have a strong bias for a null result and are at risk of suboptimal design³⁰ and suboptimal execution.³¹ It is because of these concerns that some suggest that systematic reviews and meta-analyses, including studies with these flaws, are misleading and can

²⁵ Defined by the umbrella review as being a statistically significant association found in both observational and RCT studies free from bias.

²⁶ Evidence for an association between vitamin D concentrations and dental caries in children, birth weight, maternal vitamin D levels at term and parathyroid hormone levels in patients with chronic kidney disease.

²⁷ Defined by the umbrella review as being a statistically significant association found in both observational and RCT studies, but further studies and better-designed trials are needed for firmer conclusions.

²⁸ Systemic review and meta-analysis of 73 observational cohort studies and 22 RCTs.

²⁹ For vitamins A and E, there were observational studies showing an inverse association between nutrient status and the risk of cancer and cardiovascular disease, however later RCT and systematic reviews showed that increased intake (beyond physiological levels) with these vitamins actually increases mortality and lung cancer risks (Byers 2010, Bjelakovic et al. 2012).

³⁰ In the context of nutrients that possess a “therapeutic window,” a suboptimal design may include dosing that exceeds this physiologic window resulting in detrimental effects (such as the study looking at vitamin D supraphysiologic dosing (Omenn et al. 1996)) — i.e., design of dosing, population not representative, study size too small.

³¹ Suboptimal execution in large RCTs (i.e., failure to randomize, low compliance, crossover in groups) can also occur as seen in the Multiple Risk Factor Intervention Trial (MRFIT), which is a randomized primary prevention trial to test the effect of a multifactor intervention program on mortality from coronary heart disease. Unfortunately, in this study the control group changed its behaviour in a way that was similar to the way the treatment group changed its behaviour, resulting in no change from the null (Willett 2010). This lack of a control group resulted in findings that showed smoking didn’t increase the risk of mortality, illustrating the issues associated with RCTs that have suboptimal execution. This experience suggests that we may not be able to evaluate many dietary hypotheses using decade-long randomized trials that require changes in eating behaviour.

actually be detrimental to nutritional policy development. In vitamin D research, critical biological criteria³² necessary for an RCT to be informative, may be ignored or extremely difficult to achieve, resulting in a null result (Lappe and Heaney 2012).

At a minimum, study design needs to be carefully considered in research concerning nutrient efficacy. Where RCTs can demonstrate where a health outcome is caused by vitamin D, the identification of a benefit or an absence of benefit is not clearly necessary or sufficient evidence for identifying the physiological normal range for vitamin D. In this respect, the Grades of Recommendation, Assessment, Development and Evaluation (GRADE) Working Group has developed a system for grading the quality of evidence that may be a helpful addition to the current evidence-based medicine methodology (Guyatt et al. 2008a, Guyatt et al. 2008b). A modification of this GRADE approach would allow for the ability to evaluate the quality of the study within the hierarchy of evidence so that more of a judgment on the whole body of evidence can be made. This could help when determining guidelines for a vitamin D framework. Observational evidence may be upgraded based on the magnitude of the effect, existence of a dose-response curve, or removal of all plausible confounding variables that would impact the effect. This may be a way forward in providing a more systematic approach to assessing the quality of the evidence.

What vitamin D level is safe?

As with any health policy consideration, the expectation of health benefits of vitamin D intake need to be balanced against the risks to health. Unlike vitamin D from sunlight, which has no toxicity risk, excess vitamin D from dietary sources can be toxic, however it is unclear what constitutes an excessive dose. The primary risk factor associated with vitamin D intoxication is hypercalcemia,³³ which draws calcium from the bones into the blood, potentially calcifying blood vessels, soft tissues and the kidneys (Holick 2007). In light of the concerns over the state and strength of the evidence on the safety of vitamin D, the IOM and Health Canada opted to establish a UL of 4,000 IU per day that is considered to pose no risk of adverse effects. Some experts believe the RDA and UL set by the IOM is far too conservative. However for any change to the UL to occur, clarity is needed as to what a toxic level of vitamin D intake is, and if there are any long-term safety concerns associated with higher vitamin D intake.

Vitamin D toxicity is often defined by serum 25(OH)D levels greater than 375 nmol/L, even though some authors indicate a lower value (250 nmol/L) could be associated with toxicity (Hathcock et al. 2007). Vitamin D intoxication is an extremely rare medical condition, with daily doses up to 40,000 IU per day³⁴ not being associated with hypercalcemia (Koutkia, Chen and Holick 2001, Vieth, Chan and MacFarlane 2001, Cianferotti and Marcocci 2012). Safety studies for vitamin D supplementation report no adverse effects from vitamin D₃ dosed up to 50,000 IU/day and from vitamin D₂ up to 18,000 IU/day³⁵ (Hathcock et al. 2007, Bischoff-Ferrari et al. 2010).

³² Biological criteria needed for an RCT to be informative include: use of a single form of the nutrient, use of a low-exposure control group, adequacy of dose in the treatment group, demonstration/documentation of the altered intake/exposure, use of uniform response measure, optimization of co-nutrient status (Lappe and Heaney 2012).

³³ Hypercalcemia is above-normal calcium levels in the blood that can result from excessive vitamin D intake. The classic symptoms associated with hypercalcemia include nausea, dehydration and lethargy (Koutkia, Chen, and Holick 2001).

³⁴ Serum concentrations should not exceed 200 nmol/L.

³⁵ These studies also show intermittent doses as high as 100,000 IU per day have been given with no toxic symptoms, although there is some evidence that mega-doses (300,000–500,000 IU) of vitamin D can be harmful (Sanders et al. 2010, Smith et al. 2007). These two high-dose RCTs suggest there may be potential harm associated with supraphysiological levels of vitamin D (Sanders, Nicholson and Ebeling 2013). Some are skeptical as to how much can be interpreted from these two studies because the distribution of risk factors for falls is missing, making it difficult to establish a connection between high vitamin D serum levels and fractures (Minisola et al. 2013). Daily or more frequent, intermittent dosing is a preferred supplementation method (Sanders et al. 2010).

Given this, some suggest that the UL should be changed to 10,000 IU per day (Vieth 1999, Hathcock et al. 2007, Holick 2007, Rajakumar, Reis and Holick 2013). The IOM report states that the “data do suggest is that it would be unlikely to observe symptoms of toxicity at daily intakes below 10,000 IU, while it is possible that daily intakes above could be associated with toxicity.” There is a growing number of observational studies demonstrating safety when supplementing with higher doses of vitamin D, but short-term findings related to the extreme conditions of toxicity are not the ideal basis for setting ULs for the general population, which apply to long-term exposure (Institute of Medicine 2010). There are now some RCTs underway using higher doses of vitamin D³⁶ and these studies can help address this deficiency in the literature (Scragg 2011). Without studies showing the safety of long-term exposure of higher 25(OH)D serum levels, there will continue to be concern regarding the safety of raising the recommended daily intake for the population.

Even with the extremely high doses necessary for acute vitamin D toxicity, an additional concern with the safety of vitamin D supplementation lies in the uncertainty of long-term effects. Some studies have shown a U-shape or reverse-J-shape risk curve for serum 25(OH) D concentrations and prostate cancer, esophageal, pancreatic cancer, cardiovascular disease, and all-cause mortality, with adverse effects or elevated mortality at the higher doses (75–120 nmol/L) (Melamed et al. 2008, Jia, Aucott and McNeill 2007, Stolzenberg-Solomon et al. 2010) although there are alternate theories.^{37,38} The uncertainty regarding whether disease risk is linear or in a U-shaped pattern is important to determine, as this helps dictate if prevention should be targeted at the population level or towards high-risk groups.

From a policy perspective, the UL value is a barrier to increased supplementation and fortification of food with vitamin D to achieve levels suggested for some of the non-skeletal chronic disease health benefits discussed. In terms of food fortification, the current UL levels in the IOM guidelines, particularly for children with an upper limit of 1,500 IU/day, limit the possibilities of fortification, as all food fortification must account for the UL set for children. It is clear that to achieve vitamin D levels above 75 nmol/L (if this is desirable) may require supplementation or food fortification above the upper tolerable limit in some cases (depending on the individual baseline). In terms of supplementation, to increase 25(OH)D serum levels over 80 nmol/L from the existing average level in the Canadian population (66.9 nmol/L) would require an oral-supplement intake of 2,000 to 4,000 IU/day, which is currently at the tolerable upper limit for intake in Canada³⁹ (Vieth 2006, Heaney et al. 2003).

CONCLUSION

Given our northern latitude, Canadians need to obtain much of their vitamin D through dietary sources: natural food sources, fortified or enhanced food, and supplements. Currently many Canadians are deficient by the standards set by the IOM. This paper has reviewed the current Health Canada recommendations for vitamin D and discussed some key policy implications surrounding them.

³⁶ The US VITAL study and the ViDA study from New Zealand

³⁷ An explanation for this U-shape relationship with vitamin D is that this relationship arose through either statistical fluctuations associated with low numbers of cases or alternative confounding factors (Grant 2009). This theory suggests that these studies attempt to identify the risk-modifying factors associated with some types of cancer and disease, however given there are many different confounding factors it is difficult to draw any conclusions from these studies (Grant 2009).

³⁸ An alternate explanation is that this phenomenon is based on seasonal fluctuations (Vieth 2004).

³⁹ A rough estimate of the relationship between supplementation and serum vitamin D levels suggests that each additional 1 microgram of vitamin D will increase serum 25 (OH)D levels by approximately 0.7 nmol/L (Heaney et al. 2003). For someone with a baseline level of 50 nmol/L, supplementation of 4,600 IU per/day is required to maintain a serum vitamin D concentration of 80 nmol/L (Heaney et al. 2003).

It is clear that, at minimum, public policy within Canada needs to be targeted at increasing compliance with the current intake recommendations to ensure no Canadians are deficient in vitamin D. Strategies to increase the vitamin D status of the Canadian population should include a combination of food fortification, supplements and public education. As a population strategy, food fortification is best suited to improving 25(OH)D levels, however for food fortification to meet current intake requirements, it appears that there needs to be an increase in both the amount of vitamin D added to foods and the range of foods eligible for fortification. Providing greater consumer choice by allowing more voluntary fortification is one way forward. Increasing the level of fortification of dairy products is another possible solution, although there clearly needs to be alternatives for those who don't consume milk products. Biofortification of other staples, such as bread, may provide a viable alternative. Supplementation of vitamin D is another approach that can be used to address the lack of natural sources of dietary vitamin D, particularly for individuals with poor nutrient status. Public education, particularly targeted at vulnerable populations, of the health benefits associated with vitamin D levels at 50 nmol/L could help to reduce the prevalence of 25(OH)D below these levels. Ultimately, these strategies should look carefully at appropriate food vehicles and approaches, taking into account all vitamin D sources with the goal of fulfilling requirements of intake recommendations or preferable 25(OH)D serum concentrations.

There is an economic incentive for government to achieve an optimal level of vitamin D status, due to the evidence of improved public health from doing so. Improving the health of Canadians and preventing chronic conditions will improve the well-being of Canadians and contribute to the sustainability of Canada's publicly funded health-care system. However, two key issues from the scientific literature need to be addressed before policy can be explored in this area. First, establishing what the appropriate range of normal 25(OH)D serum levels is for optimum health is a critical discussion that needs to be had when addressing whether Canadians get enough vitamin D. It is well established that maintaining adequate vitamin D levels is important for bone health and protection against rickets in children (osteomalacia in adults) or osteoporosis in adults. The issue to be addressed before policy changes can be made is whether there are benefits beyond bone health. There is evolutionary, epidemiological and clinical trial evidence that suggests additional health benefits from higher vitamin D status. However, the implications of vitamin D levels above 75 nmol/L are not clearly understood. At the crux of this discussion is the issue of whether RCT evidence is necessary or whether non-RCT evidence is sufficient for determining RDA recommendations. These are important issues for establishing a normal range of serum 25(OH)D and must be resolved before any policy recommendations can be made.

A second key issue is related to the risk of potential adverse health outcomes from vitamin D supplementation. Some are concerned that the current upper tolerable limit is too conservative and is limiting the opportunity for likely health benefits at higher recommended 25(OH)D targets like 75 nmol/L. The UL value may be an unnecessary barrier to increased supplementation and fortification of food with vitamin D to achieve levels suggested for some of the non-skeletal chronic disease health benefits. However the health benefits of vitamin D intake need to be balanced against the risks to health associated with high vitamin D intakes. Ultimately, vitamin D nutritional guidelines should reflect current scientific knowledge and any policy recommendations surrounding vitamin D intake should be based on sufficient evidence to establish the health benefits and the safety of such an increase. Determining these guidelines would be greatly aided by an agreement over what evidence, and levels of evidence, are sufficient to inform policy recommendations in the best interest of the public.

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