Review

An estimate of the economic burden and premature deaths due to vitamin D deficiency in Canada

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The objective of this work is to estimate the economic burden and premature death rate in Canada attributable to low serum 25-hydroxyvitamin D (25(OH)D) levels. Vitamin D deficiency has been linked to many diseases and conditions in addition to bone diseases, including many types of cancer, several bacterial and viral infections, autoimmune diseases, cardiovascular diseases, and adverse pregnancy outcomes. Canadians have mean serum 25(OH)D levels averaging 67 nmol/L. The journal literature was searched for papers reporting dose–response relationships for vitamin D indices and disease outcomes. The types of studies useful in this regard include randomized controlled trials, observational, cross-sectional, and ecological studies, and meta-analyses. The mortality rates for 2005 were obtained from Statistics Canada. The economic burden data were obtained from Health Canada. The estimated benefits in disease reduction were based on increasing the mean serum 25(OH)D level to 105 nmol/L. It is estimated that the death rate could fall by 37 000 deaths (22 300–52 300 deaths), representing 16.1% (9.7–22.7%) of annuals deaths and the economic burden by 6.9% (3.8–10.0%) or $14.4 billion ($8.0 billion–$20.1 billion) less the cost of the program. It is recommended that Canadian health policy leaders consider measures to increase serum 25(OH)D levels for all Canadians.

1 Introduction

Vitamin D deficiency has been linked to many diseases and conditions in addition to bone diseases, including many types of cancer, bacterial and viral infections, autoimmune diseases, and cardiovascular diseases. Several recent papers review the health benefits of vitamin D [1–6]. Schwalfenberg [2] summarized many studies on the benefits of vitamin D, with special emphasis on how these benefits relate to Canadians.

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Abbreviations: MS, multiple sclerosis; **RCT,** randomized controlled trial; **UVB,** ultraviolet-B

As most of the Canadian population lies north of 43°N, producing vitamin D from solar ultraviolet-B (UVB) irradiance is impossible for at least 4–5 months of the year [7, 8]. The Canadian diet typically provides only 5 µg (200 IU) from foods, not enough to maintain serum 25-hydroxyvitamin D levels, the main indicator of vitamin D status, in a range compatible with health benefits [7, 8]. The desirable serum 25(OH)D level is at least 100 nmol/L, a level that has generally been found to provide most of the health benefits of vitamin D [9–12].

Canadians are at high risk for vitamin D deficiency, as shown by a high prevalence of low serum 25(OH)D levels in both winter and summer [6, 13–16] (http://www.statcan.gc.ca/daily-quotidien/090702/t090702a1-eng.htm). Preliminary data from the Canadian Health Measures survey indicates that for Canadians aged 6–79 years, the mean annual serum 25(OH)D is 66.9 nmol/L, with 5% at or below severe defi-

ciency (<25 nmol/L) and only 10% at or above the optimal level (100 nmol/L) [16].

The objective of this work is to estimate the burden of disease from vitamin D deficiency in Canada and how the number of deaths *per* year as well as how the economic burden could change if the mean serum 25(OH)D of Canadians was increased from 67 to 105 nmol/L, a value that would ensure that over half of the population has levels in the optimal range. This task is hindered by the fact that for many diseases, the basis for a vitamin D dose–disease response relationship is limited to a small number of observational and cross-sectional studies along with ecological and mechanistic studies. Until recently, many of the randomized controlled trials (RCTs) used 400 IU/day of vitamin D [17], which is insufficient to produce a significant effect for any disease other than rickets. However, we argue that in the case of vitamin D, RCTs are not necessarily required to determine dose–response relationships because vitamin D is a naturally occurring compound and that as humans moved to different solar environments, skin pigmentation adapted to permit vitamin D production while still affording protection against the adverse effects of free radical formation and DNA damage [18]. In addition, all cells have vitamin D receptors and they control gene expression [19]. Given a sufficient number of observational studies, meta-analyses can be performed to determine rather robust dose–response relationships. As for evaluating whether the link between vitamin D and various diseases are causal, the criteria for causality as laid down by A. Bradford Hill [20] can be used [21].

1.2 Data sources

For this study, reports on the effects of solar UVB and vitamin D were obtained by searching the PubMed database (http://www.pubmed.gov) administered by the National Institutes of Health and the National Library of Medicine. Articles were chosen based on finding significant vitamin D effects for disease incidence or mortality rates. Included are case-control, cohort, meta-analyses of observational data and RCTs that used more than 400 IU/day vitamin D. Oral intake of 400 IU/day of vitamin D reduces the risk of rickets but has little benefit for cancer [17].

Data on deaths and death rates for 2005 for diseases related to vitamin D were obtained from the Statistics Bureau, Canada [22] (http://www.statcan.gc.ca/pub/84–215-x/2008000/tbl/tbla1-eng.htm).

The economic burden data were obtained from *Economic Burden of Illness in Canada, 1998* [23] (http://www.phac-aspc.gc.ca/publicat/ebic-femc98/pdf/ebic1998.pdf). Although this report is a decade old, it is nevertheless the most recent comprehensive report and includes both direct and indirect costs. The values were updated to values for 2008 by using the inflation factor in a recent Canadian government report [24] (http://secure.cihi.ca/cihiweb/products/nhex_2008_en.pdf).

The health benefits of higher serum 25(OH)D levels were estimated in Grant *et al.* [25]. The estimated benefits range from 10% for chronic obstructive pulmonary disease to 60% for multiple sclerosis (MS). For 2007, the reduction in economic burden for Western Europe was estimated at 187 billion € *per* year. The estimated beneficial effects of vitamin D in this study differs somewhat from that in Grant *et al.* [25] in that additional studies are now available for some diseases while the evidence for other diseases is now considered preliminary rather than strong.

Table 1 summarizes comparisons of benefits of vitamin D supplements or higher serum 25(OH)D from the literature search for the health benefits of vitamin D. Representative results are given for vitamin D-sensitive diseases important in Canada. In some cases, information is available regarding vitamin D dose–disease response at several serum 25(OH)D levels.

2 Results

2.1 Cancer

There are several studies that can be used for estimating the dose–response for cancer: the Physicians' Follow Up Health Study [41], meta-analyses determined for breast [27] and colorectal [9] cancer incidence, and the results of a RCT for all-cancer incidence [11]. The assumption is made that incidence and mortality rates have similar dose–response relationships. Support for this assumption is found in an ecological study of cancer incidence and mortality rates in the United States with respect to solar UVB doses and other factors. For most cancers, higher correlations with UVB were found for mortality rate than incidence rate [42]. From these studies, the best estimate is that increasing serum 25(OH)D from about 75 to 105 nmol/L, all-cancer incidence rates would decrease by about 25% (15–35%), a value which is adopted for Canada going from 67 to 105 nmol/L mean value. Note that the uncertainty range is not a 95% confidence interval but, rather, an estimate based on ranges reported in various studies. This approach is used throughout this paper.

2.2 Cardiovascular disease

For the family of cardiovascular diseases, there are several recent papers with odds or risk ratios for incidence or death with respect to ranges of serum 25(OH)D (Table 1). When the results of these studies are plotted in terms of hazard ratio with respect to serum 25(OH)D by quantile from four studies [29–32] in a preliminary pooled analysis, a very significant inverse correlation is found. The hazard ratios for serum 25(OH)D levels compared to 107 nmol/L are 1.2 for 80 nmol/L, 1.4 for 56 nmol/L, 1.6 for 43 nmol/L, and 2.0 for 26 nmol/L. The finding is that increasing serum 25(OH)D level from 62.5 to 105 nmol/L reduces risk by 25% (15–35%).

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Table 1. Recent results from the literature regarding disease outcome with measures of serum 25(OH)D or oral intake of vitamin D

Disease incidence	Finding with respect to serum 25(OH)D level or vitamin D supplementation	Study type	Reference
Cancer (all)	RR=0.232 (CI, 0.09, 0.60; $p<0.005$) for 1100 IU/day+1450 mg/day calcium (serum 25(OH)D increased from 29 to 39 ng/mL RR=0.59 (95% CI, 0.29–1.21; $p=0.15$) for 1450 mg/day calcium	RCT	[11]
Breast cancer	50% reduction for 30 *versus* 5 ng/mL	Meta-analysis	[26, 27]
Breast cancer	OR=0.56 (95% CI, 0.41–0.78) for 40 *versus* <20 ng/mL	CC	[28]
Colon cancer	OR=0.46 (95% CI, 0.32–0.64) for 38 compared to 6 ng/mL	Meta-analysis	[9]
Cardiovascular disease, death	HR=0.76 (95% CI, 0.60–0.95) for the highest quintile of 25(OH)D level *versus* the lowest	Cohort, Finland 933/6219	[29]
	Adjusted HR=2.36 (95% CI=1.17–4.75), for 25(OH)D <10.0 *versus* 40.0 ng/mL)	Cohort, USA 767 deaths	[30]
Coronary heart disease, incidence	RR=2.09 (95% CI, 1.24–3.54; $p_{trend}=0.02$) for <10 *versus* >30 ng/mL	Cohort 454/18,225	[31]
Coronary heart disease, death	HR=2.17 (95% CI, 1.58–2.99) <10 ng/mL; =1.40 (1.03–1.91) for >10 but <20 ng/mL	Cohort	[32]
Diabetes mellitus, incidence	Combined daily intake of >1200 mg calcium and >800 IU vitamin D was associated with a 33% lower risk of type 2 diabetes with RR of 0.67 (95% CI, 0.49–0.90) compared with an intake of <600 mg and 400 IU calcium and vitamin D, respectively		[33]
	OR=0.28 (95% CI, 0.10–0.81 for >30 *versus* <10 ng/mL (males)	Nested CC	[34]
	OR=0.62 (95% CI 0.41–0.94) for males and 0.59 (95% CI 0.38–0.91) for females for highest *versus* lowest calcium intake with higher vitamin D intake		[35]
Influenza, common cold	RR = 0.4 for 800 IU/day *versus* placebo; =0.1 for 2000 IU/day *versus* placebo	CC	[36]
Pneumonia as a complication of influenza	Adjusted r^2 for case-fatality rate with respect to UVB index=0.77 following incidence of A/H1N1 influenza in the US in 1918	Ecologic study	[37]
Falls and fractures	RR = 0.81 (95% CI, 0.71–0.92) for 700–1000 IU/day	CS	[38]
All-cause mortality	MRR = 1.26 (95% CI, 1.08–1.46) >32.1 *versus* <17.8 ng/mL	CS	[39]
	Adjusted Cox proportional HR = 1.88 (95% CI, 1.02–3.44; $p=0.04$) for mean 25(OH)D of 12 *versus* 24 ng/mL	Cohort 51/614	[40]
	Adjusted HR for subjects with levels <10.0 ng/mL was 1.83 (95% CI = 1.14–2.94) *versus* >40 ng/mL and for levels of 10.0–24.9 ng/mL was 1.47 (95% CI = 1.09–1.97)	Cross-section 1493 deaths	[30]

WHO; CC, case-control; CI, confidence interval; COPD, chronic obstructive pulmonary disease; CS, cross-sectional; FEV1, forced expiratory volume in the first second; FVC, forced vital capacity; HR, hazard ratio; NHANES III, National Health and Nutrition Examination Survey III; OR, odds ratio; RR, relative risk; SE, standard error.

2.3 Type 2 diabetes mellitus

There are three recent papers that present dose–response relationships for type 2 diabetes mellitus from observational studies [33, 34]. Calcium supplementation also reduced the risk of diabetes. In two nested-case control studies in Finland, a benefit for vitamin D was found for men but not for women [34]. The reasons for the difference were not readily apparent. However, in a study from New Zealand, vitamin D supplementation that brought 25(OH)D levels above 80 nmol/L improved insulin resistance by 12% [43]. Increasing vitamin D levels from 25 to 75 nmol/L results in a 60% improvement in insulin sensitivity [44].

2.4 MS

For MS, the primary risk factor is infection by the Epstein-Barr virus and vitamin D reduces the risk of MS by greatly reducing the risk of Epstein-Barr virus infection [45]. Based on the geographical prevalence of MS in the United States [46], vitamin D greatly reduces the risk of MS since the prevalence increases rapidly with increasing latitude, an index of wintertime solar UVB and vitamin D [47]. A value of 40% (20–60%) reduction is used. However, once MS develops, vitamin D can reduce the symptoms but not reverse the disease [48]. A recent comprehensive review of the evidence indicates that vitamin D reduces the risk of developing MS and is likely to be beneficial in treatment [49].

2.5 Fall and fractures

The minimum level of 25(OH)D to achieve optimal bone health should be 80 nmol/L for all people for two reasons: parathyroid hormone levels begin to increase when the 25(OH)D level is below 78 nmol/L [50], and a mean level of 86 nmol/L results in a 65% increase in absorption of calcium as compared to a level of 50 nmol/L [51]. A recent study showed a 72% reduction of falls when 800 IU of vitamin D were given. There was no benefit with 200/400/600 IU of vitamin D [52]. For risk of fracture, the meta-analysis of RCTs [53] is used. However, this estimate is probably an underestimate for this study since the meta-analysis compared the risk for supplementation with 700–800 IU/day of vitamin D compared to 400 IU/day and none of the treated subjects achieved a level close to 100 nmol/L. In this study, a value of 30% (95% CI, 20–40%) is used; however, since we do not have data for falls separate from musculoskeletal diseases, a value of 10% (5–15%) is used in the analysis.

2.6 Influenza, pneumonia

It has been hypothesized that epidemic influenza was seasonal largely due to annual variations in solar UVB doses [54],

and this hypothesis was then supported in a *post hoc* analysis of incidence of influenza and common cold in a 3-year vitamin D supplementation study [36]. The mechanism whereby vitamin D reduces the risk of viral and bacterial infections is through induction of human cathelicidin, LL-37 [55], which has antimicrobial and antiendotoxin properties [56]. Since bacterial pneumonia is often a consequence of influenza infection in older people and all people in the case of H1N1 influenza [57], it is noted that vitamin D also reduces the risk of pneumonia [37]. A recent study in Canada found the mean vitamin D level for the acute lower respiratory infection subjects admitted to the pediatric intensive care unit (49 ± 24 nmol/L) was significantly lower than that observed for both control (83 ± 30 nmol/L) and acute lower respiratory infection subjects admitted to the general pediatrics ward (87 ± 39 nmol/L) [58]. Based on these studies, a value of 30% (20–40%) reduction is used.

2.7 Septicemia

Septicemia is bacterial infection of the blood and is generally associated with infections contracted in hospitals, especially after operations. It was hypothesized that septicemia is vitamin D sensitive, based on the epidemiology of septicemia in the United States, which has all the hallmarks of a vitamin D-deficiency disease based on geographical and seasonal variations, racial disparities, and comorbid disease links [59]. This hypothesis paper was supported by a case-control study at Emory University that found those who developed septicemia or who were in the intensive care unit had much lower serum 25(OH)D levels than community controls [60]. As a precaution, all people undergoing operations in hospitals should increase their serum 25(OH)D levels a week prior to the operation if possible by taking 50 000 IU/day of vitamin D2 or D3 if serum levels were below 100 nmol/L [61]. In this study, a reduction of 25% (15–35%) is used.

2.8 Pregnancy outcomes

With increasing recognition of the critical role that vitamin D maintains in myriad physiological functions, there has been mounting concern about the potential impact of inadequate levels of this hormone during the critical phase of *in utero* formation and development. Emerging evidence is only now clarifying important functions that vitamin D exerts during pregnancy on mother and fetus, as summarized in Table 2.

Further, as vitamin D status in pregnancy has been linked to fetal lung development, and higher gestational intake of vitamin D linked to reduced asthma risk in offspring, there is deliberation as to whether hypovitaminosis-D may be a major determinant of the burgeoning asthma pandemic [67]. Longitudinally, maternal vitamin D

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status during pregnancy directly correlates with subsequent whole-body and lumbar spine bone mineral content in progeny at 9 years of age [68]. Research in cardiology suggests that gestational vitamin D deficiency may be a determinant of preventable infant heart failure [69], while respiratory research suggests an association between lower respiratory infection in newborns with vitamin D inadequacy likely arising from maternal insufficiency [70]. There is the concern about insufficient vitamin D as a possible factor contributing to the skyrocketing rates of autistic spectrum disorder [71, 72]. While the full extent of the economic and humanitarian impact of widespread vitamin D deficiency during pregnancy remains to be seen, there has been a call to provide pregnant and nursing women with sufficient vitamin D to obtain optimal status for themselves and their children [10]. It is assumed that costs of pregnancy could be reduced by 10% (5–15%) with higher serum 25(OH)D levels.

2.9 Summary tables

Table 3 summarizes incidence, prevalence, and deaths for vitamin D–sensitive diseases for 2004, along with an estimate of the number of deaths that could be avoided from the various diseases if the mean serum 25(OH)D level in Canada increased from about 63 to 100 nmol/L. An estimated 37 000 deaths (22 300–52 300 deaths), representing 16.1% (9.7–22.7%) of annual deaths, could be considered premature. This estimate is consistent with an estimate based on a pooled analysis of data from three studies [30, 32, 39]. Based on that analysis, an increase in all-cause mortality rate of about 20% would be expected for 67 nmol/L *versus* 105 nmol/L.

Table 4 provides an estimate of the economic burden of vitamin D-sensitive diseases in the early 2000s. Based on the economic burden for cancer and cardiovascular diseases and all diseases in 1998 (total was $159.4 billion), of which $83.9 billion was direct (hospitals, drugs, physician care, other institutions, and miscellaneous), whereas $75.5 billion was indirect (mortality, long-term illness, and short-term disability [23]), it is estimated that the total economic burden of disease in 2005 was $200 billion plus $10 billion for dental care. The reduction in economic burden from higher serum 25(OH)D levels is estimated at 6.9% (3.8–10.0%) or $14.4 billion ($8.0 billion–$20.1 billion) of total economic burden for health care.

Table 2. Obstetric and gynecologic outcomes related to inadequate vitamin D levels

Adverse outcome	Finding	Study type	Reference
Gestational diabetes mellitus	OR = 1.29 ((95% CI: 1.05–1.60) for each 12.5 nmol/L decrease in serum 25(OH)D	CC	[62]
Preeclampsia	Adjusted OR = 2.4 (95% CI, 1.1–5.4) for a 50 nmol/L decline in serum 25(OH)D	CC	[63]
Cesarean section, primary	Adjusted OR = 3.84 (95% CI, 1.71–8.62) 37.5 *versus* >37.5 nmol/L	CC	[64]
Schizophrenia in offspring	OR = 7.0 (95% CI, 0.7–75.3, *p* = 0.08) for influenza antibodies in first trimester	CC	[65]
Bacterial vaginosis	1.65-fold (95% CI: 1.01, 2.69) increase for serum 25(OH)D <20 *versus* >75 nmol/L	CC	[66]

CC, case-control; CI, confidence interval; OR, odds ratio.

Table 3. Disease statistics for Canada in 2005

Disease	Incidence (× 1000)	Prevalence (× 1000)	Deaths [22] (× 1000)	Vitamin D reduction, range (%)	Prevented deaths, range (× 1000)	Reference
Cancer [73]	137.5 [74]		67.3	25 (15–35)	16.8 (10.1–23.6)	[11]
Heart disease			51.6	25 (15–35)	12.9 (7.7–18.1)	[31]
Cerebrovascular disease			14.0	25 (15–35)	3.5 (2.3–4.9)	[74, 75]
Diabetes		1330	7.9	15 (5–25)	1.2 (0.4–2.0)	[33, 34]
MS		55–75	0.4	40 (20–60)	0.2 (0.1–0.2)	[76]
Falls, fractures			1.6	20 (10–30)	0.3 (0.2–0.5)	[77]
Influenza, pneumonia			5.8	30 (20–40)	1.7 (1.2–2.3)	[36]
Septicemia			1.7	25 (15–35)	0.4 (0.3–0.6)	[59, 60]
Vitamin D related			154.1	24.0 (14.5–33.9)	37.0 (22.3–52.2)	
All causes			230.1	16.1 (9.7–22.7)	37.0 (22.3–52.2)	

Table 4. Economic burden of diseases for Canada in 1998 extrapolated to 2008 [23, 76]

Disease	Cost in 1998 ($B)	Cost in year ($B)	Fraction linked to low vitamin D (67 nmol/L) compared with 100 nmol/L (conservative) (%)	Economic burden ($B)
Cancer	14.2	17.9 (2005)	25 (15–35)	4.5 (2.7–6.3)
Cardiovascular	18.5	20.6 (1998)	25 (15–35)	5.2 (3.1–7.2)
Diabetes types 1 and 2		9.9 (2005)	15 (5–25)	1.5 (0.5–2.5)
MS		1.0	40 (20–60)	0.4 (0.2–0.6)
Musculoskeletal[a]	16.4	20.6 (2002)	10 (5–15)	2.1 (1.0–3.1)
Influenza, pneumonia		1.4 (2000)	30 (20–40)	0.4 (0.3–0.6)
Pregnancy, prenatal, birth defects		3.7	10 (5–15)	0.4 (0.2–0.6)
Vitamin D related (total)				14.5 (8.0–20.9)
All diseases (total)	159.4	210		200
Vitamin D preventable (total)			6.9 (3.8–10.0)	

a) Arthritis and osteoporosis (assumed that osteoporosis accounts for 40% and that half can be reduced by vitamin D).

3   Discussion

This study estimates that the death rate in Canada could be reduced by 16.1% (9.7–22.7%) and that of the economic burden could be reduced by 7.3% (4.0–10.5%) if the mean serum 25(OH)D level in Canada were increased to 105 nmol/L. That this estimate is reasonably accurate is supported by a recent study of mortality rate in the United States with respect to serum 25(OH)D levels. Data on 13 331 people aged more than 20 years from the Third National Health and Nutrition Examination Survey (NHANES III) were examined [39]. In a follow-up period of 8.7 years, there were 1806 deaths. Compared with the highest quartile (25(OH)D > 80 nmol/L), those in the lowest quartile (25(OH)D < 44.5 nmol/L) had a 26% increased risk of death. There is also a meta-analysis of 18 vitamin D supplement studies that included 57 311 participants, of which 4777 died during the studies. The trial size-adjusted mean duration was 5.7 years, the mean vitamin D dose was 528 IU, and the summary relative risk for mortality from any cause was 0.93 (95% confidence interval, 0.87–0.99) [79]. The mean dose, 528 IU, is considered sufficient to raise mean serum 25(OH)D levels by about 12.5 nmol/L [11]. Thus, the results of these two studies indicate the impact vitamin D status has on mortality.

Some of the benefits ascribed to vitamin D supplementation in various studies may be due to the effects of calcium, perhaps enhanced by vitamin D. There are benefits of calcium for many types of cancer [80] and other chronic diseases [81]. The study by Lappe *et al.* [11] found about half as much reduction in cancer incidence from calcium supplementation alone as with calcium plus vitamin D. However, in the analysis presented in this study, the effect ascribed to vitamin D is thought to be separate from any additional effect of calcium.

Vitamin D can be obtained from a variety of sources. Solar UVB is the most common natural source [18, 47]. Canadians cannot produce vitamin D from solar UVB for at least 4 months of the year. At high latitudes, marine fish and mammals provided vitamin D, permitting humans to inhabit such regions [18, 82]. As an alternative, artificial solar UVB can also generate vitamin D. A few minutes in a sunbed with whole-body irradiance for those with Fitzgerald skin type 2 can generate about 10 000 IU [83, 84]. Those with skin type 1 should avoid using sunbeds, and those with skin type 5 require about five times longer to generate 10 000 IU. The simplest way to obtain adequate vitamin D is through supplements. An oral intake of 1000 IU/day of vitamin D increases serum 25(OH)D by about 15–25 nmol/L [11]. On the basis of prices available through the Internet in the United States, a year's supply of 3600 IU/day could cost as little as $10. Fortifying more foods with vitamin D is also possible. In addition to milk and orange juice [85, 86], it is possible to fortify bread and other grain products [87]. Several studies have analyzed fortifying food with vitamin D [88]. However, there would be additional costs associated with the program such as testing serum 25(OH)D levels until reasonably accurate estimates of vitamin D dose–serum 25(OH)D response become available. Also, a limited number of susceptible individuals may develop hypercalcemia. There would also be administrative and other costs. It is difficult to estimate the total cost of a vitamin D program for Canada, but if the cost is assumed to be $1 billion, it represents about 7% (5–12%) of the estimated benefits.

One consideration in changing vitamin D health policy is addressing and minimizing any adverse effects. The primary risk factor associated with vitamin D is extrarenal production of 1,25-dihydroxyvitamin D (1,25(OH)2D) that gets into the serum and may lead to hypercalcemia by drawing calcium from the bones. For most people, that complication would occur at serum 25(OH)D levels above 375 nmol/L [89]. For those with granulomatous diseases such as sarcoidosis, the body's innate immune system tries to fight a disease that is in intimate contact with the serum by generating 1,25(OH)2D. Similar effects can occur for about 10–15% of those with lymphoma. Those likely to suffer adverse effects are probably aware of their condition. They should have serum 25(OH)D,

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1,25(OH)2D, and calcium levels measured if taking vitamin D supplements greater than 1000 IU/day.

Two Canadian health organizations have already begun recommending higher vitamin D intake. On the website of the Canadian Cancer Society, they state that "Adults living in Canada should consider taking vitamin D supplementation of 1,000 international units (IU) a day during the fall and winter," a recommendation made public in the Globe and Mail newspaper on June 9, 2007. "Adults at higher risk of having lower vitamin D levels should consider taking vitamin D supplementation of 1,000 IU/day all year round" [90] (http://www.cancer.ca/Canada-wide/Prevention/Use%20Sun-Sense/Vitamin%20D.aspx?sc_lang = en) The Canadian Pediatrics Society recommends that "Consideration should be given to administering 2000 IU of vitamin D daily to pregnant and lactating women, especially during the winter months, to maintain vitamin D sufficiency" [91]. It appears that older Canadians have heeded the call for vitamin D supplementation, as adults 60–70 years in the preliminary CHMS dataset have a mean plasma 25(OH)D level of 73.5 nmol/L, a value almost 8 nmol/L above adults aged 40–59 years.

4 Concluding remarks

The results of this study strongly suggest that the personal and economic burden of disease in Canada could be significantly reduced if the mean serum 25(OH)D level was increased from its current level of 67 nmol/L to the optimal level of 105 nmol/L. However, since implementation and compliance takes time and there are health benefits of vitamin D at all stages of life, some effects of low vitamin D earlier in life may never be fully overcome, so the beneficial effects would take a number of years to be fully realized. These results should increase interest by individuals, researchers, organizations, and agencies in Canada in assessing the health benefits of higher vitamin D production and intake and modifying practices and recommendations accordingly.

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