The prevalence and determinants of adequate vitamin D intake and supplementation among Canadian children

by

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Abstract

Most Canadian children are not meeting the dietary recommendations for vitamin D and have not enough sun exposure to synthesize vitamin D in their skin. Vitamin D supplementation therefore seems a necessity. However, no study has examined whether vitamin D from diet and supplements combined is enough to meet the Canadian recommendations. Likewise, no earlier study examined factors associated with vitamin D intake from diet and supplements, which is important information for public health decision makers and public health interventions. Therefore, this study aimed to assess the adequacy of vitamin D intake through both diet and supplements (objective 1), the determinants of meeting dietary guidelines (objective 2), and to assess the prevalence (objective 3) and the determinants of the use of vitamin D supplements (objective 4) and multivitamins (objective 5) among children in the province of Alberta, Canada. In 2014, a representative sample of grade five students (10-11y) in Alberta (n=2,686) was surveyed. Data on dietary intake and the use of supplements were obtained using a modified Harvard Youth/Adolescent Food Frequency questionnaire. Parents were asked how much they cared about healthy foods and physical activity and if they encouraged their child to eat healthy foods and be physically active. The adequacy of vitamin D intake was estimated using the two cut-offs given for the DRIs, i.e. the Estimated Average Requirement (EAR) of 400 International Units (IU) and the Recommended Dietary Allowance (RDA) of 600 IU. Mixed effect multiple logistic regression analysis was employed to identify the key correlates of meeting the DRIs and supplement use. Forty five percent of students met the EAR and 22% met the RDA through both diet and supplements. When vitamin D intake from diet alone was considered, only 16% and 2% met the EAR and the RDA, respectively. Out of 29% of vitamin D supplement users, 12% used supplements on a daily basis. Although 54% used multivitamins, only 28% used them on a daily basis. Parental education, household income and physical activity were positively correlated with meeting the DRIs, and students attending metropolitan area schools were more likely to meet the EAR than students attending rural area schools. Students who resided in a metropolitan area, who were more physically active, or whose parents completed college were more likely to take vitamin D supplements, independent of student's gender, household income, body weight status and dietary practices. Students were more likely to supplement with vitamin D if their parents cared about and encouraged eating healthy foods and also cared about physical activity. The prevalence of vitamin D supplement use was highest among those who had a high vitamin D diet and those with under/normal body weight status, although supplement use was not statistically associated with either dietary vitamin D intake or body weight status. Household income, parental education and physical activity were positively associated with multivitamin use and students of parents who personally cared about eating healthy foods were more likely to take multivitamins. Public health initiatives are needed to promote supplementation of vitamin D among Albertan children. Parental awareness on the importance of providing the correct dose of vitamin D supplements to meet dietary recommendations and, educating and encouraging parents about healthy lifestyles should be a part of such initiatives.

Preface

This paper-based thesis is an original work done by Lalani Munasinghe and includes two published manuscripts and one unpublished manuscript. I analyzed data collected in 2014 as a part of the Raising healthy Eating and Active Living Kids Alberta (REAL Kids Alberta) survey. REAL Kids Alberta is a joint project of the School of Public Health, University of Alberta and Alberta Health. The survey is led by Dr. Paul Veugelers and aims to assess the impact of Alberta Health's Healthy Weights Initiative and to provide some measurable behavioral and health outcomes for children in Alberta.

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DRI	Dietary Reference Intake
EAR	Estimated Average Requirement
RDA	Recommended Daily Allowance
25(OH)D	25-hydroxy vitamin D
UVB	Ultraviolet B
SPF	Sun Protection Factor
REAL Kids Alberta	Raising healthy Eating and Active Living Kids
YAQ	Harvard Youth/Adolescent Food Frequency Questionnaire
BMI	Body Mass Index
PAL	Physical Activity Level
IQR	Interquartile Range

1. Introduction

There is increasing evidence that vitamin D has physiological and pathophysiological roles beyond its well-established role in bone metabolism. High prevalence of vitamin D deficiency and insufficiency[1-3] along with skeletal and extra-skeletal conditions accentuate the necessity of maintaining proper vitamin D status, the maintenance of which could potentially reduce the economic burden of disease[4,5] and premature deaths in Canada.[6]

Vitamin D status varies dramatically across Canada, due to the wide variations in climate and distribution of ethnic groups between and within the provinces. Nearly 30% of Canadian children have serum vitamin D concentrations that are insufficient to achieve optimal bone health[7] especially during the winter season[2] because cutaneous synthesis through sun exposure is limited due to Canada's high latitude.[8-10] Environmental, social or physical barriers such as darker skin, sun screen, lifestyle choices like clothing and time spent indoors,[4,11] and some adverse effects of continuous sun exposure such as risk of skin cancers[12] also limit the cutaneous synthesis, therefore, dietary compensation must occur. However, children do not commonly consume most natural sources like fatty fish.[13-15] The availability, accessibility and affordability of both natural and fortified foods are highly varied between provinces[16-20] and also current food choices of children[21-23] alone are not sufficient to maintain their vitamin D status[2] even through dietary fortification. Given these factors, it is rather difficult to reach the daily-recommended amount of vitamin D solely through the diet.[24] Therefore supplementation seems required for children residing in Canada. Higher prevalence of vitamin D adequacy was associated with supplement use among Canadians[1,2,25] and studies[1,2,8,9,13,16,26-33] have also suggested supplementation as a strategy to reduce deficiency.

In spite of much research, vitamin D deficiency and insufficiency are still prevalent among children in Canada[1-3,7] and Alberta.[9] The new public health report on dietary intake requirements for vitamin D based on minimal or no sun exposure was released from the Institute of Medicine on November 30, 2010[34] as an update to the guidelines established in 1997.[35] However, Canadian children have not yet been assessed after 2010 despite these higher dietary guidelines, especially using population-based studies. In addition, no public health action was implemented in response to the 2010 report. This warrants the importance of studying the prevalence and determinants of vitamin D supplement use among Canadian children in order to meet 2010 DRI recommendation. The determinants of vitamin D status among adults are well studied, but the factors associated with vitamin D supplement use among children have not been given much attention. This thesis aims to inform improvement of vitamin D nutrition among Canadian children; the information will be valuable for agencies engaged in health promotion to promote vitamin D supplement use.

This thesis begins with a short summary on the importance of vitamin D for children, main dietary sources of vitamin D, current dietary guidelines for vitamin D, and the current state of the evidence regarding vitamin D status of Canadian children, their supplement use and a description of the determinants of supplement use. Next the objectives of the current research are introduced. This "paper-based" thesis consists of three independent research papers including two published articles situated within subsequent chapters. The final chapter of this thesis includes a general discussion based on the overall findings of the research.

1.1. Overview of vitamin D

Vitamin D is a fat-soluble steroid prohormone, also known as calciferol, and can be obtained through sun exposure, diet and dietary supplements. It has two major forms,[34,36] vitamin D_2 (ergocalciferol) that comes from plant sources and vitamin D_3 (cholecalciferol) that comes from animal sources.[34,37] Both forms of vitamin D are biologically inert and the kidney metabolizes them into an active form.[38] Vitamin D_2 is less toxic than D_3,[35] and there is mixed evidence on the bioavailability of D_2 and D_3[37,39-41] and both forms have similar effectiveness in small doses but D_2 is less effective than D_3 in large doses.[34] All natural animal food sources, fortified foods and dietary supplements available in Canada have the latter form.[31,37]

The precursor of vitamin D_3, i.e. 7-dehydrocholesterol (pre-vitamin D_3), is synthesized through the action of ultraviolet B (UVB) radiation in natural sunlight and is converted to vitamin D_3 in the human skin. Vitamin D_3, which comes from both cutaneous synthesis and intestinal absorption of food or supplements is transported to the liver and is metabolized to 25-hydroxycholecalciferol, i.e. 25(OH)D or calcidiol, the major form of vitamin D that circulates in the blood and is used to determine the vitamin D status.[42,43] In the kidneys, enzymes further metabolize 25(OH)D to 1,25-dihydroxycholecalciferol, also called calcitriol, the biologically active form that humans can utilize when necessary.[24,34,36,38,42,44]

1.2. Importance of vitamin D for children

Vitamin D is an essential regulator of bone metabolism and mineralization[24,45] and its deficiency in children can cause growth retardation[38], impairment of bone tissue mineralization[11,45,46] and classic signs and symptoms of rickets.[11,45,46] Vitamin D deficiency can further contribute to hypocalcemic seizures, fractures, lower-limb deformities, delayed developmental milestones,[11] problems like dental caries[47] and abnormal dentition,[11] and muscle weakness.[11] It can also prevent children from reaching their genetically programmed height and peak bone mass.[45] Furthermore, there is an increasing interest in the non-skeletal effects of vitamin D on children including its association with the immune system, brain development[4], asthma, type I diabetes,[15,31,48] and multiple sclerosis and treatment of its symptoms.[31,49,50] Therefore, maintaining proper vitamin D status among children is critically important and is becoming a significant health concern worldwide.[26,28,51]

1.3. Current dietary guidelines for vitamin D in Canada

The urgent need to revise the 1997 vitamin D dietary guidelines for Americans and Canadians[9,52] lead to revision of the guidelines in 2010. Only the Adequate Intake (AI) and the Tolerable Upper Intake Level (UL) were identified in 1997. The AI is based on observed or experimentally determined estimates of average intake by a group of healthy people and will be used instead of the Recommended Daily Allowance (RDA) if sufficient scientific evidence is not available to calculate the Estimated Average Requirement (EAR).[34,35] The RDA meets or exceeds the requirement for 97.5% of the population and is derived from the EAR that reflects the estimated median requirement.[34,35] The UL is the highest possible average daily intake without having risk of adverse effects to almost all individuals in the general population. In 1997, the AIs for individuals aged 0-50 years, 50-70 years and above 70 years were 200 IU, 400 IU and 600 IU, respectively, and the UL for below 1 year was 1000 IU and it was 2,000 IU for those above 1 year of age.[35]

The dietary guidelines revised in 2010 include three cutoff values, i.e. the EAR, the RDA and the UL, for normal healthy persons assuming no or minimal sun exposure. Additionally, the AI was identified for those below 1 year instead of the EAR and the RDA.[34] The Table 1.1 shows the DRI cutoffs for all age groups. These cut-offs for current DRIs were also given based on serum 25(OH)D. Accordingly, EARs and RDAs for 1-18 years of age are 40 nmol/L and 50 nmol/L, respectively.[1,34] Many other Canadian institutions also have vitamin D recommendations (Table 1.2), but the amounts are much higher than the dietary guidelines established by the Institute of Medicine.

1.4. The vitamin D status of Canadian children

Vitamin D status is usually assessed by measuring serum or plasma 25(OH)D, due to its relative stability and long half-life.[36,43] It reflects vitamin D derived from food, supplements and cutaneous synthesis.[34,36] However, it does not ideally represent the actual vitamin D status, given the fact that the body's natural mechanism is to increase renal production when vitamin D is insufficient or deficient.[43,52] Based on the definition of the Institute of Medicine in 2010,[34] the circulating 25(OH)D level of 50 nmol/L or above is considered as "sufficient", 30-50 nmol/L as "potentially at risk of inadequacy" and levels below 30 nmol/L as "deficient", relative to bone health. The Endocrine Society of Canada defines circulating 25(OH)D levels of <50 nmol/L as "deficiency" and 52.5-72.5 nmol/L as "insufficiency".[53] The definitions of the Canadian Pediatric Society in 2007 was reaffirmed in 2015 with the cut-offs, <25, 25-75, 75-225, >225 and >500 nmol/L as "deficient", "insufficient", "optimal", "potential adverse effects (pharmacological)", and "potentially toxic", respectively, stating that the previously considered cut-offs for adequacy seem too low.[54]

Vitamin D deficiency and insufficiency among children living in Canada is prevalent[1-3,54] and it is worse in Aboriginal Peoples[54] and the people in the Arctic due to prolonged darkness and low milk consumption attributable to costs of food transportation to the North[55] and lactose-intolerance.[56] In 2004, 67% and 61% of Canadian children aged 1-3 years and 4-8 years met AI based on 1997 cutoffs. Those prevalence for boys and male adolescents aged 9-13 years and 14-18 years were 74% and 75%, respectively, and, 53% for girls aged 9-13 years and 41% for female adolescents (14-18 years).[57] In 2009/2011, based on 2010 cutoffs, 11% and 24% of Canadian children aged 3-5 years and 6-11 years, respectively, and 29% of adolescents aged 12-19 years were potentially at risk of inadequacy or deficiency,[1] whereas, in 2012/2013, 22% of 3-11 years-old children and 37% of 12-19 years-old adolescents were potentially at the risk of inadequacy or deficient relative to bone health.[7] Less than half (43%) of the Cree children of Quebec, Canada (8-14 years-old), who lived in areas with minimal or no cutaneous synthesis for 5-6 months of the year had inadequate or deficient, i.e. <50 nmol/L, vitamin D levels.[58]

1.5. Sources of vitamin D

1.5.1. Sun exposure

The cutaneous synthesis through sun exposure is the main source of vitamin D[9,31,42,59] and provides an average of 3,000 IU of vitamin D by exposing arms and legs to direct sunlight for 5-10 minutes.[23] Nonetheless, excessive exposure to sunlight has never caused vitamin D intoxication.[60] The cutaneous production of vitamin D is affected by factors that either influence the quantity of solar UVB radiation that penetrates the skin or alters the amount of 7-dehydrocholesterol in the skin.[45] The quantity of UVB rays reaching the earth's surface markedly decrease during November to February when the latitude is above 37°.[45] Therefore, Canada and the northern half of the United States cannot get sufficient vitamin D for sufficient cutaneous synthesis during late fall and winter months.[2,45,59, 75]

1.5.2. Diet

Diet is suggested as the best source to maintain proper vitamin D levels[16,55,61] for those with limited cutaneous synthesis. However, it is difficult in meeting dietary guidelines only through the diet[2,13,14,24,56,62] due to poor food choices of children.[13,21-23] Canadian food guide recommends all Canadians above age 2 years to consume 500mL (two cups) of milk or fortified soy beverages per day.[63]

Only a few number of natural foods contain considerable amounts of vitamin D[24,31,36,42,45,64] (Table 1.3), such as fatty fish,[16,31,36,42,45,55,64,65] egg yolk,[36,,42,45,55,64,65] red meat including liver and kidney[13,16,36,42,54] and irradiated mushrooms.[24,39,44,45,65] The richest source of vitamin D is fish and the amounts highly vary according to the species and location, with the highest amount in fish liver.[42] Vitamin D contents also vary in egg yolk[31,42] with highest during the spring,[42] and in meat[42] with highest in kidney and lowest in muscle.[42] Edible mushrooms are the only unfortified dietary source[36,44,65] available for strict-vegetarians,[65] and UVB irradiation increases their vitamin D content[39,44] with similar bioavailability as vitamin D_2 supplements.[39] Yeast is also now be irradiated to increase the vitamin D content of bread and baked goods,[40,41] but, vitamin D_2 in such baked goods may not bioavailable for humans.[40] Health Canada[66] stated that fatty fish and egg yolk as the only natural food sources rich in vitamin D available in the Canadian food supply. Furthermore, only two food items are mandatory for fortification in Canada, 1) cow's milk regardless of the fat content with 300-400 IU of vitamin D in a reasonable daily intake and, 2) margarine with not less than 530 IU of vitamin D in 100 g.[67] Although it is not mandatory, vitamin D is also added to some foods including goat's milk,[1,36,67] only if it contains <35 IU/100 mL without exceeding 45 IU/100 mL,[67] and 35 IU/100 mL for plant-based beverages[68] such as soymilk and rice beverages, and orange juice.[1,36,67] Other foods that are permitted to be fortified include meal replacements, nutritional supplements and pre-packaged meals based on their calorie contents in such a way that 10-40 IU/100 kcal and 50-100 IU/serving of vitamin D.[67] Contradictorily, in the United States, even though it is not obligatory to add vitamin D for specific food items, any food is permitted to be fortified with a specific amount of vitamin D in proportion to calorie content, i.e. 20 IU/100 kcal, if the label claims it.[69]

Fortified foods provide the majority of dietary vitamin D in Canada[70,71] and United States, whereas milk is the most prevalent source among Canadian children,[2,14,18,62] adults[71] and Aboriginal peoples,[18] except for Aboriginals residing in Arctic Canada[55,71] whose main traditional source of vitamin D is fatty fish.[55] Although milk consumption by Canadian children[22,36,62] and Canadian Aboriginal children[72] is inadequate to achieve the RDA, Aboriginal children who met or exceeded the adequate intake of milk had better vitamin D levels than those who did not.[72] Unfortunately, lactose-intolerance can make children avoid dairy consumption.[56]

1.5.3. Supplements

Supplement use is the best means to maintain proper vitamin D levels,[1,2,8,9,16,26-33,73] especially during winter,[2,31] to compensate for limited cutaneous synthesis and dietary intake. The pharmaceutical form of vitamin D available in Canada is vitamin D_3 in multivitamins and sole vitamin D supplements, and the same form is also available in Europe, Japan, and India, and D_2 is available in United States.[31] Supplements containing vitamin D are available at various dosages as liquids, pills or gummies in Canada and common multivitamins contain 400 IU per daily dose and vitamin D supplements may contain 200, 400 or 1000 IU per daily dose.[36] Fish or cod liver oil, which contains 1360 IU of vitamin D in 1 tablespoon[4,36] is also considered as a dietary supplement.[31,39]

Health Canada[66] currently recommends that all breastfed, healthy term babies from birth to 1 year and those with age above 50 receive a daily 400 IU vitamin D supplement, in addition to following Canada's Food Guide to Healthy Eating. Most Canadians who do not use supplements are unable to meet dietary guidelines during winter.[2] It has been suggested that the dose be increased during winter.[31] Only 34% of Canadians[1] and 24% of Newfoundland residents[15] took a supplement containing vitamin D. However, supplement usage data specifically for Canadian children are lacking.

1.6. Factors associated with vitamin D status among Canadian children

There is considerable literature that identifies the factors associated with vitamin D status and they are widely varied across the world. Despite this, relevant literature on Canadian children is limited. Any factor that impedes cutaneous vitamin D synthesis and/or intake through the diet and supplements is associated with the vitamin D status. Poor sun exposure is the main cause of vitamin D insufficiency,[74] thus making Canadians more vulnerable.

1.6.1. Geographical and environmental factors

The positive association of sun exposure with vitamin D status[7,16,23,33,59] is well established. Canadian children are at a high risk of insufficiency or deficiency especially during the winter season[1,2,16,36,45,71,76] because cutaneous syntheses through sun exposure is the main source of vitamin D and due to Canada's high latitude in the Northern hemisphere[8,9,36,44,45,59,71,77] as both quality and quantity of solar radiation reaching the earth's surface is important for vitamin D synthesis.[10,12] During winter, that is the period from November to March, there are insufficient UVB rays to produce vitamin D in northern latitudes.[9,10,30,45,72,78] Therefore, there is no potential to synthesize cutaneous vitamin D in Edmonton (the capital city of Alberta province in Canada; latitude 53°34'N) during the winter months, even by exposure to sunlight on cloudless days.[10] As per Michael Holick's explanation,[45,79] the main reason for the influence of season, latitude, and time of the day on circulating levels of vitamin D is the angle of sunrays that hit the earth's surface. When the angle of the sun becomes more oblique to the earth's surface, sunrays have to travel a longer distance through the ozone layer which efficiently absorbs UVB radiation, thus, impeding vitamin D synthesis. As a result, early in the morning and late in the afternoon, the rays are more oblique to the earth's surface and therefore availability for vitamin D synthesis becomes limited regardless of the season. Adequate amounts of vitamin D are synthesized during spring, summer and fall, but synthesis is completely or significantly restricted during winter period due to complete absorption of radiation as the zenith angle of the sun increases during winter months. However, provincial differences in vitamin D status[15,72,80,81] are likely due to differences in humidity, airflow rate and air pressure,[12] in addition to differences in latitude and the season.[27,33,42,59] Because the conversion of pre-vitamin D_3 to vitamin D_3 in the skin is temperature dependent, the rate of cutaneous synthesis of vitamin D directly correlates with skin temperature, which varies with humidity, airflow rate and air pressure.[12]

Industrialization substantially increases the ozone concentration in the atmosphere. This ozone, often called smog, rapidly absorbs UVB radiation thus limiting the cutaneous synthesis of vitamin D, hence, children living in polluted cities are prone to vitamin D deficiency.[75]

1.6.2. Demographic factors

Ethnicity is thought to be of a factor associated with vitamin D status due to differences in skin melanin contents. Melanin is the natural sunscreen that efficiently protects body from damaging effects by absorbing UVB radiation when exposed to sunlight.[31,45] Unfortunately, it also impairs cutaneous vitamin D synthesis.[12,71,79] Therefore, those with darker skin have less capacity to produce vitamin D,[2,7,36,42,44,45,59,60,65,71,79] thus making African, African American and Asian ethnicities more vulnerable for vitamin D deficiency.[2,45,60,78,82-84] In Canada, 27% of whites and 58% of non-whites are at-risk of vitamin D deficiency.[7] Furthermore, some cultural dress codes cover the body, thereby preventing cutaneous vitamin D synthesis.[23,65,85] However, Omand et al.[27] did not find any association of ethnicity and skin pigmentation with 25(OH)D levels among immigrants in Canada. Furthermore, Aboriginal peoples, i.e. First Nations, Inuit and Métis, residing in Canada are more vulnerable to poor vitamin D status than non-Aboriginals[18,21] due to the long dark winter periods and the availability and affordability of the few vitamin D rich market foods.[17-20,55] However, Weiler et al.[18] identified higher prevalence of vitamin D deficiency among Canadian Aboriginal women compared to white women regardless of their vitamin D intake from the diet. Also, immigrants[44,86-90] have a high risk of vitamin D deficiency.

Age is a possible predictor of vitamin D status,[23,27,36,72,80,89] although, evidence for children is limited. Younger Canadian children (6-11 years-old) have better vitamin D levels than older children/adolescents aged 12-19 years.[1,58,91] The average vitamin D level of 3-5 years-old age group (74 nmol/L) was higher than the national average (64 nmol/L) in 2009/2011 and, it was 67 nmol/L for those aged 6-11 years.[1] Among Inuit children, the median plasma levels did not differ based on their age.[72] School children in Thailand showed age differences in vitamin D sufficiency without any trend throughout the age groups.[25]

Association of child's gender with the vitamin D status is lacking and inconclusive. Canadian boys aged 6-11 have higher average vitamin D levels (72 nmol/L) than girls in the same age (63 nmol/L).[1] Similarly, girls in Saudi Arabia[85] and Lebanon[34] had lower vitamin D levels than boys and that is possibly contributed by the excess use of sunscreen, full coverage of body[33,85] and poor knowledge about vitamin D[85] and poor dietary intake.[1,33] French Canadian[81] and Inuit children[72] did not show any gender difference in vitamin D levels. Similar non-association was also obtained for children in Thailand.[25]

1.6.3. Socio-economic factors

Parental education is associated with child's nutritional status, in such a way that the effect of mother's education is nearly double the effect of father's education[92] though, the evidence on the association with the child's vitamin D status is lacking and inconclusive. Holvik et al.[89] studied five immigrant groups of men and women from Turkey, Sri Lanka, Iran, Pakistan and Vietnam living in the county of Oslo in Norway; number of years of education was identified as an important predictor of vitamin D status in the women but not in the men. Furthermore, child's knowledge of vitamin D is positively associated with their vitamin D status.[85]

Economic status is positively associated with meeting dietary guidelines for vitamin D among Montreal preschoolers,[80] and Albertan and Nova Scotian children[62] in Canada. Lebanese schoolgirls who were attending schools with high annual school fees, implying the girls had high socio-economic status, had better circulating vitamin D levels compared with girls from a lower socio-economic status.[33] Low-income and low-income-food-insecure Canadian youths aged 9-18 years had lower vitamin D intake, especially from milk consumption,[93,94] making them more vulnerable for poor vitamin D nutrition. Jordanian children[23] and children living in crowded houses compared with those in houses with no crowding[72] had particularly poor vitamin D status.

1.6.4. Physical barriers

The damaging effect of continuous exposure to sunlight also has been of much concern. Those exposed to sunlight for long periods are vulnerable for skin cancers[30,95-97,73] and therefore avoiding midday sun and wearing UV blocking clothes are suggested.[95] The preventive measures to protect the body against sun exposure recommended by the Canadian Cancer Society[98] to reduce skin cancer risk also prevent cutaneous vitamin D synthesis.[12,45,53,60,86] Vitamin D deficiency is also very common even in some sunny areas such as Australia, Turkey, India, and Middle East due to excessive clothing.[23,33,42,53,85,95]

Use of sunscreen is widely acknowledged as a protective method from developing skin cancer in the future[30,91,100-102] and better protection with higher sun protection factor (SPF),[95,101,102] which indicates the sunscreen's ability to block the skin erythema reaction induced by the UVB radiation. The Canadian Cancer Society[98] recommended applying a broad-spectrum sunscreen with a SPF of 15 or higher as that can absorb nearly 99% of the UVB radiation. Unfortunately, it also limits cutaneous synthesis of vitamin D[12,30,31,36,42,45,79,101] and puts users at high risk of deficiency even during the summer.[45,65,85] Contradictorily, experimental studies have found that the sunscreen use allows prolonged sun exposure by delaying sunburn occurrence, hence increasing cancer risk.[96,97] However, Huncharek and Kupelnick[103] rejected this negative association of sunscreen use on developing skin cancer risk in a meta-analysis.

1.6.5. Diet

Diet has consistently been identified as a determinant of vitamin D status[33,58,72,86,99] and meeting dietary guidelines for vitamin D[82] in many studies. Fortified foods play a substantially important role in improving circulating vitamin D levels in children.[23,70] Canadian children who consumed milk,[1,2,14,27,71,80] and vitamin D-fortified yogurt and cheese products[70] more frequently had better vitamin D levels. Furthermore, a higher proportion of children living in two Canadian provinces, i.e. in Alberta and Nova Scotia, who consumed milk and margarine more frequently, were able to achieve current DRIs, and surprisingly, fish consumption and the diet quality had inverse associations with vitamin D status.[62] Fatty fish is the best natural source of vitamin D that could improve vitamin D status,[15,89] although its consumption by Canadian children is low.[62] Consumption of UVB irradiated mushrooms is also positively associated with vitamin D status.[39]

1.6.6. Supplement use

Dietary supplements including cod liver oil or fish oil use is widely advocated as a key positive determinant of vitamin D status in Canada[1,2,15,27,59,80,91] and other countries,[23,86,89] whereas, some studies did not find any association.[91] Moreover, the prevalence of meeting better vitamin D status among children and adults in Canada increases with increased supplement level.[91]

1.6.7. Physical activity

Physical activity had been shown to be positively associated with meeting DRIs for vitamin D among Canadian children residing in the provinces of Alberta and Nova Scotia.[62] Comparably, sedentary activities increase the risk of vitamin D deficiency among American children.[82] Holvik et al.[89] studied five immigrant groups of men and women with native countries Turkey, Sri Lanka, Iran, Pakistan and Vietnam living in the city of Oslo in Norway and did not find an association of level of physical activity with vitamin D deficiency, except for women with moderate physical activity level.

1.6.8. Body weight status

BMI status is known to be a better predictor than the absolute body weight of vitamin D status,[100] and it is negatively associated.[12,31,34,37,54,77,104-107] A higher proportion (76%) of Canadian children aged 3 to 17 years with normal body weights currently have adequate serum vitamin D levels compared to those who are overweight (67%) or obese (52%)[7]. A similar negative relationship between BMI and vitamin D status was found among children and adolescents in United States[82] and Lebanon,[33] and female adult immigrants living in the county of Oslo in Norway.[89] However, BMI was not associated with the plasma levels of vitamin D among Canadian Aboriginals children[58,72] and women in Northern Jordan.[23] In addition to BMI, waist circumference and waist-to-height ratio also showed negative associations.[99,105]

As a fat-soluble vitamin, when vitamin D is received from the diet or cutaneous synthesis, it is absorbed and is stored in adipose tissue to be utilized when needed.[31,34] Thus, more vitamin D is possibly sequestrated into a larger pool of adipose tissue in obese individuals resulting in lower availability in the circulation.[12,25,31,107] It is also hypothesized that obese individuals have lower vitamin D metabolism in the liver[107] or increased catabolism of vitamin D into 1,25-dihydroxycholecalciferol associated with vitamin D receptors and enzymes present in adipose tissues.[25,107] Obesity-associated inflammation also can potentially increase total-body vitamin D clearance resulting in lower circulating vitamin D.[107] Some argue that elevated parathyroid hormone due to vitamin D deficiency enhances adiposity[107,108] or inhibits weight loss.[107] Vitamin D also may regulate adipose tissue mass, differentiation, and metabolism, consequently contributing to obesity.[25] Additionally, obese individuals possibly have limited sun exposure due to less outdoor activities and clothing habits,[107] which make them more vulnerable to poor vitamin D status. However, the exact mechanism is unclear.

1.7. Potential determinants of vitamin D supplement use

Although the use of vitamin D supplementation is suggested to maintain proper vitamin D status, the factors associated with vitamin D supplement use have not yet been assessed, especially for children, rather most of the studies considered multivitamin supplements. In Canada, vitamin D supplements contain 400IU or 600 IU and multivitamins available for children contain 200 IU or 400 IU of vitamin D (informal observation).

With respect to age, the prevalence of vitamin D-containing supplement use in Canada follows a J-curve, meaning the highest prevalence is at either end of the age spectrum - among both older ages and among infants - with the lowest prevalence among age 12-19 years.[91] Likewise, Janz and Pearson[1] also found a similar trend between age groups in Canada, in which the highest supplement use was among 3-5 year olds and 40-79 year-olds and lowest among those aged 12-39 years. Furthermore, 41% of Canadian females compared to 28% males took supplements,[1,91] and this gender difference was only observed for those above 20 years.[91] Additionally, the dosage of supplement also varied by age and gender.[91] Comparably, Black et al.[13] did not find any gender difference among Irish children; however, younger Irish boys (aged 5–8 years) were twice as likely to consume a multi-nutrient preparation than adolescent boys aged 13–17 years.

Middle to high income Canadians were more prone to take vitamin D-containing supplements,[2,91] though the educational status was not significantly associated with supplement use.[91] Seasonal association of supplement use among Canadians was observed only among those who were 60–79 years, with a prevalence of 61% during November to March compared to 45% during April to October, and was highest among females, i.e. 72% and 55% during winter and summer, respectively.[91]

In Canada, having at least one chronic disease, being above 40 years of age, being middle income and consuming at least 1 serving of milk daily were positively associated with supplement use among females, whereas, being age 12-19 years was inversely associated with supplement use among female children/adolescents. However, among males, only the oldest (60 –79 years) and youngest (6 –11 years) age groups and being higher and middle income was positively associated with supplement use.[91]

1.8. Objectives

This research aims to identify the prevalence of meeting the 2010 DRI recommendations and the use of vitamin D supplements with their determinants in large samples of pre-pubertal school children in the province of Alberta. In addition, we sought to discuss the importance of taking vitamin D supplements. This research involves analysis of data from grade 5 students (10-11 years-old) and parents in the province of Alberta, Canada, collected in 2014, as part of the "Raising healthy Eating and Active Living Kids in Alberta" (REAL Kids Alberta) survey. The specific objectives of this thesis research are to

- [1] assess the proportion of children meeting current dietary guidelines for vitamin D;
- [2] identify the factors associated with meeting dietary guidelines among Canadian children;
- [3] assess the prevalence of vitamin D supplement and multivitamin use by Canadian children;
- [4] identify the determinants of vitamin D supplement use among children in Canada;
- [5] compare the determinants of vitamin D supplement use with those factors associated with the use of multivitamins.

The subsequent chapters include three manuscripts. The first manuscript addresses the first and second objectives. The other three objectives are addressed in the second and third manuscripts. Specifically, the second manuscript identifies demographic, socio-economic, anthropometric, physical activity and dietary factors associated with supplement use, whereas, the third manuscript considered parental encouragement of and caring for child's healthy lifestyle.

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1.10. Tables

Table 1.1. Current Dietary Reference Intake cutoffs for vitamin D established by the Institute of Medicine[34]

Age (years)	Estimated Average Requirement (EAR)	Recommended Daily Allowance (RDA)	Tolerable Upper Intake Level (UL)
0 – 0.5*	-	-	1,000 IU
0.5 - 1*	-	-	1,500 IU
1 – 3	400 IU	600 IU	2,500 IU
4 – 8	400 IU	600 IU	3,000 IU
9 – 70†	400 IU	600 IU	4,000 IU
>70	400 IU	800 IU	4,000 IU

IU = International Units (1 µg = 40 IU)
*Adequate Intake (AI) of 400 IU
†Includes pregnancy and lactation

Table 1.2. Other recommendations for vitamin D intake exist in Canada

Institute	Recommendations
Health Canada[109]	• Keep total vitamin D intake below the UL. • Follow the Canada's Food Guide that recommends those aged ≥2 years to consume 500mL (2 cups) of milk or fortified soy beverages every day. • Adults aged >50 years: take 400 IU of vitamin D supplement daily
The Endocrine Society of Canada[53]	• Infants: at least 400 IU/d to maximize bone health, 1000 IU/d to raise the blood 25(OH)D level >75 nmol/L, and 2000 IU/d to correct deficiency. UL for 0-6 months and 6 months-1 year are 1000 and 1500 IU/d, respectively. • Children aged ≥1 years: at least 600 IU/d to maximize bone health and 1000 IU/d to raise the blood 25(OH)D level >75 nmol/L. At least 4000 IU/d for children 1–18 years to correct deficiency. UL are 2500 IU/d for 1–3 years, 3000 IU/d for 4–8 years and 4000 IU/d for >8 years • Adults aged 19–50 years: at least 600 IU/d to maximize bone health and muscle function, 1500–2000 IU/d to raise the blood 25(OH)D level >75 nmol/L, and 10,000 IU/d to correct deficiency. UL is 4000 IU/d. • Adults aged 50–70 years: at least 600 IU/d to maximize bone health and muscle function, 1500–2000 IU/d to raise the blood 25(OH)D level >75 nmol/L, and 10,000 IU/d to correct deficiency. UL is 4000 IU/d • Elderly aged ≥65: 800 IU/d to prevent falls and fractures • Elderly aged >70 years: at least 800 IU/d to maximize bone health and muscle function, 1500–2000 IU/d to raise the blood 25(OH)D level >75 nmol/L, and 10,000 IU/d to correct deficiency. UL is 4000 IU/d • Pregnant/lactating women: at least 600 IU/d and 1500–2000 IU/d to maintain the blood level >75 nmol/L • Obese children/adults: at least 2-3 times more vitamin D for their age group to satisfy body's requirement • Children/adults on anticonvulsant medications, glucocorticoids, antifungals and medications for AIDS: at least 2-3 times more vitamin D for their age to satisfy body's requirement
Canadian Pediatric Society[54]	• Pregnant/lactating women: < 1000 IU/d may be inadequate to maintain optimal levels of 25(OH)D for both mothers and their infants. • Supplement infants with 400 IU/d or relatively large doses during

	pregnancy and lactation to correct low levels of vitamin D in human milk and the resultant low levels in nursing infants. • Infants and children living in the north: 400-800 IU/d. • Overweight/obese children: may need a higher intake.
Canadian Cancer Society[110]	• Adults: get physician's advice to take 1,000 IU/d of vitamin D supplements during fall and winter. • > 50 years-old, dark skin, low outside activities, or wear clothing that cover most of the skin: get physician's advice to take 1,000 IU/d of vitamin D supplements all year round. • Breast-feeding infants: 400 IU/d.
Canadian Dermatology Association[111]	• 1,000 IU/d of vitamin D supplements, particularly during the winter.
Osteoporosis Canada[112]	• Routine vitamin D supplementation for all adults year round. • Healthy adults between19-50 years of age, including pregnant or breast-feeding women, require 400 – 1,000 IU daily. • Those over 50 or those younger adults at high risk (with osteoporosis, multiple fractures, or conditions affecting vitamin D absorption) should receive 800 – 2,000 IU daily. • Taking more than 2,000 IU of vitamin D daily should be done only under medical supervision.

Table 1.2. Vitamin D contents in dietary sources[4,24,31,36,42,55]

Food item	Approximate Vitamin D content (IU)
Fatty fish – salmon, herring, sardines, tuna, mackerel and trout	160-1600 per 100g cooked (highest in wild fresh fish, least in farmed and smoked fish)
Fish liver (highest in tuna liver)	660-13000 per 100g
Shrimp	152 per 100g
Egg yolk	20-50 per yolk
Fortified spreads	430 per 100g
Fortified cow's milk in Canada	100 per 250ml
Margarine	25-30 per 1tsp
Butter	35 per 100g
Cheese (lowest in Cheddar, highest in Swiss)	12-44 per 100g
Yogurt made with fortified cows milk	25-89 per 100g
Shitake mushrooms (non-radiated)	100 per 100g (fresh) 1660 per 100g (sun-dried)
Fortified plant beverages including soy, rice or orange juice	80-100 per 250ml
Fortified tofu	120 per 1/5 block
Fortified cereals	80-320 per 100g
Beef	0-36 per 100g
Veal	0-200 per 100g
Pork	4-92 per 100g
Lamb	4-244 per 100g
Poultry	0-56 per 100g
Liver from cow or pig	3-50 per 100g
Kidney from cow	20-93 per 100g
Arctic traditional foods - beluga blubber and oil, narwhal blubber, ringed seal liver, arctic char flesh, cisco fish eggs, lake trout flesh, loche fish eggs and liver, and sculpin fish	>200 per 100g
Arctic traditional foods - bearded seal flesh, beluga muktuk, ringed seal blubber, caribou kidney and liver, muskox fat, and whitefish	20 – 200 per 100g

2. Dietary reference intakes for vitamin D based on the revised 2010 dietary guidelines are not being met by children in Alberta, Canada

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2.1. Introduction

Vitamin D is essential for bone development[1,2] and evidence suggests extra-skeletal beneficial effects on the immune system and brain development[3] in children, though conclusions about these benefits are inconsistent. In adults, it has been associated with a wide range of cancers,[3,4] asthma[5], multiple sclerosis,[4] diabetes,[4,6] cardiovascular disease[4] and quality of life.[7] Sunlight can be an important source of vitamin D but Canadians have limited cutaneous synthesis due to the country's high latitude.[8-10] Intake of vitamin D from diet and supplements is therefore essential to prevent deficiency and strategies to optimize benefits of vitamin D should begin in childhood and continue throughout life.[11]

Although current vitamin D status among children is better than most for other age groups,[12] the most recent national data[13] based on serum 25-hydroxy vitamin D [25(OH)D] reveal that nearly 8% of Canadian children are at risk for vitamin D deficiency (<30 nmol/L) and 30% are potentially at risk for inadequacy (30-50 nmol/L). Although evidence for Canadian children are limited, possible explanations for a low cutaneous synthesis of vitamin D are increasingly indoor lifestyles,[14,15] increased encouragement of sunscreen use,[3,16] increased promotion of guidelines to avoid adverse effects of prolonged sun exposure,[16,17] and excessive clothing to protect from sunlight exposure.[18] Vitamin D status is inversely correlated with body mass index (BMI) status.[13,19,17,20] It is suspected that additional adipose tissue causes sequestration of vitamin D, resulting in increased need for vitamin D intake and production in those with excess adiposity.[17,20] Hence, high prevalence of childhood overweight and obesity[21-23] in Canada may increase the requirement for vitamin D in children.[13,17,19,24] A diet rich in vitamin D containing foods and vitamin D supplements is essential for those with excess adiposity to maintain optimal vitamin D status and also to develop lifelong healthy lifestyle habits. In addition, socioeconomic status and physical activity have been found to be positively correlated with vitamin D intake.[21] Limited available dietary sources and poor food choices[9,21,25] further increase children's risk of vitamin D insufficiency in Canada in spite of mandatory vitamin D fortification in Canada of staple foods such as milk and margarine.[26,27] The 2015 Dietary Guideline Advisory Committee,[28] an American organization, reported that vitamin D from the diet was under-consumed relative to EAR by U.S. population ages of 2 years and above.

Therefore, they recommended developing and implementing strategies at both the individual and the population level to improve intake of vitamin D to be of public health concern. Because Canadian children may be more at risk of insufficiency due to their low sunlight exposure and limited fortified food availability, a similar call to action from Canadian health bodies may be merited.

Health Canada[12] updated the dietary intake recommendations for vitamin D after the Institute of Medicine released the revised Dietary Reference Intakes (DRIs) on November 30, 2010 for people with minimal or no sun exposure.[29] Revised DRIs make three recommendations for those above 9 years; 1) the Estimated Average Requirement (EAR) which is 400 IU (International Units), 2) the Recommended Dietary Allowance (RDA) which is 600 IU, and 3) the Tolerable Upper Intake Level (UL) which is 4,000 IU. These replaced the DRIs established in 1997 that included 200 IU as the "Adequate Intake", 2,000 IU as the "Tolerable Upper Intake" and 2,400 IU as the "No Observed Adverse Effect Level".[30] Furthermore, Health Canada[12] recommends a daily vitamin D supplement of 400 IU for all breastfed, healthy term babies beginning at birth and to continue until one year of age. It also recommends a daily supplement of 400 IU for adults over age of 50, in addition to Canada's Food Guides recommendation that all Canadians over the age of two should consume 500mL (two cups) of milk or fortified soy beverages on a daily basis. There is no recommendation for supplementation for Canadians between the ages of 1-50.

As evaluations assessing children's vitamin D adequacy based on both food sources and supplements compared to the revised DRIs have not yet been conducted, the objective of the present study is to determine what proportion of Canadian children meet the updated DRI for vitamin D and which factors contribute to children meeting the DRI. First, we hypothesized that less than 50% of grade 5 students meet the DRI for vitamin D. Secondly, we hypothesized that children of socioeconomically advantaged parents are more likely to meet these criteria. We further hypothesized that physically active and normal weight children are more likely to meet the DRI recommendation for vitamin D. The conclusions from this study will provide insight for health promotion strategies that aim to improve the nutritional status of Canadian children.

2.2. Methods

2.2.1. Study design and subjects

The "Raising healthy Eating and Active Living Kids in Alberta" (REAL Kids Alberta) survey is a population-based repeated cross-sectional study initiated in 2008. It collects data on health, nutrition, physical activity, lifestyle factors, and measured height and weight, every other year from grade 5 students (10-11 years old) and their parents in Alberta, Canada. Study tools and further information on the REAL Kids Alberta survey can be found on the project website (www.realkidsalberta.ca). The present study is an analysis of secondary data collected in the spring of 2014.

One hundred and forty elementary schools across the province of Alberta were randomly selected using a one-stage stratified random sampling design. The sampling frame included all elementary schools in Alberta with grade 5 students with the exception of private schools, francophone schools, on-reserve federal schools, charter schools and colony schools. This resulted in 90.2% of all elementary students in Alberta being eligible for random selection. Schools were then stratified according to the three geographical areas based on the size of the population as "metropolitan" (Calgary and Edmonton cities each with a population of about 1 million), "city" (other municipalities with ≥ 40,000 residents) and "rural" (municipalities with < 40,000 residents). Schools were randomly selected within each stratum to achieve proportional representation.[31] 4,993 home booklets and parental consent forms were sent home with grade 5 students to be completed by parent(s) or guardian(s). Among the 3,284 home booklets (66%) returned, 2,958 students (90%) received parental consent and participated in the study resulting in an overall participation rate of 59%. Students completed a student survey designed by the REAL Kids Alberta study team containing questions about lifestyle behaviors including diet and physical activity. They also completed a modified version of the Harvard Youth/Adolescent Food Frequency questionnaire (YAQ), a validated food frequency questionnaire[32,33] used to assess diets of students 9-18 years of age. Modifications were made to suit typical language of a Canadian population (example: 'pop' instead of 'soda'), alcohol was removed to suit the participating age group, and several questions were added concerning vitamin D supplements for the purposes of this study. Details about these questions are discussed further below. Students who did not complete YAQ (n=107) and with missing data on use of multivitamin and vitamin D supplements (n=46) were excluded from the present analyses. Also those who had reported energy intakes of < 500 kcal and > 5,000 kcal were excluded (n=119) as per established criteria for the analysis of food frequency questionnaire data.[34] Data from a total of 2,686 students were available for the analysis (Figure 2.1).

2.2.3. Outcome of interest: vitamin D intake

In 2014, we added the following questions to the YAQ to assess vitamin D intake from supplement use in this population; "Do you now take vitamin D supplements (pills/drops)?", "Do you now take multivitamins?", "How often did you take vitamin D supplements over the past year?", and "How often did you take multivitamins over the past year?". These questions were reviewed by a panel of experts and piloted in the target population to ensure understanding and validity. Dietary intake was assessed using students' responses to the YAQ and Canadian Nutrient Files.[35] Data on the frequency of using vitamin D and multivitamin supplements and brand names of multivitamins were obtained to calculate the amount of vitamin D intake from each supplement. Vitamin D supplements for children are available in the form of pills and liquid drops and contain 400 IU in a daily dose. The commonly used multivitamin supplements contain 200 IU or 400 IU (informal observation). The total amount of intake from supplements was calculated by adding the average intake of vitamin D from both vitamin D (combining both pills and drops) and multivitamin supplements. Vitamin D intake from foods alone and from both diet and supplements were separately categorized according to the 2010 DRI cutoffs that consider 400 IU/d as EAR and 600 IU/d as RDA.[29]

2.2.4. Potential covariates

Other covariates included in the analysis were body weight status as determined by BMI, physical activity, household level of income and parental education. Trained evaluation assistants measured students' height to the nearest 0.1 cm using stadiometers (Seca-Stadiometers, Germany) and weight to the nearest 0.1 kg using calibrated digital scales (Health-o-meter, USA). BMI was calculated as weight kg/height^2 (kg/m^2). Height and weight measurements were collected following completion of the student questionnaires. Overweight and obesity were defined according to the age- and gender- specific cut-offs of the International Obesity Task Force BMI for children and youth.[36] A physical activity score ranging from 0 to 5, with higher scores indicating higher levels of physical activity, for each child was derived from the 29-item questionnaire adopted from the Physical Activity Questionnaire for older Children.[37] The physical activity questionnaire contains questions about active transportation, activity level inside and outside of school hours, participation in sports and other forms of active play. Information on household income and level of parental educational attainment was determined from parent responses in the home survey.

2.2.5. Statistical analyses

All analyses were weighted to represent provincial estimates of the grade 5 student population aged 10-11 y in Alberta to accommodate design effect. The data used to derive weights were obtained from Alberta Education. Descriptive statistics were presented as medians with interquartile ranges or percentages. Chi-square tests were used to test the differences in participant characteristics, consumption of vitamin D rich dietary sources and supplement intake between meeting and not meeting DRIs. To identify the association of obesity, lifestyle, socioeconomic, and demographic factors with vitamin D intake, we used multiple logistic regression models with mixed effects applied to account for the nesting of students within schools. Missing data were treated as a separate category. Data analyses were adjusted for total energy intake as per established criteria for the analysis of food frequency questionnaire data.[34] Because the present study is a secondary data analysis, the sample size was not powered to find differences between groups of children and their meeting of DRIs for vitamin D. The statistical power to test the hypothesis that the probability of meeting the DRI for vitamin D varies across socioeconomic, physical activity and BMI status groups ranged from 76-100%. Analyses were carried out with Stata, version 13.0 (Stata Corp, College Station, TX, USA). Ethical approval was obtained from the Research Ethics Board of the University of Alberta.

2.3. Results

Characteristics of grade 5 students in Alberta and their daily intakes of vitamin D are shown in Table 2.1. The prevalence of students meeting EAR and RDA based on vitamin D intake from diet and supplements were 44.61% and 21.59%, respectively. When vitamin D intake from diet alone was considered, these were 16.16% and 1.82% for the EAR and RDA, respectively. A higher proportion of boys were found to be meeting the RDA as well as children who were more active and whose parents had a higher level of education (Table 2.2). Compared to the lowest tertile of physical activity level, the medium and highest groups of physical activity levels had significantly higher proportion of children meeting the EAR (Table 2.2). Table 2.3 shows the results of the multivariate analysis of associations of gender, parental education, household income and school region with the likelihood of meeting DRI. Parental education, household income, physical activity level and metropolitan school location were positively associated with meeting the EAR independent of the effect of other covariates (Table 2.3). With the exception of school region, all of these same factors were positively associated with meeting the RDA (Table 2.3). Students from families with a university or graduate degree were 1.29 times more likely to meet the EAR as compared to those from families with secondary school education or less. Students from households with an income of more than $100,000 were 1.60 times more likely to meet the EAR as compared to those from households with an income of less than $50,000. 29.45% of children reported using vitamin D supplements and 54.08% reported taking multivitamins at any frequency (Table 2.4), 11.83% and 28.43%, respectively reported using them at least once a day. The most frequently consumed vitamin D rich food was fortified liquid milk and the least frequently consumed was fish as the main dish (Table 2.4). Of grade 5 students consuming at least one serving of milk a day (56.85%), 61.41% met the EAR and 31.06% the RDA (Table 2.4).

2.4. Discussion

Canadian national evaluations of vitamin D status have used serum levels of 25(OH)D as a proxy for meeting the RDA for vitamin D. The most recent national data from Canada from 2012/2013 estimated that 65% of the population (aged 3-79) were above the RDA for vitamin D,[13] which was a 3% reduction compared to 2007/2009.[19] In 2012/2013, 78% of children 3-11 years were estimated to be above the RDA[13] whereas in 2007/2009, 76% of children 6-11 years were above the RDA.[19] Serum values provide a better estimate of vitamin D sufficiency, as they comprise both cutaneous synthesis and intake. The vitamin D status of children based on serum 25(OH)D levels improved negligibly after the revision of dietary guidelines in 2010, and a considerable proportion of children in Canada still have not reached the recommended serum vitamin D levels. It is worth noting that the currents DRIs for vitamin D are the same for age 1 up to age 70.[29] However, it may not appropriate to use the same cut-offs for both children and adults using serum 25(OH)D to classify deficiency due to differences in their body weights and body composition. Further research is required to confirm the appropriateness of using the same cut-offs for all age groups. Findings of our study indicate that less than half of children (45%) met the EAR and less than one forth children (22%) met the RDA based on both diet and supplements, confirming the hypothesis that only less than 50% of grade 5 children meet DRI for vitamin D. Only 16% of students in our study population met the EAR through diet only, which is 6% lower than that of previous findings from the same survey of REAL Kids Alberta in 2012.[21] Results from studies using both serum 25(OH)D and those using dietary and supplement intakes come to the same conclusion, i.e. children do not get enough vitamin D. In Canada, where even the little available sun is cut off by sun barriers such as sunscreen use and clothing, contribution to vitamin D status by cutaneous synthesis is likely to be marginal. Therefore, identified poor vitamin D intake is important to identify the appropriateness of the established dietary guidelines to improve vitamin D status. However, further research is warranted to provide strong evidence.

In 2004, the average daily dietary vitamin D intakes (excluding supplements) among children (9-13 y) in Canada were 280 and 228 IU, for boys and girls respectively,[38] and 34% boys and 32% girls used vitamin/mineral supplements.[39] Those dietary intakes were much higher for boys (332 IU) and lower for girls (184 IU) in Alberta.[38] Our results demonstrated higher dietary intake for boys (median = 184 IU) but lower intakes among girls (median = 155 IU) compared to the averages in Alberta in 2004. Gender difference in vitamin D intake among children (higher intake for boys than girls) identified in our study is consistent with children in Canada[38] and United States.[40] An average child in Alberta consumes nearly half of the EAR for vitamin D from food. Therefore, it is important to increase the number of foods fortified with vitamin D[27] or to promote the use of supplements in this age group.[40-43] The most common dietary source of vitamin D in Canada is fortified milk,[21,27] but not all children have access to milk due to common problem of lactose intolerance. In addition, children living in high Northern communities are subject to inflated prices of staple food items like fortified dairy products.[43,46] Moreover, American Academy of Paediatrics recommends the intake of daily supplementation of 400 IU of vitamin D for older children and adolescents who do not obtain 400 IU/d through fortified foods.[25] Given that the children in the present study had higher supplemental intake of vitamin D from multivitamins than from specific vitamin D supplements, standardizing the amount of vitamin D contained in children's multivitamins in Canada may support the improvement of children's vitamin D intake.

Interestingly, use of supplements containing vitamin D was much more common among children in the present study compared to the national average.[19,46] However, it was less common than that of U.S. children.[40] The Canadian national survey collected self-reported data on use of any medication within past month in the household questionnaire with drug information numbers where available. The information collected during the household survey was re-confirmed during the clinic visit. However, we collected one-time self-reported data on supplement use from children. Among supplement users, only 32% children in present study met the RDA based on both diet and supplements. Possible explanations for a large proportion of Canadians (85%) meeting the RDA based on serum 25(OH)D levels[19] is because serum levels take into account exposure to solar radiation and national level data includes infants and adults over 50 who have been recommended to take supplements.[12] Furthermore, measurement errors occur when dietary intake and supplement use is self-reported by children.[47] Possible inherent errors of the food frequency questionnaire we employed[48] can result in under-estimation of dietary vitamin D intake. The chemiluminescent method used to assess the status through serum 25(OH)D in the national surveys may over-estimate the status[49,50] and vitamin D metabolism that involves in serum measurement is also not completely understood.[17] Nevertheless, only small proportions of children in our study were taking vitamin D and multivitamin supplements on daily basis and therefore most children may not have been able to meet DRI. Consequently, vitamin D supplements should be recommended for children, and parents should be aware of the necessity to use vitamin D supplements on daily basis.

The prevalence of childhood overweight and obesity is increasing in Canada[21,23,51] and in Alberta.[21] Vitamin D status is inversely correlated with BMI status[13,19,52] thought to be associated with sequestration of vitamin D into a large pool of adipose tissues.[17,20] Furthermore, it has been identified that an overweight adult requires approximately 1.5 times more vitamin D relative to a normal weight adult and an obese person requires approximately 2-3 times more.[24] The latter has not been part of public awareness campaigns and it is therefore not surprising that we did not see any differences in diet and supplement use by weight status. However, more understanding on vitamin D metabolism is required and age-specific randomized control trials are necessary to establish clinical guidelines for overweight and obese children, as evidence for the increased need of vitamin D for overweight and obese individuals is restricted to adults. As the vitamin D status in terms of serum 25(OH)D concentration is lower among Canadians with excessive body weight, we recommend awareness campaigns for parents to meet at least the current guidelines.

We found that children are unlikely to meet sufficient vitamin D solely through the diet due to low consumption of vitamin D rich dietary sources. This finding is problematic considering the limited opportunity in Canada for the cutaneous synthesis of vitamin D.[8-10] The median vitamin D intake solely from the diet among children in the present study was 167 IU/d. Therefore, an increase of 200 and 400 IU/d of vitamin D through supplements together with dietary sources is necessary to meet EAR and RDA, respectively. Similar to other findings,[19] we have also identified that those who take supplements are more likely to meet the current DRI. Consequently, a daily vitamin D supplement that contains 400 IU is essential to compensate for insufficient dietary intake. Moreover, parental education, household income, and physical activity level are associated with total vitamin D intake, so it may be important to study socio-economic groups according to their different needs for supplementation. Additionally, obese/overweight children,[17,20] those with darker skin[46,53] and those who have lactose intolerance but who do not consume enough vitamin D fortified soy beverages are vulnerable for vitamin D deficiency/insufficiency. The requirements of these groups have to be considered when recommending supplements.

This study is the first to assess the vitamin D intake of Albertan school children based on both diet and supplements. The other strengths include the use of a large provincially representative sample, its high response rate for a school-based research, the execution of multilevel regression to account for hierarchical data structure and assist the survey design effect with weighted analysis. A limitation of this study was that the use of self-reported information was not validated. However, potential bias was minimized by using a validated YAQ that is shown to be comparable in estimating typical intake over the past year to multiple 24-hour recalls. Present study was conducted using a sample of grade 5 students aged 10-11 years, and therefore, caution will be warranted when generalizing results to other children.

2.5. Conclusion

Less than half of the children in Alberta met current recommendations of EAR and less than one fifth met the RDA through both diet and supplements. A very small proportion of children met RDA only through the diet and therefore it is unlikely that any child in Alberta will achieve the RDA unless they take supplements. The median intake of 167 IU/d of vitamin D only through the diet identified in our study emphasize the importance of encouraging increased intake of vitamin D through food sources or supplements to reach the RDA of 600IU/d. Parents should be informed about current DRI for vitamin D and the importance of meeting it daily so that they can consider providing supplementation or including more fortified foods in their child's diet. Health promotion strategies that take into consideration disparities in vitamin D intake between socioeconomic status groups are necessary. Inclusion of 600 IU of vitamin D, the goal for usual intake by an individual,[54] into all multivitamin supplements available for children would be beneficial as most of the children take multivitamin supplements rather than vitamin D supplements and threat of reaching the UL of 4,000 IU of vitamin D appears unlikely. Nutritionists, health care providers, and parents may further consider the body weight of the child when deciding on supplementation as several studies have suggested that overweight and obese individuals relative to normal weight subjects, require more vitamin D to achieve a sufficient vitamin D status. We suggest further provincial level research to identify vitamin D requirements to establish age- and weight status-specific guidelines for supplement use and appropriate intake and health promotion strategies for the improvement of vitamin D status among Canadian children.

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2.7. Tables

Table 2.1. Characteristics of grade 5 students in Alberta, Canada, and their daily vitamin D intake from diet and supplements

	%, Unweighted n=2,686	%, Weighted*	Daily vitamin D intake (IU/d)*		Daily energy intake (kcal/d)
			Only diet	Both diet and supplements	
			Medians (IQR)	Medians (IQR)	Medians (IQR)
All participants			167 (105, 326)	356 (162, 562)	1671 (1237, 2234)
Gender					
Girls	53.69	53.49	155 (102, 307)	342 (157, 533)	1626 (1212, 2135)
Boys	46.31	46.51	184 (109, 342)	374 (166, 587)	1727 (1260, 2308)
Parental education†					
Secondary or less	24.68	23.19	167 (101, 324)	331 (147, 529)	1709 (1235, 2367)
College	35.29	33.54	172 (106, 329)	359 (163, 582)	1685 (1231, 2274)
University or graduate	34.77	37.89	164 (105, 325)	376 (170, 575)	1644 (1243, 2111)
Household income					
≤ $50,000	12.06	13.21	148 (91, 296)	272 (129, 516)	648 (1255, 2422)
$50,001 – $100,000	19.66	19.03	169 (104, 314)	371 (169, 564)	1634 (1279, 2145)
≥ $100,001	30.71	28.89	182 (112, 339)	374 (188, 588)	1678 (1243, 2196)
Non-disclosed/Missing§	37.57	38.87	164 (102, 328)	358 (160, 550)	1686 (1224, 2250)
School region					
Rural	50.60	39.55	168 (105, 318)	342 (163, 532)	1686 (1239, 2252)
City	18.65	8.28	158 (100, 324)	367 (162, 566)	1595 (1253, 2073)
Metropolitan	30.75	52.17	168 (105, 331)	366 (162, 580)	1669 (1236, 2241)
BMI status†					
Under/normal weight	69.17	68.59	167 (105, 323)	356 (166, 572)	1680 (1223, 2208)
Overweight	20.40	20.84	173 (105, 336)	359 (157, 561)	1664 (1267, 2289)
Obese	7.26	7.86	146 (103, 313)	332 (137, 515)	1635 (1193, 2182)
Physical activity level					
1st Tertile	33.32	34.33	145 (94, 295)	291 (135, 480)	1489 (1120, 2020)
2nd Tertile	33.32	33.11	158 (104, 310)	352 (165, 555)	1652 (1253, 2217)
3rd Tertile	33.36	32.57	213 (125, 375)	426 (222, 673)	1899 (1355, 2529)

Abbreviations: IQR, Interquartile Range; BMI, Body Mass Index

*Results of 2,686 participated students aged 10-11 years were weighted to represent provincial estimates of the grade 5 student population in Alberta and characteristics are presented as percentages and daily vitamin D intake (IU/d) as medians and IQR.

†<5% of data were missing

§26.63% responses were non-disclosed responses and 12.23%

Table 2.2. Percentage of grade 5 students meeting the Dietary Reference Intakes by demographic, socio-economic, BMI, and life style factors

Covariate	Meeting the EAR of 400 IU/d*†		Meeting the RDA of 600 IU/d*†	
	%	*p* value	%	*p* value
Gender				**0.0096**
Girls	42.77	0.0635	19.44	
Boys	46.73		24.05	
Parental education				**0.0109**
Secondary or less	41.33	0.1271	17.95	
College	45.73		24.16	
University or graduate	46.51		22.54	
Household income				0.1431
≤$50,000	37.86	0.0670	18.40	
$50,001-100,000	44.97		22.90	
≥$100,001	47.36		24.13	
Non-disclosed/Missing	44.68		20.14	
School region				0.2192
Rural	41.94	0.0562	20.09	
City	45.51		21.36	
Metropolitan	46.49		22.76	
BMI status				0.2453
Under/normal weight	44.82	0.9508	22.73	
Overweight	44.08		19.75	
Obese	43.34		17.07	
Physical activity level				**<0.0001**
1st Tertile	35.94	**<0.0001**	14.15	
2nd Tertile	44.67		20.87	
3rd Tertile	53.69		30.16	

Abbreviations: EAR, Estimated Average Requirement; RDA, Recommended Dietary Allowance; BMI, Body Mass Index

*Results of 2,686 participated students aged 10-11 years were weighted to represent provincial estimates of the grade five student population in Alberta.

†p-value from mixed effect multiple logistic regression model with children nested in schools.

Table 2.3. Associations of gender, parental education, household income, school region, body mass index and physical activity level with the likelihood of meeting Dietary Reference Intakes among of grade 5 students in Alberta, Canada

Covariate	Meeting the EAR of 400 IU/d*†		Meeting the RDA of 600 IU/d*†	
	OR (95% CI)	p value	OR (95% CI)	p value
Gender				
Girls	1.00		1.00	
Boys	1.02 (0.83, 1.24)	0.876	1.10 (0.86, 1.39)	0.445
Parental education				
Secondary or less	1.00		1.00	
College	1.28 (1.02, 1.60)	**0.030**	1.58 (1.15, 2.17)	**0.004**
University or graduate	1.29 (1.00, 1.66)	**0.049**	1.43 (1.03, 1.97)	**0.031**
Household income				
≤$50,000	1.00		1.00	
$50,001-100,000	1.57 (1.11, 2.22)	**0.010**	1.46 (1.00, 2.13)	**0.050**
≥$100,001	1.60 (1.20, 2.13)	**0.001**	1.43 (0.98, 2.09)	0.064
School region				
Rural	1.00		1.00	
City	1.24 (0.98, 1.56)	0.069	1.15 (0.87, 1.51)	0.333
Metropolitan	1.28 (1.01, 1.63)	**0.043**	1.25 (0.97, 1.60)	0.087
BMI status				
Under/normal weight	1.00		1.00	
Overweight	0.93 (0.74, 1.18)	0.574	0.80 (0.52, 1.09)	0.159
Obese	1.05 (0.71, 1.55)	0.816	0.73 (0.46, 1.16)	0.189
Physical activity level				
1st Tertile	1.00		1.00	
2nd Tertile	1.32 (1.04, 1.66)	**0.020**	1.46 (1.05, 2.04)	**0.024**
3rd Tertile	1.67 (1.34, 2.09)	**<0.001**	2.07 (1.60, 2.68)	**<0.001**

Abbreviations: EAR, Estimated Average Requirement; RDA, Recommended Dietary Allowance; OR, Odds Ratio; CI, Confidence interval; BMI, Body Mass Index

*Results of 2,686 participated students aged 10-11 years were weighted to represent provincial estimates of the grade five student population in Alberta.

†p-value from mixed effect multiple logistic regression model with children nested in schools and odds ratios (OR) were adjusted for total energy intake in addition to all other covariates in the table.

Table 2.4. Percentage of grade 5 students meeting the Dietary Reference Intakes by intake of vitamin D rich food sources and supplements

	% of students	Meeting the EAR of 400 IU/d*		Meeting the RDA of 600 IU/d*	
		%	p value	%	p value
Natural vitamin D sources					
Eggs					
< 1 per month	20.57	39.40	0.0315	18.75	0.1291
1-3 per month	36.23	43.90		20.34	
3 per month	42.32	47.77		23.97	
Fish as a main dish					
< 1 servings per month	55.49	40.96	0.0002	17.72	<0.0001
1-3 servings per month	33.77	47.91		27.48	
> 3 servings per month	9.56	55.11		23.57	
Fortified vitamin D sources§					
Milk					
≤ 2 glasses per week	18.72	15.46	<0.0001	7.49	<0.0001
2-6 glasses per week	24.00	27.51		10.11	
≥ 7 glasses per week	57.18	61.41		31.06	
Margarine					
< 1 tsp per month	43.99	39.37	<0.0001	17.98	<0.0001
1-3 tsp per month	20.94	42.78		20.64	
> 3 tsp per month	34.58	52.76		27.06	
Nutrient supplements use					
Vitamin D supplement					
Yes	29.45	72.73	<0.0001	50.43	<0.0001
No	70.55	32.87		9.55	
Form of vitamin D supplements†					
Pills only	13.88	73.23	-	47.84	-
Drops only	8.54	66.96		42.66	
Both pills and drops	7.02	78.75		65.01	
Non-users	70.55	32.87		9.55	
Multivitamins					
Yes	54.08	63.37	<0.0001	35.62	<0.0001
No	45.92	22.51		5.06	
Any supplement					
Yes	62.14	62.24	<0.0001	32.21	<0.0001
No	37.86	15.68		0.87	

Abbreviations: EAR, Estimated Average Requirement; RDA, Recommended Dietary Allowance; BMI, Body Mass Index

*Results of 2,686 participated students aged 10-11 years were weighted to represent provincial estimates of the grade five student population in Alberta and p-value from x^2 test.

†Included vitamin D supplement non-users for the calculation and did not perform x^2 test

§In Canada, it is mandatory to fortify liquid milk with vitamin D so as a reasonable daily intake should contain 300-400 IU and minimum of 530 IU in 100g of margarine[26].

2.8. Figures

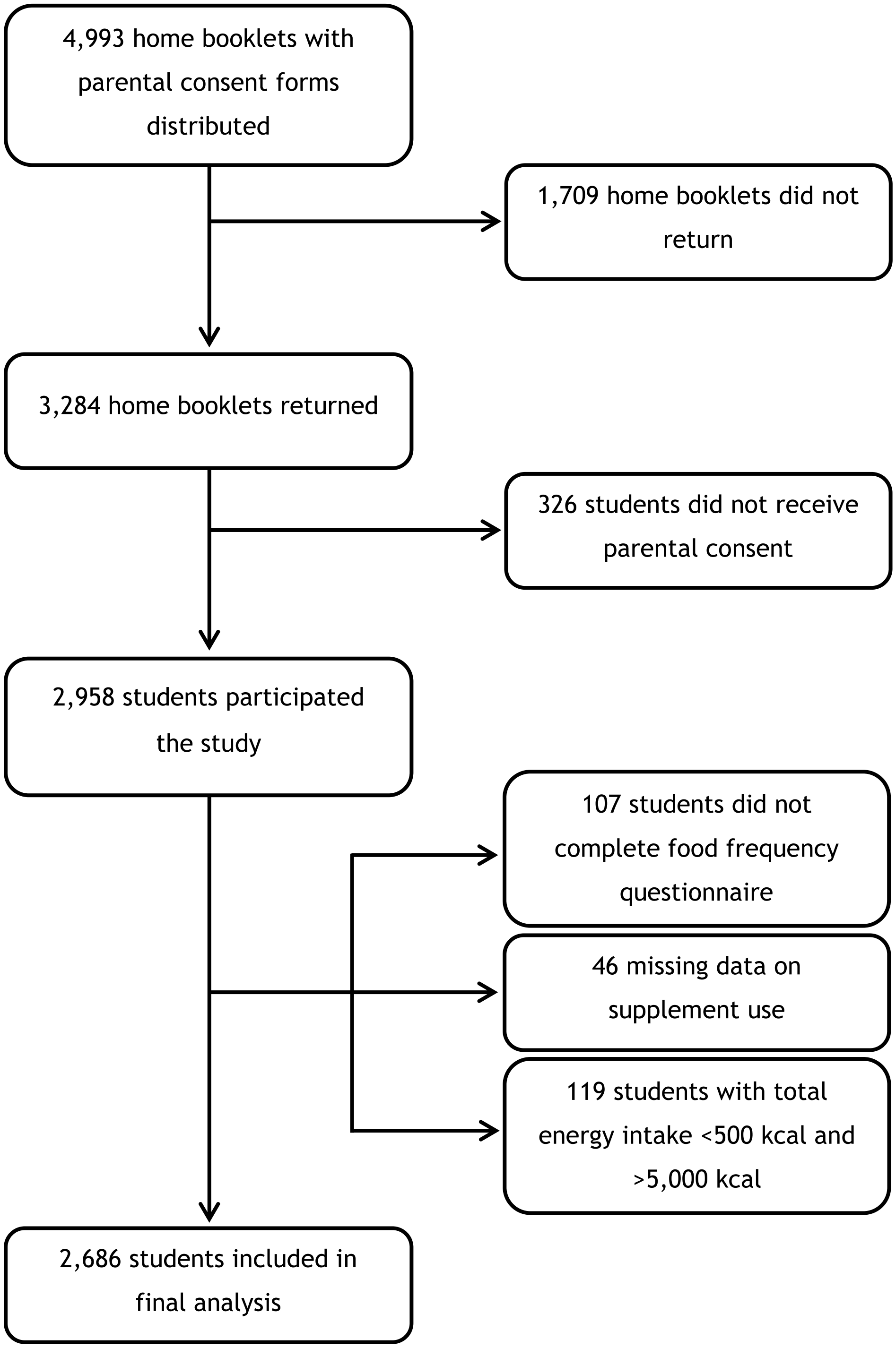

Figure 2.1. Flow chart illustrating the selection of subjects participated in the study

3. The prevalence and determinants of use of vitamin D supplements among children in Alberta, Canada: A cross-sectional study

Munasinghe LL, Willows N, Yuan Y, Veugelers PJ. The prevalence and determinants of use of vitamin D supplements among children in Alberta, Canada: a cross-sectional study, ***BMC Public Health*** 2015;15(1):1063-70. doi: 10.1186/s12889-015-2404-z.

3.1. Introduction

The 2012/2013 Canadian Health Measure Survey[1] revealed that 35% of all Canadians and more than 20% of children are at risk of poor bone health. This is presumably due to limited cutaneous synthesis of vitamin D through sun exposure because of Canada's high latitude[2,3] and poor dietary intake of vitamin D rich foods.[3-6] Obese and overweight children are potentially more susceptible for poor vitamin D status[1,7] because of sequestration of vitamin D into a larger pool of adipose tissues in the body.[8,9] Efficacy of the mandatory vitamin D fortification of designated staple foods in Canada[10,11] to ensure vitamin D adequacy is low due to under-fortification[12] and insufficient consumption.[4,12] Therefore, meeting current dietary guidelines for vitamin D that includes an estimated average requirement of 400 IU/day and a recommended dietary allowance of 600 IU/day for children over one year of age[13] is difficult without supplementation. Canadians who use supplements are more likely to maintain adequate vitamin D levels.[7,14] Studies[2,6,14-16] have emphasized the importance of supplementation as a strategy to overcome the issue of poor vitamin D status. Although all Canadians might benefit from supplements to maintain vitamin D levels,[14] Health Canada[17] only recommends a daily vitamin D supplement of 400 IU for breastfed, healthy term infants and adults over the age of fifty. There are no recommendations for the vitamin D supplementation of children.

Studies have identified age,[18,19] gender,[20] weight status,[21] socio-economic status,[19,21] level of physical activity,[20-23] quality of diet,[21,22] and parental use of supplements[18] to be associated with the use of multivitamin/mineral supplements among children. Although the factors associated with multivitamin/mineral supplement use are well studied, those associated with vitamin D supplement use among children have not been given attention. In Canada, vitamin D supplements for children are available as vitamin D supplements (containing only vitamin D) and vitamin D-containing multivitamins. However, it is advisable to use vitamin D supplements as cholecalciferol to meet dietary guidelines due to the varying forms of vitamin D (i.e., ergocalciferol and cholecalciferol) and amount of vitamin D in multivitamins. Given that the determinants of use can vary according to the type of supplement being considered,[24] the factors associated with the use of vitamin D supplements need to be studied. Awareness of such factors is crucial to inform policy decision-makers and stakeholders in planning programs to promote the optimal vitamin D status of the population through supplementation. The purpose of this study was to determine the prevalence of vitamin D supplement use and the associated factors among children in Alberta. Unlike use of vitamin D supplements, the use of multivitamins is quite common among developed nations.[19,23,24] Therefore, we also aimed to identify if there were differences in the factors associated with vitamin D supplement use with those of multivitamin/mineral use. This information would be valuable in establishing whether programs for promoting vitamin D use would need to be different from programs promoting supplement use in general.

3.2. Methods

3.2.1. The Survey and Subjects

We analyzed data on demographic and socio-economic factors, diet and supplements, and physical activity that were collected as part of the "Raising healthy Eating and Active Living Kids in Alberta" (REAL Kids Alberta) survey, a population-based study of grade five students (age 10-11 years) and their parents in the province of Alberta, Canada in 2014. A one-stage stratified random sample of 140 elementary schools across Alberta was selected. The sampling frame included all elementary schools in Alberta with grade 5 students with the exception of private schools, francophone schools, on-reserve federal schools, charter schools and colony schools. Therefore, 90.2% of all elementary students in Alberta were eligible for random selection based on three geographical strata (metropolitan, urban, and rural). Schools were randomly selected within each stratum to achieve proportional representation.[25] More details on the project aim and the measures used are available on the project's website: http://www.realkidsalberta.ca. A total of 4,993 home booklets and parental consent forms were sent home with students to be completed by parent(s) or guardian(s) and returned to school. Among 3,284 booklets returned, 2,958 students were granted consent and participated in the study (participation rate=59%). Students who did not complete the food frequency questionnaires (n=107) and 46 with missing data on use of multivitamins and/or vitamin D supplements were excluded from the present analysis. Students who had reported energy intakes of < 500 kcal and > 5,000 kcal were excluded (n=119) as per established criteria when food frequency questionnaire data is involved.[26] Therefore, the analysis of the present study was restricted to a total of 2,686 students (53.8%).

3.2.2. Outcome of interest: Vitamin D-containing supplement use

Information on use of vitamin D supplements and multivitamins was obtained from a modified Harvard Youth/Adolescent Food Frequency Questionnaire (YAQ). Under the guidance of a trained evaluation assistant, each student completed the YAQ during classroom time in a school day. In separate questions, students were asked, "Do you now take vitamin D supplements (pills/drops)?", "Do you now take multivitamins?", "How often did you take vitamin D supplements over the past year?" and "How often did you take multivitamins over the past year?". "Vitamin D supplement users" were defined as a child who reported ever taking a vitamin D supplement and "multivitamin supplement users" a child who reported ever taking a multivitamin.

3.2.3. Anthropometric, demographic, socio-economic, and lifestyle determinants

Evaluation assistants measured weight and standing height from all children to calculate Body Mass Index (BMI) as weight divided by height^2 (kg/m^2). Weight was measured to the nearest 0.1 kg using calibrated digital scales (Health-o-meter, USA) and height was measured to the nearest 0.1 cm using stadiometers (Seca-Stadiometers, Germany). Overweight and obesity were defined according to the age- and gender- specific cut-offs of the International Obesity Task Force BMI for children and youth.[27] Region of residence was defined based on the schools located in three geographical locations: metropolitan (Calgary and Edmonton, cities with a population of about one million people each), urban (other municipalities with more than 40,000 residents) and rural (municipalities with less than 40,000 residents). Data on the level of parent education attainment and household income were collected from parent responses in the home survey. Physical activity level (PAL) was identified as a single physical activity score ranging from 0 to 5 that was derived from a 29-item questionnaire adapted from the Physical Activity Questionnaire for Older Children, which has been validated for children.[28] The physical activity questionnaire contains questions about active transportation, activity level inside and outside of school hours, participation in sports and other forms of active play. Diet quality was derived using the Diet Quality Index International, a composite measure that encompasses dietary adequacy, variety, moderation, and balance ranging from 0 to 100.[29] Dietary intake data were obtained based on responses to the questions in validated YAQ[30] that assesses diets of those 9-18 years of age. Total dietary vitamin D intake and total calorie intake from food were calculated using Canadian Nutrient File.[31]

3.2.4. Statistical analyses

Data were analyzed using Stata version 13 (Stata Corp, College Station, TX, USA). Descriptive statistics were used to characterize the population and to identify the frequencies of children using vitamin D supplements and multivitamins. Mixed effect multiple logistic regression models with children nested in schools identified the association of weight status, lifestyle, socioeconomic, and demographic factors with use of vitamin D supplements and multivitamins. Akaike Information Criteria and Bayesian Information Criteria were employed to select the parsimonious multiple regression models. Missing data were treated as a separate category. Data analyses were adjusted for total energy intake when food frequency data were involved as per established criteria.[26] All analyses were weighted to represent unbiased provincial estimates of the grade 5 student population in Alberta. The Health Research Ethics Board at the University of Alberta approved this study, including data collection and parental informed consent forms.

3.3. Results

Altogether, 62.14% of grade 5 students (age 10-11 years) in Alberta participating in this study took only vitamin D supplement (8.06%), only multivitamin (32.69%), or both a vitamin D supplement and multivitamin (21.39%). The characteristics of students taking vitamin D supplements (29.45%) and multivitamins (54.08%) are presented in Table 3.1. However, of grade 5 students, only 11.83% took vitamin D supplements and 28.43% took multivitamins on a daily basis during the past year.

Table 3.2 depicts the associations of demographic, socio-economic, anthropometric and life style factors on the use of vitamin D supplements. Students whose parents completed education up to college level were more likely to take vitamin D supplements as compared to those whose parents completed secondary school education or less (univariable: OR=1.38; 95% CI=1.06, 1.78 and parsimonious: OR=1.35; 95% CI=1.05, 1.74). Students residing in a metropolitan area were more likely to take vitamin D supplement as compared to those attending schools in rural areas (univariable: OR=1.27; 95% CI=1.03, 1.56 and parsimonious: OR=1.32; 95% CI=1.06, 1.65). PAL was highly correlated with vitamin D supplement use in both univariable (1st Tertile: OR=1.39; 95% CI=1.09, 1.77 and 2nd Tertile: OR=1.68; 95% CI=1.33, 2.14) and parsimonius (1st Tertile: OR=1.39; 95% CI=1.09, 1.78 and 2nd Tertile: OR=1.70; 95% CI=1.33, 2.16) models. Table 3.3 shows that parental education, household income and PAL were associated with multivitamin use. Energy-adjusted dietary vitamin D intake was not retained in the parsimonious models for either type of supplement (vitamin D supplement in Table 3.2 or multivitamin in Table 3.3).

3.4. Discussion

This study indicated that approximately one third of school children aged 10-11 years in Alberta took vitamin D supplements and approximately half of them took multivitamins. Parental education, region of residence and PAL were determinants of vitamin D supplement use among children, independent of child's gender, household income, weight status and dietary practices. Both vitamin D and multivitamin supplement use were more prevalent among physically active children and those from families with high socioeconomic status, and use was less common among boys than among girls.

Consistent with other findings,[19,23,24] we identified that children in Alberta were more likely to use multivitamins than vitamin D supplements. Although the use of supplements (vitamin D supplements, multivitamins, or both) was twice as common among children in our study (62%) compared to the national averages in 2007/2009 of 31%[32] and in 2009/2011 of 34%,[7] only small proportions of children were taking supplements once a day, or more frequently. Therefore, promotion of supplements on a daily basis is essential to meet the recommended daily requirement of vitamin D.

Parental education was associated with use of both vitamin D supplements and multivitamins. We did not find any association of vitamin D supplement use with household income, whereas multivitamin use in our study and other studies[11,19,21] had a positive association with income. Therefore, unlike multivitamin use, vitamin D supplement use mainly depended on the knowledge of the parents, independent of their income. Students residing in a metropolitan area were more likely to take vitamin D supplements than those attending schools in rural area. However, residential area was not associated with multivitamin supplement use, and most of the multivitamins available for children in Canada contain only half of the recommended daily amount of vitamin D. Parents may have been unaware of the vitamin D composition in multivitamins or the importance of vitamin D for their children. Therefore, dissemination of public health knowledge on children's need for sole vitamin D supplements based on residential area appears to be important.

Vitamin D status of Canadians mainly depends on the diet and supplements[33] due to limited cutaneous synthesis.[2,3] Among children in Alberta, the prevalence of both vitamin D supplement and multivitamin use were low among those who consumed less vitamin D from the diet (30-35% in each tertile); therefore approximately 65-70% of the children with a low intake of dietary vitamin D were at risk of deficiency. However, we did not find any significant association in the regression analysis of dietary vitamin D intake and quality of the diet with supplement use. Some other findings on multivitamin supplement use[21,22] demonstrated that children with better quality diets were more likely to take either vitamin D or multivitamin supplements. We previously identified that only one-fifth of the students in our study met dietary guidelines for vitamin D through both diet and supplements.[34] Although it is important to encourage children to adopt healthy eating behaviours in addition to taking supplements for adequate nutrient intake,[22] our findings reveal the importance of using vitamin D supplements independent of diet quality. Public health strategies aimed at improving the use of vitamin D supplements need to make parents also aware of the importance of consuming vitamin D rich dietary sources.

Valtueña et al.[35] identified the interactions between vitamin D and PAL in two possible directions, i.e., sufficient vitamin D levels improve bone health only in active children or PAL improves bone health in individuals with sufficient vitamin D levels. Therefore, predominant use of vitamin D supplements by more active children in our study is notably interesting as proper vitamin D levels potentially better benefit the active children. Obese and overweight children may need extra vitamin D[36] to compensate for their additional requirements. They are susceptible to poor vitamin D status as a result of adipose tissue sequestration.[1,7] However, the use of vitamin D supplements and multivitamins was less common among overweight and obese children in the present study. Specifically, overweight children were the least likely to use vitamin D supplements and obese children were the least likely to use multivitamins. This association was obtained only in the unadjusted models, indicating that the relationship was confounded by demographic, socioeconomic and lifestyle factors. It is not surprising that we did not see any difference in vitamin D containing supplement use by weight status. The public is likely to be unaware that overweight and obese children need more vitamin D relative to a normal weight child.[36] The additional requirements for those above healthy body weight need to be considered when recommending supplements and more research is needed to establish weight-specific clinical guidelines for vitamin D.

To our knowledge, this is the first population-based study that describes factors associated with the use of vitamin D supplements among children in Canada. Also, only a few studies have examined the determinants of multivitamin supplement use among children. The other strengths of this study were the use of a large provincially representative sample, its high response rate for school-based research, and, the execution of multilevel regression to account for hierarchical data structure and to assist the survey design effect with weighted analysis. There were some limitations of this study. The use of self-reported information was not validated, but, potential bias was minimized by using a validated YAQ that has been shown to be comparable in estimating typical intake to multiple 24-hour recalls. Parents did not answer the question about child supplement use and therefore, it is possible that the children may not have known the difference between vitamin D supplements and multivitamins mentioned in the questionnaire in addition to recall bias. However, evaluation assistants helped minimize this issue by providing explanations while children completed the surveys. The present study was conducted using a sample of grade 5 students in Alberta and the participation rate was 59%. Therefore, caution is warranted when generalizing results to other children.

3.5. Conclusion

A low proportion of school-aged children were taking vitamin D supplements and most of them did not use them on a daily basis. Physically active children were more likely to use supplements and therefore, parents who encourage their children to be more active may also be more likely to provide them with supplements, or those who were using supplements are more likely to be physically active. Parents with low educational attainment and those who live in rural and urban areas should be the target of campaigns to promote vitamin D supplementation for children. Although overweight and obese children require more vitamin D, vitamin D supplement use was not associated with body weight status. Therefore, nutritionists and health care providers need to consider the weight status of the child when recommending supplements. Further studies are required to explore other possible determinants of supplement use such as parents' perceptions on using supplements and family history of supplements use.

3.6. References

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3.7. Tables

Table 3.1. General characteristics and the prevalence of supplement use of 10-11year-old students in Alberta, Canada

	All students, %* (n = 2,686)	Vitamin D supplement users (with or without multivitamin use), %* (n=769)*	Multivitamin supplement users (with or without vitamin D supplement use), %* (n=1,468)
Gender			
Girls	53.49	28.52	55.17
Boys	46.51	30.51	52.83
Parental education†			
Secondary or less	23.19	24.99	49.15
College	33.54	31.50	55.28
University/graduate	37.89	30.23	57.08
Household income			
≤ $50,000	13.21	28.56	47.26
$50,001 – $100,000	19.03	30.38	57.08
≥ $100,001	28.89	30.65	57.68
Non-disclosed/Missing§	38.87	28.39	52.25
Region of residence			
Rural	39.55	26.71	54.97
Urban	8.28	28.94	56.49
Metropolitan	52.17	31.60	53.03
Weight status†			
Under/normal weight	68.59	30.61	55.63
Overweight	20.84	25.96	50.90
Obese	7.86	28.40	46.51
Physical activity level			
1st Tertile	33.32	23.89	48.75
2nd Tertile	33.32	30.33	53.86
3rd Tertile	33.36	34.40	59.93
Energy-adjusted diet quality index¶			
1st Tertile	33.32	24.05	49.68
2nd Tertile	33.32	32.67	57.02
3rd Tertile	33.36	31.65	55.58
Energy-adjusted total dietary vitamin D¶			
1st Tertile	33.32	26.15	50.16
2nd Tertile	33.32	30.33	54.99
3rd Tertile	33.36	31.82	57.04

*Results were weighted to represent provincial estimates of the grade five student population (age: 10-11y) in Alberta.
†<5% of missing data
§26.63% non-disclosed responses (participants were provided option not to disclose their household income) and 12.23% missing data.
¶"Energy adjusted" DQI and dietary vitamin D intake were computed as the residuals from the regression model with total energy intake as the independent variable and absolute DQI or dietary vitamin D intake as the dependent variable as per established criteria[26].

Table 3.2. Determinants of vitamin D supplement use among 10-11-year-old students in Alberta, Canada[#]

	Univariable model Odds Ratio (95% CI)	Parsimonious model[†] Odds Ratio (95% CI)
Demographic, socio-economic and anthropometric factors		
Gender		
Girls	1.00	1.00
Boys	1.10 (0.91, 1.33)	1.03 (0.85, 1.25)
Parental education		
Secondary or less	1.00	1.00
College	1.38 (1.06, 1.78)*	1.35 (1.05, 1.74)*
University or graduate	1.29 (1.00, 1.65)*	1.21 (0.94, 1.56)
Household income[§]		
≤$50,000	1.00	1.00
$50,001-100,000	1.08 (0.80, 1.47)	1.08 (0.79, 1.48)
≥$100,001	1.08 (0.80, 1.48)	1.03 (0.74, 1.43)
Region of residence		
Rural	1.00	1.00
Urban	1.11 (0.91, 1.37)	1.13 (0.92 1.40)
Metropolitan	1.27 (1.03, 1.56)*	1.32 (1.06, 1.65)*
Weight status		
Under/normal weight	1.00	1.00
Overweight	0.80 (0.64, 1.00)*	0.82 (0.66, 1.04)
Obese	0.91 (0.60, 1.40)	0.93 (0.60, 1.43)
Lifestyle factors		
Physical activity level		
1st Tertile	1.00	1.00
2nd Tertile	1.39 (1.09, 1.77)**	1.39 (1.09, 1.78)**
3rd Tertile	1.68 (1.33, 2.14)***	1.70 (1.33, 2.16)***
Energy-adjusted diet quality index[¶]		
1st Tertile	1.00	1.00
2nd Tertile	1.16 (0.91, 1.47)	1.12 (0.89, 1.42)
3rd Tertile	1.18 (0.95, 1.46)	1.10 (0.89, 1.36)
Energy-adjusted dietary vitamin D intake[¶]		
1st Tertile	1.00	-
2nd Tertile	0.93 (0.73, 1.19)	
3rd Tertile	1.03 (0.81, 1.31)	

[#]Results were weighted to represent provincial estimates of the grade five student population (age: 10-11y) in Alberta. Vitamin D supplement users were defined as those who used vitamin D supplements irrespective of use of multivitamins.

p<0.05; ** p<0.01; *** p<0.001

[†]Adjusted for demographic, socio-economic and anthropometric factors in the table

[§]26.63% non-disclosed responses (participants were provided option not to disclose their household income) and 12.23% missing data

[¶]"Energy adjusted" DQI and dietary vitamin D intake were computed as the residuals from the regression model with total energy intake as the independent variable and absolute DQI or dietary vitamin D intake as the dependent variable as per established criteria[26].

Table 3.3. Determinants of use of multivitamins among of 10-11-year-old students in Alberta, Canada[#]

	Univariable model Odds Ratio (95% CI)	Parsimonious model[†] Odds Ratio (95% CI)
Demographic, socio-economic and anthropometric factors		
Gender		
Girls	1.00	1.00
Boys	0.91 (0.75, 1.10)	0.85 (0.70, 1.03)
Parental education		
Secondary or less	1.00	1.00
College	1.26 (1.02, 1.55)*	1.25 (1.02, 1.54)*
University or graduate	1.34 (1.07, 1.69)*	1.33 (1.06, 1.68)*
Household income[§]		
≤$50,000	1.00	1.00
$50,001-100,000	1.48 (1.10, 2.00)**	1.43 (1.05, 1.94)*
≥$100,001	1.44 (1.09, 1.91)**	1.29 (0.97, 1.71)
Region of residence		
Rural	1.00	1.00
Urban	1.06 (0.81, 1.40)	1.06 (0.81 1.39)
Metropolitan	0.92 (0.73, 1.17)	0.95 (0.76, 1.19)
Weight status		
Under/normal weight	1.00	1.00
Overweight	0.84 (0.67, 1.05)	0.88 (0.70, 1.09)
Obese	0.70 (0.50, 0.98)*	0.76 (0.54, 1.08)
Lifestyle factors		
Physical activity level		
1st Tertile	1.00	1.00
2nd Tertile	1.21 (0.99, 1.47)	1.20 (0.97, 1.47)
3rd Tertile	1.55 (1.26, 1.90)***	1.56 (1.27, 1.91)***
Energy-adjusted diet quality index[¶]		
1st Tertile	1.00	1.00
2nd Tertile	1.22 (0.99, 1.51)	1.20 (0.97, 1.49)
3rd Tertile	1.22 (0.97, 1.55)	1.13 (0.90, 1.43)
Energy-adjusted dietary vitamin D intake[¶]	1.00	-
1st Tertile	0.95 (0.77, 1.17)	
2nd Tertile	1.16 (0.97, 1.39)	
3rd Tertile		

[#]Results were weighted to represent provincial estimates of the grade five student population (age: 10-11y) in Alberta. Multivitamin users were defined as those who used multivitamins irrespective of use of vitamin D supplements.
*p<0.05; ** p<0.01; *** p<0.001
[†]Adjusted for demographic, socio-economic and anthropometric factors in the table
[§]26.63% non-disclosed responses (participants were provided option not to disclose their household income) and 12.23% missing data
[¶]"Energy adjusted" DQI and dietary vitamin D intake were computed as the residuals from the regression model with total energy intake as the independent variable and absolute DQI or dietary vitamin D intake as the dependent variable as per established criteria[26]

4. Vitamin D supplementation among children is positively associated with their parental encouragement of healthy lifestyles and personal caring for healthy lifestyles by their parents

Lalani L. Munasinghe, Yan Yuan, Erin L. Faught, Noreen Willows, Paul J. Veugelers. Vitamin D supplementation among children is positively associated with their parental encouragement of healthy lifestyles and personal caring for healthy lifestyles by their parents (Submitted to Canadian Journal of Public Health)

4.1. Introduction

Canadian children are at risk of being vitamin D deficient and insufficient due to limited cutaneous synthesis by sun exposure[1,2] and low consumption of vitamin D rich foods.[2-6] The Canadian Health Measures Survey[7] revealed that nearly 30% of Canadian children have serum vitamin D concentrations that are assumed insufficient to achieve optimal bone health. Supplementation with vitamin D may address this,[1,6,8-10] however, the use of vitamin D supplements by children in the province of Alberta, Canada is currently very low.[11] Parents are commonly unaware of the dietary recommendations and their health benefits.[12] Despite the evidence in the literature that Canadians who use supplements are more likely to maintain adequate vitamin D levels,[8,13] Health Canada currently only recommends daily vitamin D supplements for breastfed, healthy term infants and those over the age of fifty.[14] Vitamin D supplementation seems to be essential to achieve an adequate vitamin D status in other age groups as well.

Parents are in a key position to encourage health behaviors among their children.[15-22] Studies have identified positive associations of parental influence on their children's physical activity,[16-19,22] healthy eating[15,22] and vegetables and fruit consumption,[23] such that it was also found to be associated with healthy body weight,[15,18,20,21] but no previous study addresses their influence on vitamin D supplement use.

Therefore, the purpose of this study was to examine the influence of parental encouragement of, and caring about, healthy lifestyles on children's use of vitamin D supplements and multivitamins. This knowledge can inform health promotion strategies to improve vitamin D status among Canadian children.

4.2. Methods

4.2.1. Study design and subjects

We analyzed demographic, socio-economic, dietary, supplement use, and physical activity data that were collected in the spring of 2014 as part of the "Raising healthy Eating and Active Living Kids in Alberta" (REAL Kids Alberta). The REAL Kids Alberta survey is a population-based study of grade five students (age 10-11 years) and their parents or guardians throughout the province of Alberta, Canada. The sampling frame included 90.2 % of all elementary schools in Alberta with grade 5 students because francophone schools, on-reserve federal schools, and private, charter and colony schools could not be included.[24] A total of 140 elementary schools were randomly selected from three geographical strata (metropolitan, urban, and rural) to achieve proportional representation.[24] More details on the project aim and the measures used are available on the project's website: http://www.realkidsalberta.ca. A total of 4,993 parent surveys and parental consent forms were handed out to students to be completed by parent(s) or guardian(s) at home. Among the 3,284 home booklets returned to school (66%), 2,958 students (90%) were granted parental consent and participated in the study resulting in an overall participation rate of 59%. Observations of students who did not complete the food frequency questionnaires (n=107) and who had missing data on use of multivitamins and/or vitamin D supplements use (n=46) were excluded from the analysis. A total of 119 students, who had reported energy intakes of <500 kcal or >5,000 kcal were also excluded as per established criteria when food frequency questionnaire data are involved.[25] Final analysis of the present study was restricted to a total of 2,686 students (53.8%).

4.2.2. Assessment of outcome measures: Vitamin D-containing supplement use

Each student completed a modified version of the Harvard Youth/Adolescent Food Frequency Questionnaire (FFQ) on a school day with the guidance of a trained evaluation assistant. The FFQ has been validated for use in children and adolescents aged 9-18.[26] The FFQ was modified to collect information on the use of vitamin D supplements and multivitamins by including the questions "Do you take vitamin D supplements (pills/drops)?" and "Do you take multivitamins?". These questions were reviewed by a panel with expertise in nutrition and piloted in the target population to ensure their understanding and validity. The commonly available multivitamin supplements for school children such as Flintstones®, One a Day®, and Gummy Vites®, contain vitamin D (informal observation). In this study we define "Vitamin D supplement users" as children who reported ever taking a vitamin D supplement and "multivitamin supplement users" as children who reported ever taking a multivitamin.

4.2.3. Assessment of exposures variables

Survey questions for parents included (1) “To what extent do you encourage your grade 5 child to eat healthy foods?”, (2) “To what extent do you encourage your grade 5 child to be physically active?”, (3) “How much do you personally care about eating healthy foods?”, and (4) “How much do you personally care about staying fit and exercising?”. The responses for each question were given as an ordinal scale from 1 to 4, where a response of 1= “not at all”, 2= “a little bit”, 3= “quite a lot” and 4= “very much”.

4.2.4. Assessment of potential confounders

Parents reported students’ gender in the home survey. Data on the level of parent education attainment and household income were collected from parent responses in the home survey. Evaluation assistants measured students’ weight to the nearest 0.1 kg using calibrated digital scales (Health-o-meter, USA) and standing height to the nearest 0.1 cm using stadiometers (Seca-Stadiometers, Germany). Body Mass Index (BMI) was calculated as weight divided by height squared (kg/m^2). Overweight and obesity were defined according to the International Obesity Task Force BMI cut-off points adjusted to age- and gender-specific categories for children and youth.[27] Region of residence was defined as metropolitan (Calgary and Edmonton, cities with a population of about one million people each), urban (other municipalities with more than 40,000 residents) and rural (municipalities with less than 40,000 residents), based on the schools located in three geographical strata.[24] Child physical activity level (PAL) was identified as a single physical activity score ranging from 0 to 5, which was derived from a 29-item questionnaire adapted from the validated Physical Activity Questionnaire for Older Children.[28] Diet quality was derived using the Diet Quality Index-International, based on adequacy, variety, moderation, and balance, with scores ranging from 0 to 100, 0 representing the lowest and 100 the highest diet quality.[29] Dietary intake data were obtained based on responses to the questions in the FFQ, validated for children and adolescents.[26] Total calorie intake from food was calculated using Canadian Nutrient File.[30]

4.2.5. Statistical analyses

The response categories of the exposure variables of interest of ‘not at all’ and ‘a little bit’ were combined into one category due to the small number of responses. Descriptive statistics were used to characterize the students’ and parents’ responses. Mixed effect logistic regression analysis with children nested within schools were applied to examine the associations of vitamin D supplement and multivitamin use among children with their parents care about healthy foods and physical activity, and their encouragement to undertake these behaviors. We first applied univariable regression analyses to quantify the unadjusted associations. Second, we applied multivariable regression analyses to adjust for the confounding effects of student gender, parental education, household income, region of residence, body weight status, PAL and energy adjusted diet quality index. We adjusted for PAL and diet quality to quantify the association of parenting behaviors on supplement use independent of these children's lifestyles. Third, we constructed two parsimonious regression models in which we considered both parental encouragements to eat healthy foods and to be physically active simultaneously, or in which we considered both parental personal care on those behaviors simultaneously along with the potential confounders. Last, we constructed a full parsimonious regression model that considered all exposure variables simultaneously along the potential confounders to quantify their independent contribution to vitamin D-containing supplement use. Model selection was done using Akaike Information Criteria and Bayesian Information Criteria. An interaction model was built to identify any synergistic effect on the four exposures of interest. Missing data for some of the confounder variables were treated as a separate category. An "energy adjusted diet quality index" was computed from the residuals of a regression model with total energy intake as the independent variable and diet quality index as the dependent variable, as per established criteria[25]. All analyses were weighted to represent unbiased provincial estimates of the grade 5 student population in Alberta. Data were analyzed using Stata version 13 (Stata Corp, College Station, TX, USA).

4.3. Results

Characteristics of grade 5 students and their parents/guardians are presented in Table 1. The percentages were weighted to represent provincial estimates of the grade 5 student population (age: 10-11 year-old) in Alberta. The proportions of students taking vitamin D supplements and multivitamins are 29.45% and 54.08%, respectively. The majority of the parents/guardians reported to personally care about and to encourage their children to eat healthy foods and to be physically active (Table 1).

Table 2 shows the associations of parental encouragement to eat healthy foods, parental encouragement to be physically active, parental personally caring about healthy eating and parental personally caring about physical activity with the use of vitamin D supplements. Parental encouragement of and caring about eating healthy and personally caring about physical activity were positively associated with vitamin D supplement use after adjusting for potential confounders. Students whose parents encouraged them 'very much' (OR=1.52; 95% CI=1.06, 2.18) and whose parents personally cared 'very much" (OR=1.44; 95% CI=1.09, 1.90) about eating healthy were more likely to use vitamin D supplements as compared to those whose parents encouraged or cared 'not at all' or 'a little bit' (Table 2). Students whose parents personally cared 'quite a lot' (OR=1.55; 95% CI=1.17, 2.05) and 'very much' (OR=1.67; 95% CI=1.26, 2.22) about being physically active were more likely use vitamin D supplements as compared to those whose parents reported 'not at all/a little bit' (Table 2). Parental personal care about being physically active remained significant when caring about healthy eating and caring about physical activity were considered simultaneously (parsimonious model: data not shown). Likewise, parental personal care about being physically active remained significant in a parsimonious model with all four exposures of interest (parental encouragement to eat healthy eating and to be physical active, and parental personal care about healthy eating and for being physically active). According to the analysis, parents personally caring 'quite a lot' (OR=1.53; 95% CI=1.14, 2.06) and 'very much' (OR=1.57; 95% CI=1.10, 2.25) vs. 'not at all/a little bit' about physically active were strongly associated with vitamin D supplement use in the final parsimonious regression model adjusting for confounders and the other three exposure variables.

Table 3 depicts the association of parental encouragement of and care about healthy eating and being physically active with vitamin D-containing multivitamin supplement use. Students whose parents personally cared 'quite a lot' (OR=1.61; 95% CI=1.14, 2.29) and 'very much' (OR=1.49; 95% CI=1.06, 2.27) about eating healthy foods were more likely to use multivitamin supplements as compared to students whose parents personally cared 'not at all/a little bit'. In a parsimonious regression model with all four exposures of interest these OR's for parental personal care were 1.56 (95% CI=1.08, 2.27) and 1.50 (95% CI=1.01, 2.22) for 'quite a lot' and 'very much' relative to 'not at all/a little bit', respectively.

4.4. Discussion

To our knowledge, this is the first study that revealed the association of children's use of vitamin D supplement and multivitamins with their parental encouragement of healthy lifestyles and their parents' personally caring about healthy lifestyles. In this large population-based study, we identified a positive association between parental encouragement of child healthy eating and personally caring about eating healthy and being physically active with child vitamin D supplement use. Also parental caring about eating healthy foods was identified to be positively associated with multivitamin supplement use.

Our research program had previously revealed that both parental encouragement of child healthy eating and parental caring about healthy eating are independently associated with the diet quality of their children.[15] In addition, our research program had revealed that parental caring, encouraging, and engaging in physical activity are independently and positively associated with children's physical activity levels and negatively associated with prevalence of overweight.[18] Also other studies revealed that parental influences lead to better diets and higher activity levels.[15-19,22,23] However, no earlier study addressed the importance of parental encouragement of and caring about the use of vitamin D supplementation and multivitamins, though we had previously identified parental education as a determinant of vitamin D supplement use among children.[11]

The diet is the best way to meet nutritional requirements for healthy children.[31,32] However, as Canadian children have limited sun exposure and do not consume enough vitamin D rich foods to meet the daily requirement[3,4] supplementation with vitamin D seems essential to achieve good bone health. Vitamin D supplementation, however, receives little public health priority for Canadians over the age of one[14]. Drury et al.[12] reported that 86% of parents of children between the ages 6 months and 5 years in the UK were not aware of the recommendations for vitamin D supplementation for their children and also were not aware of the potential benefits of vitamin D. Health promotion strategies are thus needed to create awareness of the existence of recommendations and the importance of vitamin D for bone health. The use of multivitamins among Canadian children is more common than use of vitamin D supplements.[11] Promotion of vitamin D supplements is preferred to optimize vitamin D status among children as promotion of multivitamins may come with potential adverse effects resulting from unnecessary high intakes of other nutrients.[33,34] In the present study we had revealed that parental caring about healthy lifestyles is associated with use of vitamin D supplements. Education of parents to care about their health and that of their children may therefore contribute to the use of supplements and a better vitamin D status. We had also revealed that encouragement of healthy lifestyles was associated with the use of supplements among children. This seems to imply that education of the importance of vitamin D in combination with promotion of parental encouragement of supplement use may increase its use among children and improve their vitamin D status, but intervention research will be needed to establish this.

Strengths of the present study include the use of a large provincially representative sample with a relatively high response rate for school-based research and the execution of multilevel regression to account for hierarchical data structure. We accounted for the survey design effect with weighted analysis. However, non-response may cause bias in the estimates if the missing data are not random. There are also some limitations of this study. Self-report can be a cause of error, though the use of validated instruments, the FFQ and the Physical Activity Questionnaire may have minimized this to some extent. In addition, it is possible that the children may not have been accurate in distinguishing vitamin D supplements and multivitamins. However, evaluation assistants helped minimize this issue by providing explanations to children while they completed the questionnaires. Further, health behavior questions are prone to social desirability bias. And lastly, caution is warranted when interpreting causality due to cross-sectional nature of the study design.

4.5. Conclusion

Our study revealed the importance of the role of parents for achieving adequate vitamin intake by their children: parental encouragements of healthy lifestyles were observed to be associated with the use of vitamin D supplements and multivitamins. Less than one third of children in this study reported using vitamin D supplements despite the fact that the dietary intake of vitamin D among

Canadian children is often inadequate and vitamin D deficiency and insufficiency are prevalent. Public health initiatives are needed to promote vitamin D supplement use among children. Our findings suggest that education and parental encouragement of healthy lifestyles and supplementation with vitamin D should be part of such initiatives.

4.6. References

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4.7. Tables

Table 4.1. Characteristics of 10-11 year-old students in Alberta, Canada and their parents' responses*

	% of students (n = 2,686)
Parental encouragement for children to eat healthy foods	
Not at all/A little bit	7.12
Quite a lot	45.71
Very much	44.31
Parental encouragement for children to be physically active	
Not at all/A little bit	12.04
Quite a lot	42.32
Very much	42.73
Parental personal care for eating healthy foods	
Not at all/A little bit	13.12
Quite a lot	45.70
Very much	38.06
Parental personal care for being physically active	
Not at all/A little bit	21.66
Quite a lot	45.27
Very much	30.20
Vitamin D supplements	
Users	29.45
Non-users	70.55
Multivitamins	
Users	54.08
Non-users	45.92
Gender	
Girls	53.49
Boys	46.51
Parental education†	
Secondary or less	23.19
College	33.54
University/graduate	37.89
Household income	
≤ $50,000	13.21
$50,001 – $100,000	19.03
≥ $100,001	28.89
Non-disclosed/Missing§	38.87
Region of residence	
Rural	39.55
Urban	8.28
Metropolitan	52.17
Weight status†	
Under/normal weight	68.59
Overweight	20.84
Obese	7.86

*Results were weighted to represent provincial estimates of the grade 5 student population (age: 10-11 year-old) in Alberta.

†<5% of missing data

§26.63% non-disclosed responses (participants were provided option not to disclose their household income) and 12.23% missing data.

Table 4.2. Associations of vitamin D supplement use with parental encouragement and care about healthy lifestyle practices*

	Vitamin D supplement users	Univariable model			Multivariable model§		
	% (n=769)	OR	95% CI	p value	OR	95% CI	p value
Parental encouragement for children to eat healthy foods†							
Not at all/A little bit	5.34	1.00			1.00		
Quite a lot	43.53	1.37	0.97, 1.94	0.076	1.31	0.91, 1.90	0.150
Very much	48.17	1.65	1.17, 2.33	**0.004**	1.52	1.06, 2.18	**0.024**
Parental encouragement for children to be physically active†							
Not at all/A little bit	10.06	1.00			1.00		
Quite a lot	39.99	1.18	0.84, 1.65	0.333	1.10	0.77, 1.57	0.590
Very much	47.18	1.47	1.09, 1.98	**0.012**	1.27	0.92, 1.75	0.148
Parental personal care for eating healthy foods†							
Not at all/A little bit	10.47	1.00			1.00		
Quite a lot	44.32	1.30	0.97, 1.73	0.080	1.25	0.94, 1.67	0.129
Very much	41.87	1.55	1.18, 2.04	**0.002**	1.44	1.09, 1.90	**0.011**
Parental personal care for being physically active†							
Not at all/A little bit	15.85	1.00			1.00		
Quite a lot	47.09	1.60	1.22, 2.11	**0.001**	1.55	1.17, 2.05	**0.002**
Very much	34.24	1.82	1.40, 2.38	<**0.001**	1.67	1.26, 2.22	**<0.001**

*Results were weighted to represent provincial estimates of the grade 5 student population (age: 10-11 year-old) in Alberta. Vitamin D supplement users were defined as those who used vitamin D supplements irrespective of use of multivitamins.
†<4% of missing data.
§Adjusted for student gender, parental education, household income, region of residence, body weight status, physical activity and the energy adjusted diet quality index.

Table 4.3. Associations of vitamin D-containing multivitamin use with parental encouragement and care about healthy lifestyle practices*

	Multivitamin users	Univariable model			Multivariable model§		
	% (n=1,468)	OR	95% CI	p value	OR	95% CI	p value
Parental encouragement to eat healthy foods†							
Not at all/A little bit	5.80	1.00			1.00		
Quite a lot	45.84	1.48	1.05, 2.11	**0.026**	1.34	0.94, 1.92	0.109
Very much	46.01	1.59	1.16, 2.18	**0.004**	1.35	0.97, 1.90	0.076
Parental encouragement to be physically active†							
Not at all/A little bit	10.73	1.00			1.00		
Quite a lot	42.06	1.26	0.91, 1.74	0.161	1.16	0.82, 1.64	0.387
Very much	44.83	1.40	1.02, 1.93	**0.039**	1.17	0.83, 1.66	0.365
Parental personal care of eating healthy foods†							
Not at all/A little bit	10.39	1.00			1.00		
Quite a lot	47.74	1.75	1.25, 2.44	**0.001**	1.61	1.14, 2.29	**0.007**
Very much	39.22	1.68	1.23, 2.30	**0.001**	1.49	1.06, 2.08	**0.021**
Parental personal care of being physically active†							
Not at all/A little bit	20.21	1.00			1.00		
Quite a lot	46.27	1.21	0.97, 1.51	0.094	1.16	0.92, 1.45	0.215
Very much	31.20	1.23	0.97, 1.56	0.092	1.08	0.84, 1.39	0.525

*Results were weighted to represent provincial estimates of the grade 5 student population (age: 10-11 year-old) in Alberta. Multivitamin users were defined as those who used multivitamins irrespective of use of vitamin D supplements.
†<3% of missing data
§Adjusted for student gender, parental education, household income, region of residence, body weight status, physical activity and the energy adjusted diet quality index.

5. General Discussion and Conclusion

Maintaining proper vitamin D status during childhood is critical as children are growing and need to minimize the consequent risk of later chronic diseases through optimum nutrition. The prevalence of vitamin D deficiency or insufficiency among Canadian children has not yet changed even after the introduction of revised dietary guidelines in 2010,[1,2] and it can be due to the fact that no formal recommendation on supplement use has been established for children. The present study highlighted the importance of vitamin D supplementation for children in Canada to meet dietary recommendations, and the determinants of meeting dietary guidelines and supplement use. It also provided useful information that would be important for public health initiatives to promote supplementation and disclose knowledge in order to improve vitamin D status.

This study revealed that only a very low proportion of children in Alberta met the RDA target from both diet and supplements (45% met the EAR and 22% met the RDA), and the proportion was lower still when only the diet was considered (16% met the EAR and 2% met the RDA) (Chapter 2). This finding indicates the difficulty in meeting dietary guidelines only through the diet. A more recent double-blind randomized control study[3] assigned Canadian children aged 2-8 years to one of the 3 dietary vitamin D target groups, i.e. control, EAR (400 IU/day) and RDA (600 IU/day), for 12 weeks during winter and early spring. Based on the argument that 60% of the EAR group met the target through diet that was set to be sufficient to meet the requirement of only 50% of the population, and 96% of both treatment groups met sufficient serum 25(OH)D levels (>50 nmol/L), the authors[3] suggested that the EAR could be too high. Contradictorily, Godel[4] stated that the intake of 400 IU/day seems not enough. In addition to some issues of generalizing results from randomized control trials, the authors did not consider the fact that only 42% of the RDA group met their target through the diet, which was set to be sufficient to meet the requirement of 97.5% of the population. Furthermore, the DRI recommendations were derived mainly considering supplement-based randomized controlled trials in adults from countries with much better vitamin D status than Canada[3] and even the previous cutoff of 200 IU was unable to meet the targets for both Albertan and all Canadian children.[5] Recently, researchers[6,7] raised the argument that the revised DRI cutoffs for dietary intake were not enough to meet the serum vitamin D targets and Heaney et al.[8] confirmed it. They[6] criticized that there is a statistical error in the estimation of the RDA for vitamin D; thus, the cutoffs for the RDA introduced by the Institute of Medicine (600 IU for 1-70 years-old and 800 IU for above 70 years) are highly underestimated. However, Health Canada[9] confidently refused the critique raised regarding the statistical error in assessing DRIs after reviewing and analyzing the data. The other institutions in Canada such as The Endocrine Society,[10] the Canadian Pediatric Society,[4] and the Canadian Dermatology Association[11] also recommended higher intakes of vitamin D for children. Based on the estimation using a dual approach that included a meta-analysis and an analysis of data from a large preventive health program, a normal weight individual needs 1,885 IU to achieve serum level of 58 to 171 nmol/L,[12] in whom, it is not feasible to achieve this amount without supplements. The inability to meet the DRI targets especially through diet alone together with low prevalence of using vitamin D supplements (29%) and very low use of it on a daily basis (12%) in the present study further emphasizes the necessity of promoting vitamin D supplements. Moreover, the same dietary recommendation cut-offs are established for both United States and Canada despite the fact that comparable to a child in the United States,[13] a Canadian child has limited options to select fortified foods and comparably lower cutaneous synthesis due to the higher latitude of Canada. Nevertheless, Brett et al.[3] recently stated that the regular intake of vitamin D from the diet would better sustain vitamin D status than that from the supplements. Due to limitations associated with consuming fortified foods such as lactose-intolerance[14] and limited availability or accessibility,[15] the cost associated with natural sources such as fatty fish,[16,17] and the higher requirement due to obesity[12,18-20] and fat mal-absorption,[19] it is rather difficult to achieve DRIs only through the diet. Therefore, mandatory fortification of milk substitutes and the use of supplements could better address the issue. However, the adjustment for Canadian food fortification and the inclusion of fatty fish had little impact on the measurement of vitamin D from food.[21] The supplement use of Canadians based on age that followed a J-shape curve[22] indicates the importance of having formal recommendations for children to use supplements, as the formal recommendations are only available for infants and those aged above 50 years.[20]

Among the factors associated on meeting the current dietary guidelines in the present study, physical activity level had a higher influence than parental education and income (Chapter 2). Also, PAL was positively correlated with both vitamin D supplement use and multivitamin use (Chapter 3). Additionally, children of those parents who encouraged and personally cared about their children being physically active were more likely to use vitamin D supplements independent of their actual PAL (Chapter 4). Therefore, possibly those parents of the physically active children may be more health conscious[23] and thus promote physical activity and vitamin D intake through diet and the supplements. Life style factors like physical activity are feasible to be encouraged in both school setting and at household level, where the children spend all of their time. In addition to parental awareness of the importance of vitamin D supplementation, parental education on healthy lifestyle practices should be a part of public health initiatives to promote vitamin D intake.

BMI status of the Albertan children in this study was not associated with either meeting dietary guidelines (Chapter 2) or vitamin D supplement use (Chapter 3). This is also likely due to no formal recommendations by Health Canada or the Institute of Medicine for vitamin D supplement use for overweight and obese children, and also available dietary guideline cutoffs that are not BMI-specific, despite the fact that overweight and obese individuals need extra vitamin D.[12,18] It is suggested that the daily vitamin D intake for overweight and obese adults to be 2,802 IU and 6,235 IU, respectively[12] or, 1.5 times and 2-3 times higher values relative to normal weight,[18] respectively, indicating the essentiality of supplements for children with excess body weights. The same authors further suggested reconsideration of DRI cutoff values[6,12] and providing body weight-specific cut-offs.[12] Because of the child-obesity epidemic in Canada[24,25] together with the high prevalence of low vitamin D levels among children, both parents and health professionals need to be aware of the extra requirement of vitamin D for children with excess body weights. Importantly, the Endocrine Society of Canada recommends obese children and adults to take at least 2-3 times more vitamin D as required for their age group[10] and the Canadian Pediatric Society[4] suggests to consider the varying levels of vitamin D requirement based on the body weight and BMI when setting dosage levels.

As the vitamin D status of Canadians mainly depend on vitamin D intake and no study has been done to collect data to identify the vitamin D intake of Canadian children after revision of dietary guidelines in 2010, this is the first study that identified the vitamin D intake from both diet and supplements as well as whether the children met the DRI targets. Moreover, for the first time, this study revealed some important factors associated with vitamin D supplement use among children. Additionally, the other strengths included a large school-based survey with a high response rate, use of a rigorous study design and protocols, consideration of mixed effect models as the statistical approach, weighting, adjusting for potential confounders and direct anthropometric measurements. However, the limitations of this study also need to be mentioned. One of the potential drawbacks is the inaccuracy of analyzing vitamin D contents of foods; the Nutrient File may not include every food item, possible bias in recalling dietary intake data, and that usually the FFQ best captures relative rather than absolute individual intakes. Those potential drawbacks were minimized through; (1) using a validated FFQ, (2) collecting dietary intake data for the last year that provided much stable information, (3) dropping unusual data with energy intake <500 kcal and >5,000 kcal from the analysis, (4) using the most recently updated Nutrient File to identify vitamin D composition, and (5) adjusting all dietary data for total energy intake as per established criteria.[26] Self-reported questionnaires may have some other drawbacks such as provision of socially desirable responses and inability to differentiate vitamin D supplements from multivitamins or other medications, but these were also minimized by completing questionnaires with the help of experienced evaluation assistants and collecting data on the brand names of the supplements. The cross-sectional nature of this study limits the interpretation of directionality and causality of the associations.

In conclusion, a large proportion of Albertan children failed to meet the DRI targets and the consumption of vitamin D rich foods is infrequent, indicating the importance of having formal recommendations to use vitamin D supplements for children. Parental encouragement of healthy lifestyles, body weight status, parental education and area of residence are important factors to be considered when making public health initiatives to promote vitamin D supplementation. It is worthwhile to note that the household income was not associated with vitamin D supplement use even if it was associated with multivitamin use. Despite the importance of mandatory fortification of more staples and milk substitutes, the formal recommendations for vitamin D supplementation is the most economical, straightforward and instantaneous mode of improving vitamin D nutrition among children and an immediate public health initiatives are necessary. Parental awareness about the importance of using vitamin D supplements on a daily basis, and education and parental encouragement of healthy lifestyles, especially for those of children with excess weights, are highly acknowledged.

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