Vitamin D Knowledge, Perceptions, Intake and Status among Young Adults: a Validation & Intervention Study Using A Mobile ‘App’

by

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ABSTRACT

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Vitamin D aids in the maintenance of bone health by enabling calcium absorption, and low concentrations of vitamin D are implicated in a host of chronic disease states. Adequate vitamin D intake during adolescence and young adulthood is crucial, as peak bone mass is formed during this time. However, many young adults do not meet the recommended intakes for vitamin D. The studies described herein examined vitamin D knowledge, perceptions, intake and blood vitamin D$_3$ concentrations among a total of 209 young adults aged 18-25 living in Canada. Qualitative focus groups examined vitamin D knowledge and beliefs among young adults (n=50). The mobile Vitamin D Calculator application (‘app’) was validated as a measure of dietary vitamin D intake in this population. The app was then used in testing effects of a behavioural intervention aimed at increasing vitamin D knowledge, intake and status among young adults (n=109). A theoretical model based on the Theory of Planned Behaviour and Prototype Willingness Model was used to predict behavioural intentions related to vitamin D intake in the same sample at baseline (n=109). Results indicated that vitamin D knowledge, intake, and status in this population were fairly low. The proportion of participants who met the recommended intake of vitamin D (i.e., Estimated Average Requirement) was greater among individuals who used vitamin D supplements than those who did not. The behavioural intervention led to modest increases in vitamin D knowledge, intake and perceived importance of vitamin D supplement use among those who completed the
intervention study (n=90). Blood vitamin D₃ levels increased from pre- to post-intervention in both groups; participation in the intervention did not improve vitamin D status. This research highlights the need for greater awareness and education regarding the importance of vitamin D among young adults, the utility of providing personalized nutrition information and use of self-monitoring to improve intake, and the potential for vitamin D supplementation to help individuals meet intake requirements. Potential policy implications (e.g., expanded vitamin D fortification of foods, increased national vitamin D intake recommendations) are discussed.
This thesis is based on the following manuscripts and publications:


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CHAPTER 1: INTRODUCTION

Vitamin D is critical for maintaining bone health due to its function in enabling calcium absorption and may prevent bone-related diseases including rickets, osteoporosis and osteomalacia (IOM, 2010). Adequate vitamin D status may also lead to a myriad of other health benefits, including reduced risk of cancer, cardiovascular disease, autoimmune diseases, multiple sclerosis, and diabetes mellitus (Schwalfenberg, 2007).

Current estimates indicate that the vitamin D concentrations among many Canadians are insufficient for optimal health, especially in the winter (Genuis, Schwalfenberg, Hiltz & Vaselenak, 2009; Greene-Finestone et al., 2011; Schwalfenberg, 2007; Vieth, Cole, Hawker, Trang & Rubin, 2001; Whiting, Langlois, Vatanparast & Greene-Finestone, 2011). This is primarily due to the fact that levels of solar ultraviolet B rays (UVB) are insufficient to promote vitamin D synthesis during the Canadian winter (Webb, Kline & Holick, 1988). Another reason is that Canadians are not consuming dietary sources of vitamin D in sufficient quantities to prevent insufficiency. Many Canadians do not eat the two servings of fish per week recommended in Canada’s Food Guide (Health Canada, 2007); in fact, only 15% of fish consumers and 5% of shellfish consumers meet these recommendations (Canadian Aquaculture Industry Alliance, 2011). Moreover, although cow’s milk is fortified with vitamin D in Canada (Canadian Food Inspection Agency, 2012), milk consumption has declined in recent decades and is not regularly consumed by all members of the population (Calvo et al., 2004; Vieth, 2012). Overall, these factors contribute to the prevalence of vitamin D insufficiency in Canada.
This is concerning, as maintaining adequate vitamin D status to support bone density aids in the prevention of age-associated bone disease in both sexes (IOM, 2010). Low bone density is a concern for women due to the increased risk of developing osteoporosis following menopause (IOM, 2010); however, it poses a risk for men as well. According to Osteoporosis Canada (2012), one in eight men over age 50 suffer from osteoporosis.

Although bone diseases tend to develop later in life, most bone mass is formed during the late teens and twenties, and cannot be significantly increased after age 30 (Abrams, 2003). The period from adolescence to young adulthood is thus considered a critical window for the accumulation of skeletal mass, and adequate consumption of calcium and vitamin D during this time is crucial (Heaney et al., 2000). Unfortunately, many young adults do not meet the recommendations for vitamin D status. Although recent research suggests that 75 nmol/L serum vitamin D is the minimum concentration required for optimum health (Dawson-Hughes et al., 2005; Holick & Chen, 2008; Vieth, 2011), data from the 2012-2013 Canadian Health Measures Survey indicates that only a quarter (24.1%, 95% CI: 15.0-36.5) of young adults aged 18-25 have plasma vitamin D levels at or above 75 nmol/L (Statistics Canada, 2015a). Evidently, the vitamin D intake and status of Canadians must be improved during this critical window from adolescence to adulthood.

1 Use with caution; coefficient of variation is between 16.6% and 33.3%.
The transition to adulthood is also a time in which individuals tend to gain increased responsibility for diet and health-related issues. The term “emerging adulthood” has been used to refer to the period from age 18-25 in which increased independence and autonomy are gained (Nelson, Story, Larson, Neumark-Sztainer & Lytle, 2008). This period is considered important for the development of long-term health behaviours (Nelson et al., 2008) and presents a unique opportunity for dietary intervention.

Targeting adolescents and young adults for health behaviour change can be difficult. Some researchers have used the term “young invincibles” (Bibbins-Domingo & Burroughs Peña, 2010) to describe the feelings of invincibility and disregard for future health consequences that often accompany this life stage. Somewhat problematically, maintaining adequate vitamin D status depends on a variety of modifiable factors that require individual choice and in many cases conscious effort. These behaviours include: (a) regular use of vitamin D supplements; (b) adequate consumption of natural dietary sources of vitamin D (i.e., oily fish) and vitamin D-enriched foods (i.e., vitamin D-fortified milk); and, (c) meeting the specific criteria to ensure sufficient UVB exposure for skin synthesis (i.e., exposing bare, unprotected skin at the correct time of day during specific months, for an adequate duration of time according to skin type). Young adults who feel that they are not at risk for poor health (Bibbins-Domingo & Burroughs Peña, 2010) may not make a deliberate effort to engage in these behaviours.

Another factor that may deter youth from meeting vitamin D requirements is a lack of understanding due to mixed messaging. There is currently a debate surrounding optimal
vitamin D status and dietary recommendations in the scientific community (Cannell, 2011; Schwalfenberg & Whiting, 2011; Veugelers & Ekwaru, 2014). As a result, conflicting study results and recommendations are often publicized in the media (Beck 2015; Gillinov, 2014; Mercola, 2014; Picard, 2015), leading to misunderstandings among the general public. In addition, public health messages promoting skin protection and sunscreen to prevent skin cancer often conflict with those that encourage sun exposure for the prevention of vitamin D deficiency, creating a dilemma (Fine & Fine, 2004; Holick, 2001). Taken together, these conflicting messages may create confusion and/or misperceptions among young adults regarding the need to obtain sufficient vitamin D from dietary sources or solar UVB. Despite the potential for confusion, little research has been conducted to examine public knowledge and perceptions towards vitamin D in North America (i.e., Boland, Irwin & Johnson, 2015; Gallo, Jean-Philippe, Rodd & Weiler, 2010; Wingard, 2010).

Similarly, few studies have conducted interventions to increase vitamin D intake, especially among young adult men and women. One study included an intervention to increase bone mineral density in teenage girls aged 14-16 years (Debar et al., 2006), while a second aimed to increase the calcium and vitamin D intake of young women aged 19-30 years (Bohaty, Rocole, Wehling & Waltman, 2008); however, both studies excluded men. A few interventions have aimed to increase vitamin D intake or vitamin D-related health outcomes in other populations, including middle-aged, pre- or post-menopausal women (Drieling, Ma, Thiyagarajan & Stafford, 2011; Jamal et al., 1999; Manios, Moschonis, Katsaroli, Grammatikaki & Tanagra, 2007), Chinese-American
mothers (Lv & Brown, 2011), and the elderly (Teems, Hausman, Fischer, Lee & Johnson, 2011; Vande Griend et al., 2008). Given the limited research in this area, it is currently unclear: (a) what young adults know or believe about vitamin D; (b) how these factors affect their vitamin D status and intake behaviours; and, (c) how to best to intervene and engage young adults on the importance of this nutrient to their personal health.

Given the aforementioned challenges with engaging youth on chronic disease prevention, new methodologies may be needed to intervene and stress the importance of vitamin D in this population. The increasing use of smartphone applications (‘apps’) (Statista, 2015) points to mobile health apps as a promising tool with which to target adolescents and young adults (Holzinger, Dorner, Födinger, Valdez & Ziefle, 2010). Mobile health apps are some of the most highly used apps on the market (Kratzke & Cox, 2012) and have been used in research studies to promote healthy habits among youth (e.g., Hebden et al., 2014). Further, one-fifth of smartphone users have at least one health app, and young adults aged 18-29 years use mobile phones to look up health or medical information more frequently than adults of any other age group (Fox & Duggan, 2012). However, while one study used computer-tailored feedback to increase vitamin D and calcium intake (Lein, 2014), no studies to our knowledge have conducted a vitamin D intervention using a mobile platform.

**Study Purpose**
The purpose of the current study was therefore to: (a) assess the vitamin D knowledge, perceptions, intake and status of young adult men and women aged 18-25 years; and, (b) to test the efficacy of a behavioural intervention using a mobile “Vitamin D Calculator” app in this population.
**Theoretical Framework**

In order to encourage dietary improvement among young adults, it is important to consider the factors that predict health behaviour change in this population. Health behaviours are tied to individual attitudes, norms, intentions, perceived behavioural control (Azjen, 1991) and willingness to perform behaviour (Gerrard, Gibbons, Houlihan, Stock & Pomery, 2008a). The current study thus examined outcome measures (i.e., vitamin D intake and status) in relation to these constructs. Specifically, the study was grounded in the Theory of Planned Behaviour (TPB; Azjen, 1991) and the Prototype Willingness Model (PWM; Gibbons, Gerrard, Blanton & Russell, 1998). The TPB was chosen due to the fact that it has been used extensively in health behaviour research to predict behaviour, primarily via the influence of behavioural intentions and perceived behavioural control (Godin & Kok, 1996). The PWM was included because it includes additional concepts (prototype similarity and evaluation, which affect behavioural willingness) that are especially relevant to adolescent and young adult populations (Gerrard et al., 2008a). In the current study, elements of the two theories were combined to predict vitamin D intake and status among young adults.

**Objectives**

The objectives of this dissertation project were as follows:

1. To assess knowledge of, and perceptions toward, vitamin D in a young adult population. (Focus Group Study; Appendix R, and Intervention Study; Chapter 5)
2. To validate the mobile Vitamin D Calculator app as a measure of dietary vitamin D intake in this population (Validation Study; Chapter 4).
3. To determine current intake and status of vitamin D among a sample of young adults in Canada (Intervention Study; Chapter 5).

4. To assess whether a behavioural intervention using the Vitamin D Calculator app could improve intake, blood levels, knowledge and/or perceptions of vitamin D in this population (Intervention Study; Chapter 5).

5. To test whether the Theory of Planned Behavior and Prototype Willingness Model could be used to predict vitamin D intake and/or status in this population (Assessment of the Theoretical Model; Chapter 6).

Thesis Overview
This dissertation consists of a literature review, four manuscripts and a general discussion. The literature review provides background on the physiology, functions and sources of vitamin D, current intake recommendations, factors relating to vitamin D concentrations and status among Canadians, public knowledge and perceptions surrounding vitamin D, the utility of mobile apps in health research, and an overview of two relevant health behaviour theories. The subsequent four chapters comprise manuscripts stemming from three distinct phases of the research project. Phase one was a series of focus groups that served as a needs assessment to gather qualitative baseline data on the general knowledge and perceptions of young adults regarding vitamin D, as well as preferred strategies for the dissemination of online vitamin D information. Phase two validated the Vitamin D Calculator app as a measure of dietary vitamin D intake among young adults. The third phase consisted of a randomized control trial (RCT) that aimed to improve knowledge, perceptions, intake, and blood levels of vitamin D among young adults living in Ontario. Two manuscripts were derived from phase three; the first
describes the efficacy of a behavioural intervention in which the mobile Vitamin D Calculator app was used to track vitamin D intake. The final manuscript is based on the theoretical framework and tested whether items grounded in the Theory of Planned Behaviour and/or Prototype Willingness Model could predict intentions and behaviours related to vitamin D intake in a young adult population. The final chapter of this thesis integrates and summarizes key findings, original contributions and implications of the dissertation project as a whole.
CHAPTER 2: LITERATURE REVIEW

The Physiology of Vitamin D

Vitamin D is derived from a steroid and is considered a seco-steroid due to the fact that one of its four rings is broken. Vitamin D from plants is derived from ergosterol, which is activated to form vitamin D$_2$ (also known as ergocalciferol or ercalciol). In animals and humans, the steroid 5,7-cholestradienol (also known as 7-dehydrocholesterol), is synthesized in the skin. When exposed to sunlight, some of the cutaneous 7-dehydrocholesterol is converted to pre-vitamin D$_3$ (also known as precalciferol). Within two to three days, pre-vitamin D$_3$ is converted into vitamin D$_3$ (also known as cholecalciferol). Vitamin D$_3$ diffuses from the skin into the blood, and is transported in the blood by vitamin-D binding protein (DBP), which is synthesized in the liver. Vitamin D$_3$ may also come from the diet (as described in ‘Sources of Vitamin D’, below). Dietary vitamin D$_3$ is absorbed in the small intestine and transported through the bloodstream to the liver by chylomicrons. Similarly, vitamin D$_3$ that has diffused through the skin and bound to DBP is primarily carried to the liver, but may also be picked up by other tissues such as muscle and adipose (Gropper, Smith & Groff, 2005).

In the liver, cholecalciferol is converted via enzymatic reactions to 25-hydroxyvitamin D$_3$ or calcidiol, referred to herein as “25(OH)D”. This form of vitamin D is released into the bloodstream, where it is again transported by DBP and taken up by the kidney where it is converted to 1,25(OH)$_2$D$_3$, or calcitriol. Whereas the half-life of calcitriol in the body is approximately 15 hours, calcidiol has a longer half-life of approximately 15 days (Jones, 2008). Calcidiol thus represents the main form of circulating vitamin D in the
bloodstream and calcidiol (25(OH)D) concentrations are most frequently used to reflect vitamin D status. In summary, vitamin D status depends on both dietary vitamin D intake and cutaneous synthesis following exposure to sunlight (Gropper et al., 2005).

Calcitriol acts like a steroid hormone, acting on target organs. The intestine, bone, and kidney have traditionally been considered the primary targets of vitamin D; however, more recent research suggests that it acts on a variety of other sites, including cardiac, muscle, pancreas, brain, skin, hematopoietic (i.e., blood) and immune system tissues. Calcitriol generally promotes cell differentiation of these tissues; research evidence indicates it may also be able to inhibit the proliferation and growth of cancer cells (Gropper et al., 2005). One of the primarily roles of calcitriol is to act in conjunction with parathyroid hormone (PTH) to maintain serum calcium concentrations. When blood calcium concentrations are low (a state known as hypocalcaemia), PTH is secreted and stimulates the conversion of 25(OH)D to 1,25(OH)2D3, primarily in the kidney, which acts on target tissues to increase serum calcium concentrations. In doing so, calcitriol and PTH affect the intestine, bone and kidney. In the intestine, calcitriol facilitates increased absorption of calcium and phosphorus; in the distal renal tubule of the kidney, calcitriol is involved in the stimulation of calcium and phosphorus reabsorption, induced by PTH. Finally, PTH and calcitriol help to mobilize calcium and phosphorus from the bone to achieve homeostasis of blood calcium levels. It is believed that differentiation of hematopoietic cells, induced by calcitriol, may influence the production of osteoclasts. Osteoclasts mediate bone resorption, the process by which bone is broken down to release calcium into the bloodstream. It is important to note that in addition to its
interactions with calcium and phosphorus, calcitriol also interacts with vitamin K, since vitamin K-dependent proteins are involved in the binding of calcium in the bone and kidney (Gropper et al., 2005).

**Sources of Vitamin D**

Vitamin D comes from three major sources: sunlight (UVB radiation), dietary sources (including natural sources and fortified foods and beverages), and oral vitamin D supplements.

**Sunlight**

Vitamin D is unique in that we can obtain it from sunlight. At a wavelength of 290-320 nanometers, UVB radiation penetrates uncovered skin and converts 7-dehydrocholesterol to pre-vitamin D₃, which is converted to vitamin D₃ in the body. UVB radiation exposure and vitamin D synthesis may be affected by season, time and length of day, cloud cover, smog, skin melanin concentrations, and sunscreen. Although differences have been documented according to geographical region (i.e., latitude), latitude does not consistently predict average serum vitamin D concentrations at the population level (NIH, 2011).

Research indicates that complete cloud cover may reduce UV radiation by 50%, while shade may reduce it by 60%. Further, as UVB radiation does not penetrate glass, exposure to sunshine through a window does not initiate cutaneous synthesis of vitamin D. In terms of sun protection, sunscreen with an SPF of 8 or higher seems to block UVB
rays. Since most people do not use sufficient amounts, cover all sun-exposed skin evenly or reapply regularly, it is likely that the skin synthesizes some vitamin D even when sunscreen is used (NIH, 2011). However, a recent randomized clinical trial found that serum vitamin D concentrations increase exponentially with decreasing thickness of applied sunscreen, indicating that sunscreen use may block cutaneous vitamin D production (Faurschou et al., 2012).

**Supplements**

Vitamin D supplements come in two different forms: D$_2$ (ergocalciferol) and D$_3$ (cholecalciferol), which differ chemically in their side-chain structure. Both types increase concentrations of 25(OH)D in the blood (NIH, 2011). Vitamin D$_2$ is produced through the UV irradiation (i.e., exposure to UV radiation) of ergosterol in yeast and mold (i.e., mushrooms), whereas vitamin D$_3$ is produced through the irradiation of 7-dehydrocholesterol from lanolin and the conversion of cholesterol (NIH, 2011). Since the 1930s, it was assumed that the two forms were equally effective in humans (Armas, Hollis & Heaney, 2004); this assumption was primarily based on their shared ability to cure rickets and the fact that the metabolism and actions of the two forms are identical (NIH, 2011). Although evidence about the differing effects of D$_2$ versus D$_3$ is not conclusive, it seems that while the two forms are equivalent at nutritional doses (NIH, 2011), at higher doses, D$_3$ is more effective at increasing serum 25(OH)D levels than D$_2$ (Trang et al., 1998; Armas et al., 2004). In fact, a study examining the effects of extremely high doses (50,000 IU) of vitamin D$_2$ versus D$_3$ supplements in healthy male adults found that vitamin D$_2$ is less than one third as potent as vitamin D$_3$ and has a
shorter duration of action. Results indicated that although both supplements produced similar initial rises in serum 25(OH)D over the first three days of treatment, levels continued to rise in the subjects treated with vitamin D₃, with levels peaking at 14 days, whereas serum 25(OH)D levels quickly declined in the subjects treated with vitamin D₂ and did not differ from baseline at 14 days (Armas et al., 2004).

**Dietary Sources**

Fortified foods constitute the primary source of dietary vitamin D in Canada. In Canada, cow’s milk and margarine must be fortified with vitamin D (Canadian Food Inspection Agency, 2012); fluid milk may also be vitamin D-fortified in the USA, but fortification is not mandatory, and is not universally required in other countries (Reginster, 2005). Other foods and beverages that are permitted (but not routinely) to be fortified with vitamin D in Canada include goat’s milk, soy beverages, yogurt, cheese, and orange juice. It is important to note that fortified cheese and yogurt do not contain as much vitamin D as fluid milk (Health Canada, 2007). Although fluid milk and breakfast cereals are the primary sources of vitamin D in the USA, until recently breakfast cereals have not been fortified with vitamin D in Canada (Calvo, Whiting & Barton, 2004). In spring 2013, Kellogg’s became the first Canadian company to add vitamin D to their Special K cereal line (Kellogg’s, 2013). Health Canada granted Kellogg’s a Temporary Marketing Authorization and a select few of other Kellogg’s cereal brands were fortified in the following year; these cereals typically provide about 20% vitamin D per serving (Kellogg’s, 2014). Bread that is baked with UV-irradiated yeast has been found to be a bioavailable source of vitamin D₂ (Hohman et al., 2011). Consequently, the FDA
increased the amount of vitamin D from baker’s yeast that is allowed in bread and baked goods from 90 IU to 400 IU per 100g. Lallemand, a Canadian company that operates in Québec, Canada as well as the USA, Europe and Africa, has begun to produce baker’s yeasts that may be used for this purpose (Lallemand, 2012). Recently, Stonemill Bakehouse began selling bread made with vitamin D-irradiated yeast in Canada. Two slices provide about 90 IU of vitamin D (Stonemill Bakehouse, 2015).

Natural dietary sources of vitamin D are more rare, and include fatty/oily fish (e.g., herring, salmon, mackerel, tuna, sardines and cod), beef liver, veal, cheese, and egg yolks (Gropper et al., 2005; NIH, 2011). These foods typically provide vitamin D₃ or its metabolite 25(OH)D₃. Cod liver oil is another source of vitamin D; however, given that concentrations of vitamin A far exceed vitamin D concentrations in most modern cod liver oil supplements, many researchers recommend against it due to the possible risk of vitamin A toxicity (Cannell et al., 2008). Some mushrooms that have been exposed to UV radiation may also provide vitamin D₂ in variable amounts (NIH, 2011) and recent research indicates that vitamin D₂ from irradiated mushrooms may be as effective at improving vitamin D status as vitamin D₂ or D₃ from supplements (Keegan, Lu, Bogusz, Williams & Holick, 2013).

**Current Recommendations**

Over the past decade there has been some confusion regarding the amount of vitamin D required for optimal health. In order to address this issue, the Canadian and American governments asked the Institute of Medicine (IOM) to review the most recent dietary reference intakes (DRIs) for calcium and vitamin D, which were established in 1997. In
November 2010, the IOM released new DRIs for vitamin D. The Estimated Average Requirement (EAR) for vitamin D was set at 400 International Units (IU) (equivalent to 10 μg) and the Recommended Dietary Allowance (RDA) at 600 IU (15 μg) for most age groups. The RDA for adults over the age of 70 years was set at 800 IU (20 μg), to address changes in body composition and bone health with aging (IOM, 2010). These amounts were increased from the 1997 recommendations, which recommended 200 IU for adults 18-50 years, 400 IU for 51-70 years, and 600 IU for those over 70 years (IOM, 1997). The Tolerable Upper Intake Level (UL) was also raised from 2000 IU (50 μg) to 4000 IU (100 μg) for adults of all age groups; this level is lower for infants and children (IOM, 2010). The 2010 dietary reference intakes are shown in Figure 2.1 below.

Vitamin D concentrations in the body depend on both sun exposure and dietary intake. As stated by the IOM, “The amount of sun exposure one receives varies greatly from person to person, and people are advised against sun exposure to reduce the risk of skin cancer. Therefore, the committee assumed minimal sun exposure when establishing the DRIs for vitamin D” (IOM, 2010). Importantly, the IOM committee that reviewed the DRIs for calcium and vitamin D reviewed over a thousand studies examining vitamin D in relation to various health outcomes. The committee concluded that the evidence supporting an association between vitamin D and other health outcomes beyond bone health were inconclusive (IOM, 2010). Thus, the 2010 recommendations are based on the evidence for bone health only. These dietary reference intakes (DRIs) used 25(OH)D concentrations to define vitamin D deficiency (<30 nmol/L), the EAR (40 nmol/L), and the RDA (50 nmol/L) (Whiting, Langlois, Vatanparast, & Greene-Finestone, 2011).
It is also interesting to note that vitamin D is mentioned in the 2007 version of Canada’s Food Guide. The Food Guide recommends that Canadians “have 500mL (2 cups) of milk every day for adequate vitamin D. Drink fortified soy beverages if you do not drink milk” (Health Canada, 2007). In addition, since the dietary pattern recommended in Canada’s Food Guide would not provide enough vitamin D to meet the Adequate Intake (AI) established by the IOM for older adults, Health Canada recommends that in addition to following Canada’s Food Guide, all adults over the age of 50 take a daily supplement of 400 IU (Health Canada, 2007).

Figure 2.1: RDI for Vitamin D and Calcium (IOM, 2010)
Definitions of Insufficiency, Deficiency & Upper Limits

It is important to note that there is a lack of consistency when it comes to the cut-offs used to define vitamin D ‘adequacy’, ‘deficiency’, ‘insufficiency’ and ‘inadequacy’. The cut-off points used to define these terms vary depending on study and organization. The terms ‘inadequacy’ and ‘insufficiency’ will be used interchangeably in the current paper to refer to a vitamin D status that is less than optimal for good health. The term ‘deficiency’ will be used to refer to a more severe deficit in 25(OH)D levels (usually defined as <25nmol to <30 nmol/L, depending on the study).

Vitamin D deficiency can occur when usual intake is lower than recommended amounts over time, exposure to sunlight is limited, the kidneys cannot convert 25(OH)D to its active form, or absorption of vitamin D from the digestive tract is inadequate (NIH, 2011). Deficiency symptoms in children and adolescents include rickets, impaired fractional calcium absorption, and decreased bone mineral content. In young and middle-aged adults, symptoms include impaired fetal skeletal outcomes, impaired fractional calcium absorption and an increased risk of osteomalacia, which results in weak bones. In older adults, symptoms include impaired fractional calcium absorption and fracture risk. Although these symptoms occur at different concentrations of 25(OH)D, based on the evidence reviewed by the IOM, most deficiency symptoms tended to be associated with concentrations less than 30nmol/L (IOM, 2010). Achieving the recommended amounts of vitamin D solely from natural food sources can be quite difficult; as a result, consumption of foods fortified with vitamin D and exposure to sunlight are usually needed to maintain adequate blood vitamin D levels. Since sun exposure is often inadequate in North
America, taking daily vitamin D supplements may be helpful in achieving optimal vitamin D status (IOM, 2011).

**Rickets**
Rickets is typically characterized by the softening of bones; it is a demineralization of bones before epiphyseal closure (closure of round bones) primarily due to a deficiency or impaired metabolism of vitamin D, phosphorus or calcium. Rickets primarily occurs in children and typically leads to fractures or deformities such as bowed legs (Pattan et al., 2011). Rickets is still prevalent in many countries around the world. A systematic review examining the prevalence of nutritional rickets worldwide reported cases in Europe, the UK, Asia, Africa, the Middle East, immigrant infants in Australia and New Zealand, parts of South America (Argentina, Uruguay and Colombia), and certain populations in North America (Thacher, Fischer, Strand & Pettifor, 2006). In Canada, vitamin D-deficiency rickets persists in certain populations. A study published in 2007 reported an annual incidence rate of 2.9 cases per 100,000. Rates were highest among those with darker skin pigmentation, those who are breastfed without supplementation, and those who live in the Northern regions of the Yukon, Northwest Territories and Nunavut (Ward, Gaboury, Ladhani & Zlotkin, 2007).

**Vitamin D Toxicity**
As noted earlier, the upper limit (UL) for vitamin D for those 9 years of age and older is 4000 IU per day. Consistent long-term intakes above the UL increase the risk of adverse health effects (IOM, 2011). According to the National Institutes of Health, most studies suggest that the threshold for vitamin D toxicity is associated with supplementation of
10,000 to 40,000 IU per day and serum 25(OH)D levels of 500–600 nmol/L (Garland, French, Baggerly & Heaney, 2011; NIH, 2011). Excessive exposure to sunlight does not result in vitamin D toxicity. It is believed that constant skin exposure to heat may lead to the photo-degradation of pre-vitamin D₃ and vitamin D₃ as it is being formed, and that some vitamin D₃ is converted to non-active forms. Further, thermal activation of pre-vitamin D₃ leads to the formation of other non-vitamin D forms that limit formation of vitamin D₃ (NIH, 2011). Achieving vitamin D toxicity purely from food sources is also unlikely; vitamin D toxicity is much more likely to occur from supplementation (NIH, 2011).

Vitamin D toxicity can lead to a variety of symptoms including nausea, vomiting, decreased appetite, anorexia, weight loss, weakness, constipation, polyuria and heart arrhythmias. Importantly, excessive intake of vitamin D can raise serum calcium concentrations (i.e., hypercalcemia), leading to tissue calcification. As a result, the heart, blood vessels and kidneys may become damaged (NIH, 2011). In the Women’s Health Initiative, postmenopausal women who took daily calcium supplements of 1000 mg and vitamin D supplements of 400 IU had a 17% increased risk of developing kidney stones over a seven year period (Jackson et al., 2006). Consumption of extremely high amounts of vitamin D through supplementation (i.e., above 10,000 IU per day) has been shown to cause kidney and tissue damage (IOM, 2010). However, early research by Vieth (1999) suggested that toxicity was most often associated with intakes above 40,000 IU/day, and a review by Jones (2008) concluded that hypercalcemia tends to occur at 25(OH)D concentrations above 375-500 nmol/L. A more recent study found no evidence of a link
between vitamin D concentrations of 50-250 nmol/L and the development of kidney stones, indicating that this should not be a concern among those taking vitamin D supplements (Nguyen et al., 2014). Similarly, a large observational study examining data from 2002-2011 found that toxicity was rare in those taking vitamin D supplements, and even among patients with serum 25(OH)D levels above 125 nmol/L, an increased risk of hypercalcemia was not observed (Mayo Clinic, 2015).

Although most evidence suggests that intakes up to 10,000 IU per day are safe (Glade, 2012) and that toxicity symptoms associated with daily intakes below this threshold are uncommon, the IOM (2010) report remained conservative – concluding that intakes that lead to serum concentrations above 125 nmol/L may be associated with adverse health effects (NIH, 2014). In summary, like other fat-soluble vitamins, extreme doses (i.e., >10,000/day) of supplemental vitamin D should be avoided due to toxicity concerns. However, vitamin D amounts above the IOM’s 2010 recommendation of 600 IU/day or serum levels above 50 nmol/L are likely not only safe, but may promote optimal health. As we see below, vitamin D plays an important role in maintaining health, from its classical functions (i.e., bone health) to more novel findings, including its role in the immune system and associations with various disease states.

**Bone Health: the Classical Function of Vitamin D**

Vitamin D is best known for its importance in maintaining bone health, and plays a key role in bone mineralization. Vitamin D deficiency can lead to the development of rickets in children and bone loss and osteomalacia in adults (Need et al., 2008). Blood
concentrations of 25(OH)D (as opposed to calcium intake) have been cited as the primary predictor of bone mineral density in adults over the age of 20 (Bischoff-Ferrari et al., 2009). As such, research suggests that adequate vitamin D may reduce the risk of falls (Broe et al., 2007; Cherniack, Florez, Roos, Troen, & Levis, 2008) and in conjunction with calcium may reduce bone loss, prevent fractures and treat osteoporosis (Brown, 2008; Chapuy et al., 1992; Cherniack et al., 2008; Holick, 2007; Lips, 2001; Trivedi, Doll & Khaw, 2003). A recent report on the prevention of fractures in long-term care patients (Papaioannou et al., 2015) recommended vitamin D supplements of 800 to 2000 IU/day for those at high or low risk of fracture, based on moderate-quality evidence. However, the report also noted that vitamin D (with or without calcium) likely has no effect on non-vertebral fractures, quality of life, or muscle strength, and that the data regarding prevention of falls were imprecise (Papaioannou et al., 2015).

Similarly, other studies have called into question the evidence regarding the role of vitamin D in preventing falls and fractures. For instance, a review by Moon, Harvey, Davies & Cooper (2014) found that there was insufficient evidence to conclude that low serum 25(OH)D concentrations increase childhood fracture risk. A report by the US Preventive Services Task Force (USPST) concluded that there was insufficient evidence to weigh the harms and benefits of: a) vitamin D and calcium supplementation for the primary prevention of falls and fractures in premenopausal men and women; or b) for the use of calcium and vitamin D supplements greater than 1000 mg and 400 IU, respectively for the primary prevention of fractures in non-institutionalized postmenopausal women (Moyer & USPST, 2013). A systematic review and meta-analysis concluded that vitamin
D supplementation did not prevent hip fractures (Lai, Lucas, Clements, Roddam & Banks, 2010) and another review concluded that vitamin D and calcium supplements may prevent bone fractures in post-menopausal women and older men; although vitamin D alone may not prevent fractures at the doses tested thus far (Avenell, Mak, & O'Connell, 2014). Similarly, a meta-analysis found that vitamin D plus calcium (but not vitamin D alone) may reduce fracture risk in adults (Chung, Lee, Terasawa, Lau & Trikalinos, 2011). However, other reviews have found positive effects of vitamin D on the risk of falls and fractures in the elderly (Mitchell, Cooper, Dawson-Hughes, Gordon & Rizzoli, 2015; Rastogi Kalyani et al., 2010).

Vitamin D may also help to maintain dental health. A systematic review suggested that the pooled effect of supplemental UV radiation, vitamin D₃ and vitamin D₂ was associated with a 47% reduction in the incidence of dental caries in children; however, given that evidence of publication bias was found, the conclusion was made with low certainty (Hujoel, 2012). In summary, more evidence is required in order to determine the role of vitamin D in the prevention of falls, fractures and dental caries among various lifestage groups.

**Novel Functions of Vitamin D**

Beyond the classical associations with bone health, a growing body of evidence suggests that vitamin D may have many functions in the body, and may be associated with many other health outcomes. Both genomic and non-genomic mechanisms of action have been established (Gropper et al., 2005) and the active metabolite of vitamin D (calcitriol;
1,25(OH)₂D₃ has been found to play a role in the immune system, cellular growth and differentiation, gene transcription (Carlberg & Campbell, 2013) and signal transduction pathways (Gropper et al., 2005).

Two main surface receptors through which calcitriol may elicit pregenomic and genomic effects are the vitamin D receptor (VDR) and the 1,25D₃-membrane-associated, rapid-response, steroid-binding (MARRS) protein receptor; formally known as ERp57/GRp58. (Nemere, Garcia-Garbi, Hämerling & Winger, 2012). The VDR is most concentrated in metabolic tissues such as bone, kidney, and intestines, but has been found in nearly every tissue in the body, including those of the immune, reproductive and endocrine systems, muscles (including smooth, skeletal and heart muscles), and in the brain, skin, and liver (Verstuyf, Carmeliet, Bouillon & Mathieu, 2010). The MARRS receptor has been found in osteoblasts, osteoclasts and odontoblasts, and play a critical role in cellular function, including mediation of calcitriol’s effects in chondrocytes (cartilage cells), intestinal and kidney cells (Khanal & Nemere, 2007). Mouse knockout models suggest that the MARRS receptor (but not VDR) is required for calcitriol-stimulated calcium uptake (Nemere, Garbi, Hämerling & Khanal, 2010) and phosphate uptake in intestinal endothelial cells (Nemere et al., 2012). Given the various roles of the MARRS and VDR surface receptors and the ubiquitous presence of VDR in the body, it is unsurprising that vitamin D is implicated in the wide range of health outcomes discussed below.

Cancer

Vitamin D deficiency has been linked with an increased risk of several types of cancer, including breast, colon, colorectal, ovarian and prostate (Blackmore et al., 2008; Garland,
Higher vitamin D status has also been associated with decreased all-cancer risk (Lappe, Travers-Gustafson, Davies, Recker, & Heaney, 2007) and an increased rate of survival from breast (Mohr, Gorham, Kim, Hofflich & Garland, 2014), bowel (University of Edinburgh, 2014) and colorectal cancer (Zgaga et al., 2014). Correspondingly, calcitriol has been shown to inhibit the growth of several types of cancer cells, via disruption of cell cycles, apoptosis, cellular differentiation, or inhibition of angiogenesis (Bernardi, Johnson, Modzelewski, & Trump, 2002; Deeb, Trump & Johnson, 2007; Welsh, 2007). Vitamin D has therefore been implicated as a potential anti-cancer agent (Deeb et al., 2007). However, research also shows that the MARRS protein receptor may interfere with the ability of calcitriol to inhibit growth of breast cancer cells, suggesting that the effect of vitamin D as an anti-cancer agent depends on levels of MARRS expression (Richard, Farach-Carson, Rohe, Nemere & Meckling, 2010). Further research on this interaction is warranted.

**Cardiovascular Outcomes**

Vitamin D deficiency has also been associated with a range of cardiovascular outcomes, including increased risk of congestive heart failure (Zitterman et al., 2003) and cardiovascular disease (Brøndum-Jacobsen, Benn, Jensen & Nordestgaard, 2012; Zittermann, Schleithoff, & Koerfer, 2005) and increased presence and severity of coronary artery disease (Verdoia et al., 2014). Studies suggest that vitamin D may help lower blood pressure in patients suffering from hypertension (Larsen, Mose, Bech, Hansen & Pedersen, 2012) and type 2 diabetes (Loyola University Health System, 2013). A large meta-analysis examining genetic factors associated with 25(OH)D levels found that higher plasma concentrations of vitamin D were associated with decreases in systolic
and diastolic blood pressure and a decreased odds ratio of hypertension (Vimaleswaran et al., 2014). Correspondingly, vitamin D supplementation can influence blood lipids; supplemental vitamin D and calcium was shown to decrease LDL cholesterol in post-menopausal women enrolled in a double-blind control trial, and higher serum vitamin D concentrations were associated with higher HDL cholesterol and lower LDL and triglyceride concentrations (Schnatz et al., 2014). Further, lower vitamin D status in childhood has been linked to atherosclerosis 25 years later in adulthood (Juonala et al., 2015).

**Diabetes, Insulin & Blood Glucose**

Research has revealed associations between vitamin D and reduced risk of: type I (Munger et al., 2013; Hypponen, Laara, Reunanen, Jarvelin, & Virtanen, 2001) and type II diabetes mellitus (Knekt et al., 2008; Pittas et al., 2006). Higher vitamin D concentrations may reduce the risk of prediabetes progressing into diabetes (Dutta et al., 2014), and one study also found that vitamin D and calcium supplements may improve the metabolic profile of pregnant women suffering from gestational diabetes mellitus (Asemi, Karamali & Esmailzadeh, 2014). Results of an animal study suggest that vitamin D may also help with body weight and blood sugar control (Endocrine Society, 2014); further, authors of a recent study suggested that vitamin D deficiency may play a larger role in type II diabetes than obesity (Clemente-Postigo et al., 2015).

Higher concentrations of vitamin D have been associated with decreased insulin resistance (Chiu et al., 2004; Norman, Frankel, Heldt, & Grodsky, 1980; von Hurst et al., 2008), including increased insulin sensitivity in obese adolescents (Belenchia, Tosh,
Hillman, & Peterson, 2013) and decreased risk of metabolic syndrome (Brenner et al., 2011).

**Immune Function and Susceptibility to Disease**

Vitamin D deficiency is more common among critically ill children, and associated with greater severity of critical illness (McNally et al., 2012) and lower concentrations of C-reactive protein in critically ill patients (Van den Berghe, 2003). Vitamin D is ultimately thought to influence innate immune function (Alvarez-Rodriguez et al., 2012); low vitamin D concentrations have been linked to autoimmune diseases and bacterial and viral infections (Khoo et al., 2012; Schwalfenberg, 2007), including septicemia (Jeng et al., 2009), pneumonia and influenza (Brundage & Shanks, 2008; Grant & Giovannucci, 2009). Patients suffering from systemic lupus have been shown to have more severe symptoms when vitamin D concentrations are low (Yap, Hoi & Morand, 2012). One study suggests that vitamin D may be used in conjunction with antibiotics to accelerate the treatment of pulmonary tuberculosis (Coussens et al., 2012). Animal models have also shown that the absence of vitamin D may influence immune cells that play a role in causing the inflammation, insulin resistance and plaque accumulation that causes diabetes and cardiovascular disease (Oh et al., 2015). Further, recent research suggests that vitamin D concentrations may affect gene expression – including genes responsible for immune function, stress response and DNA repair (Hossein-nezhad, Spira & Holick, 2013).

**Fertility and Pregnancy Outcomes**

Vitamin D status has also been examined in relation to fertility and reproduction. A review that examined the link between vitamin D and fertility noted that mice missing the
VDR exhibit decreased sperm count and motility as well as abnormality of the testis, ovary and uterus. In men, higher vitamin D status has been linked with increased testosterone production, improved semen quality and androgen status. Vitamin D also affects female fertility, influencing production of the female sex hormones estradiol and progesterone. Maternal vitamin D concentrations affect a variety of pregnancy outcomes (Grant, Schwalfenberg, Genuis & Whiting, 2010). Higher vitamin D concentrations may improve pregnancy outcomes in women undergoing in vitro fertilization or in those suffering from polycystic ovarian syndrome (Lerchbaum & Obermayer-Pietsch, 2012), and have been linked to a decreased risk of uterine fibroids (Baird, Hill, Schectman & Hollis, 2013). A systematic review and meta-analysis found that having an insufficient maternal vitamin D concentration (as defined within each study) was associated with an increased risk of gestational diabetes, pre-eclampsia, small for gestational age infants, lower birth weight infants and risk of bacterial vaginosis (Aghajafari et al., 2013).

In addition, a growing body of evidence suggests that maternal vitamin D concentrations contribute greatly to neonatal vitamin D status, and that deficiency during pregnancy and lactation can lead to insufficiency in infants (Karras et al., 2013; Weiler, 2008) and lower bone mass later in life (Javайд et al., 2006). Mounting evidence also suggests that higher 25(OH)D concentrations during pregnancy or infancy may reduce the risk of autism (Cannell 2008; Cannell & Grant, 2013). Lower vitamin D status has been linked to more painful labours (American Society of Anesthesiologists, 2014) and a greater risk of severe preeclampsia (Bodnar et al., 2014). Adequate vitamin D is important for both the developing fetus and newborn, and many researchers personally believe that
breastfeeding mothers require higher intakes of vitamin D (Heaney, 2014.).

**Aging and Cognition**

Recent research suggests that vitamin D may be implicated in cognitive function. Studies have found that higher vitamin D intake is associated with a reduced risk of Alzheimer’s disease (Annweiler et al., 2012), possibly through its role in eliminating amyloid plaques, a hallmark of Alzheimer’s disease (Mizwicki et al., 2013). A large longitudinal study found that elderly individuals who were severely vitamin D deficient (<25 nmol/L) had a 122% and 125% increased risk of developing Alzheimer’s disease and dementia, respectively (Littlejohns et al., 2014). One study found that women with very low concentrations of vitamin D had a higher risk of global cognitive impairment and global cognitive decline (Slinin et al., 2012) and another found that after cardiac arrest, vitamin D deficient patients (<25 nmol/L) were seven times more likely to suffer from poor neurological outcomes (European Society of Cardiology, 2014). Finally, rats fed a diet low in vitamin D developed free radical damage to the brain, and performed more poorly on cognitive tests of learning and memory, suggesting that vitamin D may play a role in cognitive decline (Keeney et al., 2013). Finally, a review examined the associations between vitamin D and several diseases associated with aging, including cognitive decline, depression, osteoporosis, cardiovascular diseases, high blood pressure, type II diabetes, and cancer. The researchers concluded that although associations have been observed, much work is needed to clarify the role of vitamin D in each of these disease states. They called for universal guidelines related to testing and treating vitamin D deficiency in order to combat these diseases among an aging population (Meehan & Penckofer, 2014).
Mood, Depression and Psychiatric Disorders

Vitamin D has been implicated to play a role in the pathogenesis of depression, including seasonal affective disorder (SAD) (Berk et al., 2007; Stumpf & Privette, 1989), and to be associated with SAD symptoms (Shea, 2011). However, a review concluded that the current evidence supporting this link is inconclusive (Howland, 2011). Conversely, a more recent study found that healthy young women with lower concentrations of vitamin D were more likely to exhibit symptoms of clinical depression (Kerr et al., 2015). A pilot study also suggests that large doses of vitamin D may help to improve mood in women suffering from type II diabetes (Loyola University Health System, 2013).

Vitamin D may play a role in other psychiatric disorders; according to one review, individuals who are deficient in vitamin D (cut-offs varied by study) were 2.16 times as likely to be diagnosed with schizophrenia as those with sufficient concentrations (Valipour, Saneei & Esmaillzadeh, 2014). Further, higher vitamin D concentrations may reduce the symptoms of autism (Cannell & Grant, 2013); the link may be due to the fact that the vitamin D receptor activates three hormones (serotonin, oxytocin and vasopressin) that affect the social behaviour changes seen in autism (Patrick & Ames, 2014). Finally, given the association between low vitamin D concentrations and schizophrenia, depression, bipolar disorder and impaired cognitive function, one study examined the relationship between plasma 1,25(OH)₂D₃ concentrations and basic personality traits (as per the NEO Five-Factor Inventory). Interestingly, the researchers found that higher plasma 1,25(OH)₂D₃ concentrations were associated with greater extraversion and openness, and suggested that calcitriol might influence personality traits.
and behaviours through its various effects on the brain (Ubbenhorst, Striebich, Lang, & Lang, 2011); however, it is important to point out that this was an association only and cannot demonstrate causation.

**Multiple Sclerosis, Respiration and Other Physical Impairments**

Higher vitamin D concentrations have been associated with a decreased risk of multiple sclerosis in several studies (Ascherio & Munger, 2007; Munger et al., 2004; Ponsonby, Lucas, & van der Mei, 2005; Pierrot-Deseilligny, 2009). An animal model found that giving mice calcitriol followed by vitamin D supplements was able to halt or reverse the progression of multiple sclerosis (Nashold, Nelson, Brown, & Hayes, 2013).

Vitamin D deficiency has also been related to lung function (Choi et al. 2013) and structure (Zosky, et al., 2011). Plasma 25(OH)D concentrations have been inversely associated with duration spent in the intensive care unit (ICU) (Quraishi, McCarthy, Blum, Cobb & Camargo Jr., 2015), and vitamin D supplements have been shown to reduce lung disease flare-ups by over 40 percent in vitamin D deficient patients suffering from chronic obstructive pulmonary disease, which includes chronic bronchitis and emphysema (Martineau et al., 2014). Correspondingly, vitamin D deficiency has been associated with more frequent asthma exacerbations (Confino-Cohen, Brufman, Goldberg & Feldman, 2014).

Vitamin D deficiency has been associated with muscle weakness, limb pain, and impaired physical function (Dhesi, et al., 2004; Latham, Anderson, & Reid, 2003; Montero-Odasso & Duque, 2005), and may be a contributor to poor mobility in severely obese individuals.
(Ahern et al., 2014). Conversely, higher vitamin D intake is related to a lower risk of rheumatoid arthritis (Merlino et al., 2004; Ponsonby et al., 2005) and has been found to decrease pain and increase mobility in obese osteoarthritis patients (Glover et al., 2015). Vitamin D deficiency has also been implicated in alcoholic myopathy (Wijnia et al., 2012). Further, vitamin D may be used in the treatment of psoriasis (Lehmann, Querings, & Reichrath, 2004) and to reduce the pain of fibromyalgia sufferers (Wepner et al., 2014).

**Mortality**

Given that vitamin D deficiency has been linked to such a wide array of health outcomes, it is not surprising that researchers have observed an association between vitamin D status and mortality risk. Vitamin D deficiency has been linked with a higher risk of death from both cardiovascular disease and cancer (Schottker et al., 2014) and a significantly increased risk of death following cardiac arrest (European Society of Cardiology, 2014). Low vitamin D concentrations, along with elevated PTH was associated with an increased risk of mortality in older adults (Kritchevsky et al., 2012), and individuals genetically predisposed to have low vitamin D concentrations were found to have an increased risk of all-cause mortality, including cancer but not cardiovascular disease (Afzal, Brøndum-Jacobsen, Bojesen & Nordestgaard, 2014). Finally, a large cohort study found a “reversed J-shaped” curve with respect to vitamin D status and mortality, suggesting that both low and high vitamin D concentrations may increase mortality, with the highest risk at lower levels (Durup et al., 2015). However, some vitamin D experts have criticized this study, proposing instead that the relationship between health and vitamin D status follows neither a “J-shaped” nor “U-shaped” curve;
arguing that the risk of negative health outcomes initially declines dramatically, then declines slowly and then reaches a plateau as a function of 25(OH)D concentrations (GrassrootsHealth, 2015a).

**A Call for Higher Recommendations**

Much of the data above suggests that very low vitamin D levels are associated with negative health outcomes; similarly, some studies have found health benefits associated with higher blood vitamin D concentrations. In fact, a growing body of evidence suggests that supplemental vitamin D at doses greater than the amounts recommended by the IOM (2010) may be needed to achieve a clinical benefit. For instance, one study examined the effect of supplementation with calcium (1200 mg) and vitamin D (400 IU; equivalent to the EAR set by the IOM in 2010) in postmenopausal women with osteoporosis. Although serum 25(OH)D levels increased significantly after 3 months using this dose of 400 IU, the majority (86%) of the supplement group did not reach optimal 25(OH)D status, which was defined as 75 nmol/L (Pignotti, Genaro, Pineheiro, Szejnfeld, & Martini, 2010). Another study found that treating vitamin D deficient patients (<50 nmol/L) with 5000 IU was more effective at achieving optimal serum 25(OH)D concentrations (≥75 nmol/L) compared to 2000 IU. Muscle strength parameters improved with both doses (Diamond, Wong & Golombick, 2013), which were both well above the RDA set by the IOM (2010). A third study examined sun exposure, skin reflectance, skin pigmentation and vitamin D intake in university students. The researchers found that participants with high skin reflectance and high sun exposure would require 1300 IU of supplemental vitamin D per day in the winter months in order to maintain the target serum 25(OHD) level of 75
nmol/L (Hall et al., 2010). Those with low skin reflectance and low sun exposure would require a supplement of 2100-3100 IU year-round to meet this target (Hall et al., 2010), well surpassing the RDA of 600 IU/day.

Indeed, many researchers and health associations have indicated that the 2010 recommendations are too low. In an official letter entitled “A Canadian response to the 2010 Institute of Medicine vitamin D and calcium guidelines” (Schwalfenberg & Whiting, 2011), Canadian vitamin D researchers contested the IOM recommendations. These researchers argued that the cut-off for 25(OH)D should be 80 nmol/L, rather than the current 50 nmol/L, due to the associations between vitamin D and calcium absorption and PTH (Schwalfenberg & Whiting, 2011). They also cite research indicating that higher concentrations of serum 25(OH)D are needed for improved health outcomes including dental health, stress the fact that many Canadians have low concentrations of vitamin D, and note that the IOM did not adequately address the higher concentrations required during pregnancy (Schwalfenberg & Whiting, 2011). Similarly, lead vitamin D researchers including Dr. Vieth, Dr. Heaney, and Dr. Holick have published articles suggesting that the optimal serum vitamin D level should be at least 75 nmol/L, as opposed to 50 nmol/L as recommended by the IOM (Dawson-Hughes et al., 2005; Holick & Chen, 2008; Vieth, 2011).

Major health associations also recommend concentrations higher than those of the IOM (Canadian Cancer Society, 2015; Osteoporosis Canada, 2015). In 2010, the Canadian Osteoporosis Society released updated guidelines, which concluded that an optimal
serum concentration of 25(OH)D of over 75 nmol/L is needed to improve most health outcomes including fracture risk, and noted that supplementation would be required to achieve this concentration. The guidelines recommend daily supplements of 400 to 1000 IU for adults under 50 years of age, and 800 to 2000 IU for those over 50 years, and state that a daily supplement of 800 IU should be regarded as a minimum dose for all adults with osteoporosis (Hanley et al., 2010). The Canadian Cancer Society (CCS) recommends that all Canadian adults consume 1000 IU per day in the fall and winter months, and that those who are over 50 years, have dark skin, do not spend much time outside or wear clothing that covers most of their skin should take 1000 IU year-round (CCS, 2015). While remaining well below the TUL, it is important to note that this recommendation is almost twice as high as the current RDA of 600 IU/day.

Given that health associations are willing to surpass the IOM in their recommendations for vitamin D intake, it comes as no surprise that many vitamin D researchers are pushing the belt even further. In 2014, Dr. Paul Veugelers, a lead vitamin D expert, published a letter in the journal *Nutrients* that formally accused the IOM of making a statistical error in their calculation of the RDA for vitamin D (Veugelers & Ekwaru, 2014). The IOM (2010) report indicated an RDA of 600 IU/day, in order to achieve a serum value of at least 50 nmol/L for 97.5% of the population (i.e., the definition of the RDA). Veugelers and Ekwaru (2014) posited that intakes of 600 IU per day would bring 97.5% of individuals above a serum level of only 26.8 nmol/L, rather than 50 nmol/L, as originally calculated by the IOM. After reassessing the studies reviewed in the IOM (2010) report, the authors concluded that a vitamin D intake of 8,895 IU/day would be required to
achieve serum concentrations above 50 nmol/L. Given that this recommendation is on the order of 15 times greater than the RDA, the authors stated that the recommendation warranted caution (Veugelers and Ekwaru, 2014). Shortly after, a team of researchers (including renowned vitamin D expert Dr. Heaney) published a response in the same journal (Heaney, Garland, Baggerly, French & Gorham, 2014). In this letter, Heaney et al. (2014) calculated that an average intake of 7000 IU/day would be needed in order to bring 97.5% of the population to 50 nmol/L; not far from the level recommended by Veugelers and Ekwaru (2014).

Recently, North American not-for-profit organizations such as GrassrootsHealth (California, USA) and Pure North S’Energy Foundation (in collaboration with the University of Calgary; Alberta, Canada) have come together to support the claims made by these researchers. Recent advocacy work has included public opposition of the IOM (2010) recommendations (GrassrootsHealth, 2015b) and support for the more recent recommendations of lead vitamin D researchers (GrassrootsHealth, 2015c). Furthermore, Pure North has placed half-page advertisements in the Toronto Globe and Mail and created a petition that urges Health Canada to change the RDA for vitamin D (Pure North, 2015).

Despite these advocacy efforts, Health Canada and the IOM stand by their recommendations. In fact, in March 2015 the IOM posted an announcement on its website that states, “to be clear, the goal is not, and should not be, to assure that 97.5% of the population exceeds the serum value linked to the RDA” (IOM, 2015). Similarly,
Dietitians of Canada wrote a letter to the Minister of Health urging Health Canada and the IOM to continue to use due diligence in evaluating evidence relating to vitamin D (Dietitians of Canada, 2015). They stressed the importance of not relying on low-level observational evidence to change public health recommendations for vitamin D, despite the pressure from groups like Pure North S’Energy Foundation. The letter also reminded the Minister that research regarding other nutrients (such as vitamin E, beta-carotene and folic acid) followed a similar course, and early observational evidence suggesting that high doses were optimal was later disproven (Dietitians of Canada, 2015, p. 2).

Perhaps unsurprisingly, the dispute surrounding vitamin D has also made public news headlines as of late. In early 2015, health reporter André Picard published an opinion piece in the Toronto Globe and Mail in which he criticized the recommendations of advocacy groups. In his piece, Picard argued that observational evidence linking high amounts of vitamin D supplementation to increased health outcomes are insufficient to assume a causal effect (Picard, 2015). A few months later, the Globe and Mail’s Leslie Beck, R.D., followed suit with an article that aimed to clear up some of the controversy surrounding how much vitamin D Canadians should consume. She noted that more research is needed to conclude whether levels above the current TUL of 4000 IU/day are safe (Beck, 2015). Beck pointed to the “VITAL” trial as a potential source of additional data that could help resolve the debate (Beck, 2015); this trial is an ongoing longitudinal RCT examining whether vitamin D supplements of 2000 IU/day will reduce the risk of developing cancer, cardiovascular disease and stroke (VITAL, 2015). Controversy surrounding the optimal recommendations for vitamin D intake will likely continue for
some time. In the meantime, in order to understand the implications of this debate and what these recommendations mean for the public, it is prudent to examine how Canadians actually fare in terms of vitamin D status. The following section will summarize the factors that influence vitamin D status, the groups most at risk for deficiency, and vitamin D status in Canada.

**Vitamin D Status**

The metabolite 25(OH)D is considered the best assessment of vitamin D status, and is typically measured from serum, however free plasma 25(OH)D concentrations can be measured as well (Zerwekh, 2008). Vitamin D status depends on a number of factors besides dietary intake, including sun exposure, age and ethnicity. UV intensity from sunlight is affected by a number of factors, including latitude, altitude, season, time of day, pollution, as well as cloud cover and ozone levels. Sun exposure also depends on the amount of bare skin exposed; sunscreen, clothing, and head coverings/veils will reduce subcutaneous vitamin D synthesis (Hall et al., 2010). Furthermore, the level of UVB radiation at one location may differ due to variations in cloud cover, ozone levels, amount of surface reflection and aerosols (Webb & Engelsen, 2006). Skin synthesis of vitamin D decreases with age (NIH, 2011), and higher levels of PTH are also associated with vitamin D deficiency and may lead to secondary hyperparathyroidism in old age (Lips, 2001). Ethnicity is a factor due to its association with skin pigmentation. Melanin, the major skin pigment in humans, reduces subcutaneous synthesis of vitamin D. Darker skin is associated with higher concentrations of the pigment melanin in the epidermal layer of the skin. Thus, individuals with more melanin, such as those of African American descent, have a darker skin pigmentation and lower skin reflectance. These individuals
require longer periods of sun exposure in order to synthesize vitamin D concentrations equivalent to those of European ancestry, who tend to have lighter skin pigmentation and higher skin reflectance (Hall et al., 2010). In 1975, Thomas B. Fitzpatrick – a dermatologist at Harvard University developed the Fitzpatrick Skin Type scale, which classified skin types (I to VI) according to reactivity to the sun (Fitzpatrick, 1975). Those with naturally darker skin (i.e., Fitzpatrick Skin types V-VI) are generally protected from skin cancer due to their skin pigmentation, whereas those with lighter skin tend to be more at risk (Fitzpatrick, 1988).

In general, serum 25(OH)D levels tend to be higher with greater dietary intake (from both natural and fortified food sources and supplements); sun exposure (i.e., higher UV index, less cloud cover, and more time spent in direct sunlight); and percentage of bare skin exposed and lower melanin levels (Hall et al., 2010). Additionally, data from observational studies suggest that serum 25(OH)D levels tend to be higher in women who take oral contraceptives (Hall et al., 2010; Harris & Dawson-Hughes, 1998).

**High Risk Groups**

Certain groups are at an increased risk of having inadequate vitamin D status. Breastfed infants are at increased risk of vitamin D inadequacy because human breast milk alone often does not supply the infant with adequate vitamin D, providing anywhere from less than 25 IU to 78 IU per day (NIH, 2011). Since breast milk is related to the mother’s vitamin D status, those who supplement with high doses of vitamin D may have higher concentrations in their milk. Studies have found that the incidence of rickets in Canadians and among African Americans in the USA have been much higher among breastfed
infants (NIH, 2011). The American Academy of Pediatrics recommends that breastfed infants be supplemented with 400 IU per day, which is the RDA for vitamin D during infancy (NIH, 2011). Older adults are also at an increased risk of developing vitamin D insufficiency. As we age, the skin cannot synthesize vitamin D as efficiently. Older adults also tend to spend more time indoors, and may have inadequate intake of vitamin D (NIH, 2011). Aboriginal communities are also at a higher risk of vitamin D deficiency; native Canadian Cree mothers and infants in Manitoba have been shown to be severely deficient, even during the summer months (Lebrun et al., 1993). In addition, research indicates that native mothers in the Inuvik zone of the Northwest Territories have significantly lower blood vitamin D concentrations than non-native mothers (Waiters, Godel & Basu, 1998).

Those with limited sun exposure are also at a higher risk of inadequate vitamin D status, as they are unlikely to obtain adequate vitamin D from the sun. At-risk groups include housebound individuals, older adults in long-term care settings, those who cover their skin with long clothing, veils or head coverings for religious reasons, those whose occupations limit their sun exposure (NIH, 2011) and those who are institutionalized (Bruyere, Decock, Delhez, Collette & Reginster, 2009). These individuals may benefit from fortified foods and vitamin D supplements.

Since vitamin D is a fat-soluble vitamin, percent body fat also affects one’s vitamin D status. Dietary fat is required for absorption of vitamin D, and most commercial vitamin D tablets and drops contain a small amount of fat to facilitate absorption. However,
vitamin D inadequacy may become an issue for those who have health conditions resulting in fat malabsorption, such as Crohn’s disease, cystic fibrosis, and some forms of liver disease (NIH, 2011). Similarly, individuals who have had gastric bypass surgery may become deficient in vitamin D over time, since this surgery involves bypassing the section of the upper small intestine where vitamin D is absorbed. These individuals may require higher levels of vitamin D from fortified foods and supplements (NIH, 2011). On the other end of the scale, those who are obese may be at an increased risk of inadequacy. Research from both clinical and epidemiological studies has shown that obese individuals (i.e., BMI > 30) tend to have lower vitamin D status (Botella-Carretero et al., 2007; Goldner et al., 2008; Parikh et al., 2004; Snijder et al., 2005; Wortsman et al., 2000). Although obesity does not affect the skin’s ability to synthesize vitamin D from the sun, because vitamin D is fat soluble, greater amounts of subcutaneous fat lead to greater sequestering of vitamin D into fat cells and a lower release into the bloodstream. Thus, obese individuals may require more vitamin D to achieve adequate serum 25(OH)D concentrations compared to those who are normal weight (NIH, 2011). Finally, in a new line of research, a large cohort study using genetic markers confirmed that a higher BMI was associated with lower concentrations of available vitamin D in the body (Vimaleswaran et al., 2013).

**Vitamin D Intake and Status**

Vitamin D insufficiency or deficiency has been documented in many nations worldwide, from Iran to Australia (Schwalfenberg, 2007). One review concluded that inadequate serum 25(OH)D is a global problem, citing studies that documented a high prevalence of low vitamin D concentrations among older adults in Canada, the USA, Denmark,
Finland, Norway, Sweden, Belgium, France, Germany, Ireland, the Netherlands, Switzerland, and the UK (Reginster, 2005). This section will review the literature relating to vitamin D intake and status in Canada. Note that definitions for deficiency, insufficiency, and sufficiency vary between studies.

**Status in Canada**

*National data.* National data from the 2004 Canadian Community Health Survey (CCHS) indicate that mean dietary vitamin D in Canadian adults aged 19-50 was 204 IU for women and 232 IU for men (Health Canada, 2004). Health reports associated with the 2004 CCHS reported that of all the nutrients with an EAR, the highest proportions of inadequacy were found for vitamin D (Health Canada, 2012). The most recent national data on vitamin D status in Canada comes from the 2012-2013 Canadian Health Measures Survey (CHMS) (Statistics Canada, 2015b). Results of this national survey indicated that plasma 25(OH)D vitamin D levels among Canadians aged 6-79 dropped from 67.7 nmol/L in 2007-2009 to 61.0 nmol/L in 2012-2013 (Statistics Canada, 2015b). The mean plasma 25(OH)D concentration among young adults aged 18-25 was 60.1 nmol/L (95% CI: 52.4-67.7; Statistics Canada, 2015a), and fewer than a quarter (24.1%) of those aged 18-25 had concentrations at or above 75 nmol/L (Statistics Canada, 2015a); the cut-off currently associated with optimal health (Dawson-Hughes et al., 2005; Holick & Chen, 2008; Vieth, 2011). A report by Janz and Pearson (2013) analyzed the 2012-2013 CHMS data; although their cut-off for sufficiency was 50 nmol/L, a few points are worth noting. For one, more Canadians were below the cut-off during the winter

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E 95% CI: 15.0-36.5; Use with caution; coefficient of variation is between 16.6% and 33.3%.
compared to the summer months (40% vs. 25%, respectively), and females tended to have higher plasma 25(OH)D concentrations than males. Importantly, when compared to other age categories, young adults aged 20-39 had the lowest proportion of individuals exceeding the 50 nmol/L cut-off, at only 59%. In addition, while only about one third (34%) of Canadians reported taking vitamin D supplements, taking a supplement helped to meet the recommendations. Specifically, 85% of those who took vitamin D supplements met the cut-off of 50 nmol/L, compared to 59% of non-supplement users (Janz & Pearson, 2013).

**Vitamin D intake and status among young adults.** Several studies have examined vitamin D status, intake, or supplement use in Canadian adults (i.e., Baraké, Weiler, Payette & Gray-Donald, 2010; Genuis et al., 2009; Green, Barr & Chapman, 2010; Poliquin, Joseph & Gray-Donald, 2009). However, only a few studies have examined vitamin D status specifically in youth or young adults living in Canada. Vieth, Cole, Hawker, Trang and Rubin (2001) asked approximately 800 young women aged 18-35 to self-report their consumption of vitamin D from milk and multivitamins, and measured their serum 25(OH)D concentrations. Results indicated that the average vitamin D intake was 184 IU per day. Serum 25(OH)D concentrations differed by race; from December to April, 20-28% of white women had low 25(OH)D concentrations, and non-white women had significantly lower vitamin D status in the summertime and year round. Only a quarter (25%) reported taking vitamin D-containing supplements, about one third (34%) consumed virtually no vitamin D from milk or multivitamins, and 46% reported not drinking milk. Overall, the researchers concluded that self-reported intake of vitamin D
from milk and/or vitamins did not prevent low vitamin D status in the wintertime, and that the recommended amounts were too low to prevent insufficiency (Vieth et al., 2001).

Secondly, a three-part dissertation study conducted by Mark (2009) examined the vitamin D status of Québec youth. In the first study, results indicated that over 93% of youth had suboptimal 25(OH)D levels (defined as <75 nmol/L) at the end of winter and beginning of spring. Vitamin D deficiency (defined as <27.5 nmol/L) increased with age in both sexes; girls from low income households also tended to have lower serum 25(OH)D concentrations (Mark et al., 2008). In the second study, milk consumption and physical activity were found to be modestly associated with increases in serum 25(OH)D levels. The study also analyzed data from the 2004 CCHS and found that sweetened beverages were displacing milk among low-income boys and food insecure girls. The author concluded that population interventions to increase dietary vitamin D intake should be examined in Canadian youth (Mark, 2009).

Finally, one study examined vitamin D status in a sample of young adults of diverse ancestry living in the Greater Toronto Area (Gozdzik, 2008). Results indicated that 25(OH)D concentrations were low in young Canadian adults, particularly in those of non-European ancestry, and vitamin D intake was found to be insufficient to maintain optimal vitamin D concentrations throughout the year. Vitamin D concentrations were varied by season; serum 25(OH)D concentrations were substantially lower in winter than fall. Although vitamin D intake was found to be an important year-round predictor of 25(OH)D concentrations, skin pigmentation and sun exposure were also important
predictors during times when UVB is adequate for cutaneous vitamin D synthesis. The author concluded that higher vitamin D intakes are required to counteract the seasonal drop in vitamin D concentrations and to ensure adequate vitamin D concentrations year-round for those at risk of vitamin D insufficiency (Gozdzik, 2008).

Summary of findings. A few conclusions can be drawn from these studies. Firstly, all studies that examined seasonality found that serum concentrations were higher in the spring/summer compared to the winter months in Canada. Secondly, vitamin D supplements tend to help individuals meet requirements. Most importantly, national data indicate that vitamin D intake and status among Canadians is fairly low in comparison with more recent recommendations (i.e., blood concentrations of at least 75 nmol/L; Dawson-Hughes et al., 2005; Holick & Chen, 2008; Vieth, 2011, and an intake of ≥1000 IU/day; CCS, 2012). Indeed, national data indicated blood vitamin D levels hovering around 60 nmol/L (Statistics Canada, 2015b) and intakes below 250 IU/day (Health Canada, 2004). Concerningly, these levels also fail to meet the relatively conservative RDA of 600 IU/day set by the IOM (2010). These findings suggest that many Canadians may have suboptimal vitamin D status, especially in the winter months. Indeed, a review concluded that there is a high prevalence of vitamin D insufficiency in both Canada and the USA, and that dark-skinned individuals living in the northern latitudes are at high risk year-round (Calvo & Whiting, 2003). Low vitamin D status is clearly an issue that needs to be addressed in Canada. Below, food fortification will be discussed as a potential avenue with which to improve national vitamin D status.
Food Fortification: a Solution to Vitamin D Insufficiency?

As described previously, specific foods (i.e., cow’s milk and margarine) are enriched with vitamin D by law (Canadian Food Inspection Agency, 2012) in order to prevent deficiency among Canadians. Unfortunately, current fortification levels may not be sufficient. The Canadian government does not mandate that dairy products such as cheese, yogurt, butter, cream or ice cream be fortified with vitamin D, and only recently have certain brands of yogurt been manufactured with small amounts of vitamin D-fortified milk (Calvo et al., 2004). Further, despite being the main dietary source of vitamin D among Canadians, consumption of cow’s milk has decreased in recent decades and is not consumed by some individuals due to cultural factors, lactose intolerance, veganism and/or personal preference (Calvo et al., 2004; Vieth, 2012). Milk consumption is particularly low in certain subgroups such as African Americans; paradoxically, individuals with darker skin pigmentation have the greatest physiological need for dietary vitamin D (Calvo et al., 2004). Correspondingly, some researchers have argued that current fortification levels in Canada (as well as other countries including the USA and Germany) are insufficient to prevent vitamin D insufficiency in the majority, i.e. 97.5% of the population (Calvo et al., 2004; Vieth, 2012).

Increased food fortification may have the potential to increase serum vitamin D concentrations on a national scale. A recent meta-analysis that examined the efficacy of vitamin D food fortification found that a mean individual vitamin D intake of 440 IU/day from fortified foods increased 25(OH)D concentrations by 19.4 nmol/L, translating to a 1.2 nmol/L increase in serum vitamin D for every 1 mg of vitamin D consumed (Black,
Seamans, Cashman, & Kiely, 2012). Study authors concluded that food fortification has the potential to increase serum vitamin D concentrations at the population level (Black et al., 2012). Greater food fortification of the Canadian food supply (i.e., expansion to products other than cow’s milk and margarine) would also help Canadians meet the recommended intakes without having to take a vitamin D supplement (Vieth, 2012). This would be beneficial, as population-wide adherence to a supplement is likely to be low (Vieth, 2012). Unfortunately, policies regarding fortification are frequently met with opposition by policy makers and the food industry, largely due to potential costs and public disapproval of the government ‘tampering’ with the food supply (Vieth, 2012). As it stands, current fortification levels are too low to prevent vitamin D insufficiency in Canada, and this does not come without financial consequences.

**Economic Burden of Vitamin D Deficiency**

Given the increased attention placed on vitamin D in recent years, demand for blood vitamin D testing has increased in Canada (from 29,000 tests in 2004 to 700,000 in 2009) – as have the associated costs. A Canadian news article reported a one hundred percent cost increase in one year in British Columbia (CBC News, 2010). As a result, many Canadian provinces (including Ontario, Manitoba, Saskatchewan, Alberta, British Columbia, Nova Scotia, PEI, Newfoundland and Labrador) have elected not to provide financial coverage for vitamin D testing unless it is medically necessary (CBC News, 2010; Ontario Ministry of Health and Long-term Care, 2012). The Ontario Health and Insurance Plan (OHIP) eligibility is limited to patients suffering from osteoporosis, rickets, osteopenia, renal disease, malabsorption syndromes (e.g., Crohn’s or celiac disease), or those who are taking medications that affect vitamin D metabolism (e.g.,
corticosteroids and drugs used to prevent fat absorption) (Government of Ontario, 2010). Otherwise, physicians are encouraged to promote the dietary vitamin D recommendations, and patients who wish to receive vitamin D testing but who do not qualify for OHIP coverage must personally cover the cost of the test (Government of Ontario, 2010).

In addition to the cost of testing, the health consequences related to vitamin D deficiency and insufficiency also place a burden on the Canadian economy. A study examining the economic burden of vitamin D deficiency in Canada estimated that the total direct and indirect economic costs of conditions related to vitamin D totaled $200 billion in 2005, plus an additional $10 billion for dental care (Grant et al., 2010). The study concluded that the mortality rate in Canada could be reduced by about a sixth (16.1%) and the economic burden could be reduced by 7.3% if the average serum 25(OH)D level in Canada was increased to 105 nmol/L (Grant et al., 2010). It is important to note that this 25(OH)D threshold is quite high, and the cost projection is an estimate only and thus may reflect an overestimation. This is especially true given that the research evidence regarding the role of vitamin D in a range of health conditions is inconclusive. Nevertheless, the cost of vitamin D testing in Canada is clear.

**Knowledge and Perceptions of Vitamin D**

The research presented above clearly demonstrates that vitamin D insufficiency is a global issue, that current fortification levels are too low to prevent it, and that the economic costs of this issue in Canada are pronounced. Given this and the fact that achieving vitamin D status depends largely on deliberate, individual behaviours (i.e.,
achieving adequate sun exposure and consumption of fortified foods and/or supplements), determining public knowledge of, and perceptions towards vitamin D is important from a public health standpoint.

Few North American studies have looked at public perceptions and knowledge of vitamin D. One Canadian study examined the vitamin D supplementation practices of mothers of infants in the Montreal area using a cross-sectional phone survey. Results indicated that 74% of infants who were exclusively breastfed and 55% of those who received mixed feeding (i.e., formula and breast milk) met the Health Canada recommendation that breastfed infants should receive a daily vitamin D supplement of 400 IU for at least the first 6 months. Of those who were exclusively formula-fed, only 36% met the recommended dose of 400 IU per day. Common reasons that mothers gave for not supplementing their infants (or not supplementing consistently) were that they were no longer breastfeeding, they did not realize it was necessary, lack of time, forgetting, supplementing only in the winter, or that the infant disliked the supplement. Six percent of breastfeeding mothers responded that their health professional had not informed them about the need for vitamin D supplementation (Gallo et al., 2010). A dissertation project used focus groups and interviews to examine knowledge and perceptions about vitamin D among 22 female college students in South Carolina, USA. Results indicated that this small sample of college females had a broad knowledge of vitamin D overall, including its sources and roles in the body (Wingard, 2010). Only one study to our knowledge has examined vitamin D knowledge among Canadian young adults, and found that knowledge was poor overall (Boland, Irwin & Johnson, 2015). The findings from these
North American studies were limited to female samples (i.e., mothers of infants, college-aged women); thus, knowledge among the broader population of young adult men and women in Canada is lacking. Further research is needed in order to better understand knowledge and perceptions of vitamin D in Canada. This information may also help shed light on the reasons why Canadians engage in specific behaviours related to vitamin D status.

**Health Behaviour Theory**

Health behaviours (such as taking dietary vitamin D supplements, or avoiding the sun to reduce the risk of skin cancer) and the reasons behind them differ widely among individuals. The two health behaviour theories outlined below describe some key factors that are widely believed to predict health behaviours.

**Theory of Planned Behaviour**

The Theory of Planned Behaviour (TPB; Azjen, 1991) theorizes that perceived control influences both intentions and behaviour, and that attitudes, norms, and perceived behavioural control are all important predictors of behavioural intentions. Thus, in the context of health, symptoms that are perceived to be more controllable will be associated with higher intentions to engage in precautionary or preventative behaviours, as well as a higher likelihood of actually engaging in the behaviour (Azjen, 1991).

**Prototype Willingness Model**

The Prototype Willingness Model (PWM; Gibbons et al., 1998) is a dual-process model designed to address non-intentional, but volitional risk behaviour in adolescents. The model addresses the fact that certain behaviours (especially ones that involve risk) are
performed despite a lack of intention. This is especially true among adolescents and young adults, who may be driven more by willingness to engage in a behaviour than by conscious intention (Gerrard, et al., 2008a). The model consists of a reasoned pathway and a social reaction pathway. The reasoned pathway is used for decisions involving more systematic or analytic processing and consists of both attitudes and subjective norms as predictors of behaviour. In contrast, the social reaction pathway involves more heuristic processing and is relevant to behaviours that are not necessarily planned or thought out. This pathway is characterized by images (referred to as ‘risk prototypes’), and is influenced more by affect and intuition than by deductive reasoning. The heuristic pathway involves two variables: willingness and prototype perceptions. This pathway is relevant to situations in which an individual does not plan to engage in a specific behaviour, but may be willing to take the risk under specific circumstances (Gerrard et al., 2008a). Thus, by examining willingness and risk prototypes, the PWM extends the TPB and presents an opportunity to predict behaviours that are not necessarily intentional.

**Theory Applications**

Several studies have used the TPB and/or PWM to predict health behaviours. A study by O’Connor and White (2010) utilized the TPB and found that attitude, dread, and subjective norms were significant factors influencing participants’ willingness to try different health products, vitamin supplements and functional foods. Lv and Brown (2011) found that a TPB-based intervention was effective at improving the calcium and vitamin D intake of Chinese-American women. The TPB has been successful at predicting intentions to engage in various health-protective behaviours, including
physical activity (Blanchard et al., 2008; Kwan, Bray, & Martin Ginis, 2009), condom use (Heeren, Jemmott, Mandeya & Tyler, 2007; Wiggers et al., 2003), breastfeeding (Bai, 2007; Saunders-Goldson & Edwards, 2004; Wambach, 1997) healthy eating behaviours (Carson, 2010; Chan & Tsang, 2011; Conner, Bell & Norman, 2002; Middleton, 2007) and use of vitamin supplements (de Nooijer, Onnink, & van Assema, 2010; Pawlak et al., 2008). It has also been used in studies specifically relating to vitamin D intake or supplementation (de Nooijer et al., 2010; Engels, van Assema, Dorant & Lechner, 2001; Johnson, 2010; Lv & Brown, 2011; Olson, 2008).

The PWM is most often used to predict willingness to engage in unhealthy or risky behaviours, and is often used in conjunction with the TPB. For example, Rivis, Abraham and Snook (2011) used the TPB and PWM to examine younger and older male drivers’ willingness to drive while intoxicated. Todd and Mullan (2011) used the PWM and TPB to examine binge-drinking behaviours among female undergraduate students. Gerrard, Gibbons, Stock, VandeLune and Cleveland (2005) used the PWM to examine factors related to smoking initiation in African American pre-adolescents, while Sommer Hukkelberg and Dykstra (2009) used the PWM to predict smoking behaviours among Norwegian adolescents. Taking a slightly different approach, one study examined positive and negative anticipated emotions (positive affect, negative affect and regret) among college students using the PWM (O'Hara, 2011).

Although the PWM is most applicable to risky health behaviours, it has been used in a few studies (alone or in conjunction with the TPB) to examine health-protective
behaviours. Rivis, Sheeran and Armitage (2006) examined the predictive capacity of elements of the PWM – above and beyond the TPB for both adolescent health-protective and health-risk intentions, and found that these elements were equally predictive of health-risk and health-protective behavioural intentions. Skin protection is an example of a health-protective behaviour examined using the PWM; one study used the PWM to examine UV protective behaviours in road maintenance workers (Gerrard et al., 2008b) while another used the TPB, PWM and an additional health behaviour model to predict skin protection behaviour in individuals with occupational skin disease (Matterne, Diepgen & Weisshaar, 2011). The TPB and PWM have also been used to predict the altruistic practice of organ donation (Hyde & White, 2010).

Thus, although traditionally applicable to risky behaviours, the PWM has potential as a model to predict health-protective behaviours—such as taking vitamin D supplements or eating vitamin D-rich foods. However, both predicting and encouraging health-protective behaviours can be quite difficult, especially among young adults who may have other competing priorities. One avenue to explore within the young adult population is the use of mobile technology.

**Mobile Applications in Health Research**

The Internet has become an increasingly important and popular research tool over the past couple of decades. Conducting research online has many advantages. It allows for instant communication and feedback, enables researchers to engage a larger sample (e.g., those from remote or distant locations, or those with accessibility issues), often requires less effort for the participant (i.e., since online surveys can be completed from the
comfort of one’s own home), and allows researchers to provide links to valuable online resources. Indeed, web-based platforms have been used in a variety of studies examining knowledge, perceptions, behaviours and/or experiences related to health and wellness, including: smoking behaviours, intentions to quit (Prochaska et al., 2011) and use of e-cigarettes (Dawkins, Turner, Roberts & Soar, 2013); food safety issues, such as knowledge and preventive behaviours during a Salmonella outbreak (van Velsen et al., 2014); intentions to be tested for STIs and HIV (Westmaas et al., 2012); the burden of specific disease states on patients (Gordon et al., 2013); sexual health (Wimpissinger, Springer & Stackl, 2013) and pregnancy issues (Peel, 2010); perceptions of vaccination (Bolton-Maggs et al., 2012) and influenza (Tozzi, Gesualdo & Ugazio, 2012); dietary supplement recommendations among healthcare workers (Stuber, Bruno, Kristmanson & Ali, 2013); nutrition knowledge among vegetarians (Hoffman, Stallings, Bessinger & Brooks, 2013); and physical activity and nutrition among adolescents (Storey et al., 2012).

An increased reliance on technology has been accompanied by widespread use of mobile phones, which represent another useful platform with which to conduct research. Mobile phones provide a convenient, hand-held method of instant communication and feedback with the research program, and have shown positive results in health behaviour studies. For instance, one RCT used mobile phones and text messaging to improve medication adherence in patients with type II diabetes (Vervloet et al., 2011) and another study used daily text messages as part of an intervention to increase physical activity among sedentary women (Fukuoka, Lindgren & Jong, 2012).
Smartphones (i.e., mobile phones with data and internet capabilities) may represent an even more promising research tool, as they allow for the use of mobile ‘apps’, online software applications designed to run on smartphones, tablets and other mobile devices. In 2015, it was projected that about 180 billion apps would be downloaded worldwide that year, with that number expected to increase to almost 270 billion by 2017 (Statista, 2015). The use of mobile apps related to health is also on the rise; according to a review by Kratzke & Cox (2012), health apps are some of the most highly used on the market, with 17,000 mobile health and medical apps available at the time of publication. Within the health care sector, nationwide surveys report that 80% of physicians carry a mobile device, many of whom use mobile health applications for purposes such as diagnoses, searching for drug and treatment references, keeping up-to-date on new research, and educating patients (Downing Peck, 2011). Finally, many health organizations have also developed mobile apps. For instance, the Heart & Stroke Foundation of Canada released a free mobile app that aims to reduce the risk of heart disease and stroke. The app provides users with a customized risk profile, allows them to track their progress, and includes features such as reminders, positive reinforcement, and social support (Heart and Stroke Foundation, 2012).

Unsurprisingly, health researchers are beginning to incorporate apps into their research designs, especially among interventions aiming to increase physical activity or healthy eating. Fukuoka et al. (2012) examined use of a mobile app and a pedometer to increase physical activity among sedentary women, and concluded that this methodology might be
useful for motivating women to be physically active. A matched case-control trial conducted in Australia compared the use of a web-based program called *10,000 Steps* to a smartphone version of the program. Results indicated that app users were more likely to log daily steps and to log more than 10,000 steps at each entry (Kirwan, Duncan, Vandelanotte & Mummery, 2012).

Mobile apps have also been used in studies examining caloric or nutrient intake, or to encourage healthy eating. Tsai and colleagues (2007) examined use of the Patient-Centered Assessment and Counseling Mobile Energy Balance app, which allows users to self-monitor caloric balance, and found that the mobile app users scored the same as, or better than participants using a paper diary method of calorie tracking. Lieffers and Hanning (2012) conducted a review examining eighteen apps designed for dietary assessment and self-monitoring, and found that mobile apps frequently led to better adherence to self-monitoring behaviours, and changes to dietary intake and/or anthropometrics, compared to traditional methods. The authors highlighted the potential use of mobile devices in dietetic practice (Lieffers and Hanning, 2012).

Given these advantages and their growing popularity, mobile apps also have great potential as a health-promoting research tool among the general public. Young adults aged 18-29 are the greatest owners of smartphones and report using their phones to look up health or medical information significantly more than adults of other ages (Fox & Duggan, 2012). As such, mobile health apps may be an especially effective tool with which to conduct health and dietary interventions in this age group.
CHAPTER 3: Preferences of Young Adults Regarding Dissemination of Online Vitamin D Information

ABSTRACT

Purpose: To determine an appropriate intervention methodology for young adults regarding the dissemination of online vitamin D information.

Methods: Participants were 50 men and women aged 18-25, living in Ontario, Canada. Eight focus groups (4 male; 4 female) were conducted using open-ended questions; participants also completed a demographic questionnaire. Audio files were transcribed verbatim; thematic analysis was used to identify key themes.

Results: Thematic analysis revealed that an effective educational intervention geared towards this population should be simple, brief, interesting, personally relevant, credible, and include incentives.

Conclusions: Feedback regarding intervention methodology could be used to inform interventions aiming to increase intake of vitamin D or other nutrients among young adults.

INTRODUCTION

Vitamin D plays a key role in bone health by increasing calcium absorption, helping to prevent rickets in children and osteomalacia in adults (IOM, 2010). Vitamin D may increase innate immune function (Alvarez-Rodriguez et al., 2012) and deficiency has been associated with a host of disease states, including cancer (Blackmore et al., 2008;  

Please refer to Appendix R (Supplementary Data) for description of results relating to vitamin D knowledge and perceptions among young adults, which was gathered from these focus groups.
Garland et al., 2006; Gross, 2005; Holick, 2006), cardiovascular disease (Brøndum-Jacobsen, Benn, Jensen & Nordestgaard, 2012; Zittermann et al., 2003) diabetes mellitus (Hypponen, Laara, Reunanen, Jarvelin & Virtanen, 2001; Knekt et al., 2008; Munger et al., 2013; Pittas et al., 2006) multiple sclerosis (Ascherio & Munger, 2007; Munger et al., 2004; Pierrot-Deseilligny, 2009; Ponsonby, Lucas & van der Mei, 2005) rheumatoid arthritis (Merlino et al., 2004) metabolic syndrome (Brenner et al., 2011; von Hurst et al., 2008) and insulin resistance (Belenchia, Tosh, Hillman & Peterson, 2013; Chui, Chu, Go & Saad, 2004). Adequate vitamin D intake is therefore important at all ages, and particularly during the period from 18-25 years, referred to as “emerging adulthood” (Nelson et al., 2008). This is a time of increased independence and autonomy that is considered crucial for developing patterns of long-term health behaviors, and has been cited as an often overlooked, yet important window for dietary behaviour change (Nelson et al., 2008). Emerging adulthood is also a critical period for the development of skeletal bone mass, which reaches about 90% of its potential during late adolescence, hits its peak by about age 25-30 (Abrams, 2003) and cannot be significantly increased after this time (Gropper et al., 2005). Adequate consumption of calcium and vitamin D during young adulthood is therefore essential for the maintenance of optimal health (Heaney et al., 2000). The current adult Recommended Dietary Allowance (RDA) for vitamin D is 600 IU/day (1-70 years) (IOM, 2010), and several researchers have recommended serum vitamin D$_3$ concentrations of ≥75 nmol/L for optimum health (Dawson-Hughes et al., 2005; Holick & Chen, 2008; Vieth, 2011). Unfortunately, national data indicate that adults 19-30 years consume an average of only 236 IU vitamin D/day from food sources
Despite the importance of adequate vitamin D intake to long-term health, targeting health behaviour change among emerging adults can be difficult. The term “young invincibles” has been used to describe this life stage (Bibbins-Domingo & Burroughs Peña, 2010), which is often associated with feelings of invincibility and a disregard for future health consequences. Vitamin D poses an additional challenge because the most well documented outcomes of deficiency (i.e., osteomalacia, osteoporosis) occur in old age (NIH, 2014), perhaps decreasing the perceived importance of meeting recommendations during the younger years. The internet is a promising mode of delivery for health-behaviour change geared at young adults (Crutzen et al., 2011), and online interventions focusing on dietary behaviours such as nutrition (Maes et al., 2011), weight maintenance (Gow, Trace & Mazzeo, 2010), and alcohol consumption (Bingham et al., 2010; Saitz et al., 2007) are emerging. However, few researchers have conducted online interventions related to vitamin D (Drieling, Thiyagaraja & Stafford, 2011) or examined vitamin D knowledge among young adults (Boland et al., 2015). Thus, little is known about how to effectively communicate with or engage this population regarding the importance of vitamin D to health and disease prevention. The current study therefore aimed to determine preferred strategies for dissemination of online vitamin D information among a young adult population.

E 95% CI: 15.0-36.5; Use with caution; coefficient of variation is between 16.6% and 33.3%.
**METHODS**

**Participants and Recruitment**
Research participants (N=50) were recruited using convenience sampling from the Guelph, Ontario area using online and poster advertisements in the community and the University of Guelph campus. Advertisements recruited participants for a one-hour informal discussion relating to vitamin D and health; participants expressed their interest by email. Participants were required to be 18-25 years of age and fluent in English. The University of Guelph Research Ethics Board granted approval for this study.

**Measures**
A short demographic survey collected data on age, sex, race, education level, employment, and student status. Participants were asked to provide feedback on a series of strategies relating to communicating information about vitamin D and its health outcomes. Five main strategies were proposed: (a) educational messages presented in a text-based format; (b) statistics; (c) educational messages delivered by a health professional; (d) video testimonials by a young adult; and, (e) an interactive survey. Participants were also asked about their preference for positive versus negative messaging and short versus long-term health effects of vitamin D. Questions were pilot-tested with a group of 6 participants, leading to the revision of one item; see supplemental materials for question wording.

**Procedure**
A qualitative approach was taken in order to gain an in-depth understanding of young adults’ views and preferences with regards to receiving information about vitamin D. Eight focus groups were conducted at the University of Guelph in August 2012 (4 each with men and women, separately). After providing written informed consent, participants
completed a demographic survey. Two trained female facilitators (JS; PhD, RD, and SG; MSc, PhD candidate) led the semi-structured focus groups (4 groups run by each facilitator). A series of open-ended questions were asked; participants answered freely and were occasionally prompted for elaboration. Participant responses were recorded by audio as well as abbreviated type; responses were linked to unique ID numbers rather than names for anonymity. The researchers concluded that theoretical saturation was reached once similarities between discussions emerged and few new ideas were introduced. Participants received a $50 dollar gift card as compensation.

**Data Analysis**

Demographic statistics were analyzed using SPSS software (IBM SPSS Statistics for Windows version 20.0, IBM Corp., Armonk, NY, 2011). Chi-squared tests were used to test for significant differences between men and women on demographic variables. Audio files were transcribed verbatim using ExpressScribe (ExpressScribe Software, NCH Software, Boston, MA, 2002). A post-positivist approach was taken (Baronov, 2012); the researchers acknowledge the influence of social and cultural context on participant responses and researcher assumptions, as well as biases of the researcher (i.e., interest in health, nutrition and vitamin D). Responses were analyzed using thematic analysis, as per the procedure outlined by Braun and Clarke (2006). After becoming familiar with the data, the first author developed a coding scheme to identify key ideas and concepts. A list of key themes was generated from the initial codes. Eight themes were initially identified; further refinement resulted in five final themes. An external coder independently analyzed the eight transcripts to identify major themes and subthemes. Agreement on any discrepancies was reached through verbal discussion. This process led to minor refinement of the final themes, including alteration of two theme names and the
promotion of one code to a subtheme.

**RESULTS**
Fifty participants (22 men; 28 women) completed the study (100% participation rate); sample characteristics are listed in Table 3.1. Groups consisted of 3-8 participants (M=6). Participants ranged from 18-25 years (M=21.9 years) and the majority were Caucasian (78%). Ninety-four percent had at least “some” university education. Chi-squared tests indicated that males and females did not differ significantly on any socio-demographic variables, however more women (n=18) had taken a nutrition course than men (n=8), \( p=0.05 \).

**Table 3.1: Sample Characteristics of Participants in Focus Group Study (n=50)**

<table>
<thead>
<tr>
<th></th>
<th>% (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sex</strong></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>56.0% (28)</td>
</tr>
<tr>
<td>Male</td>
<td>44.0% (22)</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
</tr>
<tr>
<td>18-19</td>
<td>14.0% (7)</td>
</tr>
<tr>
<td>20-21</td>
<td>30.0% (15)</td>
</tr>
<tr>
<td>22-23</td>
<td>32.0% (16)</td>
</tr>
<tr>
<td>24-25</td>
<td>24.0% (12)</td>
</tr>
<tr>
<td><strong>Race</strong></td>
<td></td>
</tr>
<tr>
<td>White/Caucasian</td>
<td>78.0% (39)</td>
</tr>
<tr>
<td>Other</td>
<td>22.0% (11)</td>
</tr>
<tr>
<td><strong>Highest level of Education</strong></td>
<td></td>
</tr>
<tr>
<td>High school, Apprenticeship or Professional Certificate</td>
<td>6.0% (3)</td>
</tr>
<tr>
<td>Some university or undergraduate degree</td>
<td>82.0% (41)</td>
</tr>
<tr>
<td>Some graduate school, graduate degree or certificate</td>
<td>12.0% (6)</td>
</tr>
<tr>
<td><strong>Student status</strong></td>
<td></td>
</tr>
<tr>
<td>Currently a student</td>
<td>74.0% (37)</td>
</tr>
<tr>
<td><strong>Employment</strong></td>
<td></td>
</tr>
<tr>
<td>Unemployed</td>
<td>30.0% (15)</td>
</tr>
<tr>
<td>Part-time</td>
<td>40.0% (20)</td>
</tr>
<tr>
<td>Full-time</td>
<td>30.0% (15)</td>
</tr>
</tbody>
</table>
Analysis of focus group transcripts revealed that while personal preferences for receiving vitamin D information varied widely, five key themes emerged.

**Theme 1: Time is of the Essence.** In regards to almost every proposed methodology, it was apparent that young adults valued their time. Messages related to vitamin D information would therefore be well received only if they were short and concise. In a discussion of text-based online information, one man admitted, “I think like if it’s going to be on the Internet, brevity’s definitely key, just because a lot of people’s mindset when they are browsing is very uh…um, cut-throat I’d say.” Others agreed, with statements such as: “You don’t wanna overwhelm people with text or uh, unnecessary information” and “Yeah, the longer it is, like for me, then the more—less likely [it is that] I’m going to read it. For like stuff on the Internet, you know, like, I have a really short attention span for that stuff, so it’s like… I don’t care.” Most participants also agreed that brevity is key when it comes to video messaging. One woman suggested, “See I can see something like little, mini videos, like if they were 45 seconds to a minute long or something; really short, sort of like you clicked on it and it was, you know, almost commercial-style…” A few individuals also commented that they would prefer text to video, because it would allow them to quickly skim for important points. As explained by this woman:

> Well I would be more into reading something, yeah something short, just because I’d like, skim through it and pick out the things that I want to learn. But things like videos, I never watch them, no, ‘cause like I’d have to sit there for like the 5 minutes to watch it, whereas if I’m reading I’ll just be like finished, and then I can go on if I want to.

Similarly, while several women liked the idea of an interactive quiz, the likelihood of participation depended on the amount of free time available to them. In contrast, most men stated that they would not take the time to participate in a vitamin D quiz. One man
admitted, “Um…if I got to a point where it said, ‘Now take this fun quiz about vitamin D’, I’d go back to playing Free Cell\(^3\) or something.” Clearly, free time is valuable to these young adults, and effective materials must be concise in order engage youth, who might rather spend their leisure time on other activities.

A sub-theme that emerged was “stress simplicity”. When asked “what could we do that would get you to make changes to your diet?” several participants responded that the message should focus on simple, specific changes. One man explained how explicitly outlining the desired behaviour change makes the message simpler: “If you could somehow quantify um, like in distinct terms like, what I needed to do … if it was like ‘The average Canadian drinks X amount of glasses per day; drink one more’, or something. That kind of makes it simple for what I need to do.” A few participants also suggested emphasizing how easy it is to meet the RDA. One man pointed out that while vitamin D status may not be a pressing issue compared to other chronic health conditions, it is easier to manage: “Well even just in the winter, as you say, it’s like, it’s just one pill to make sure you [reach the recommendations]– or supplement, or even your multivitamin. If it’s just one pill, that’s pretty easy as well.” As this man suggested, taking a daily supplement is an easy way to prevent vitamin D deficiency, and is a good example of a message that would be a short and simple to communicate.

**Theme 2: Intervention materials require a ‘hook’**. The second theme that emerged was that in order to be effective and engaging, information must be catchy and

\(^3\)A computer-based card game
interesting. Comments by both men and women indicated that materials would be engaging if they were: visually appealing (including images, animations or infographics), interactive, attention-grabbing, surprising, shocking, scary, touching, or memorable. One woman suggested using shock-value to engage viewers:

*What about those old – you know those old smoking commercials? Like it’s extreme but like you know that one where . . . I think it was the husband of the lady who worked in the diner who died from, from lung cancer who’d never smoked a day – something like that. Like it’s a big shock factor, but we all remember that commercial and we know exactly what it was for, so something like that might help it click.*

Another man stated that he wouldn’t take the time to read vitamin D information unless it caught his attention, again demonstrating that young adults value their free time, and stressing the importance of leading with ‘a hook’:

*I don’t know that I’d read something specifically just about like, facts. Um, I guess it really depends how it’s sort of put forth, like if it’s um . . . if I see an article that’s like new research done about . . . “these crazy results”, then I would read something like that. Um, but if it’s, if I see an article that just says, “Learn these facts about vitamin D”, I wouldn’t take the time to read that, I don’t think.*

In discussions of positive versus negative messaging, although individual preferences varied, several men and women mentioned that they were more likely to remember a fear-provoking message. As stated by this young man: “I think fear works so much better, ‘cause you’ve been hearing like your entire life, you know, ‘Insert X is good for building strong bones.’ Like everything is good for building strong bones. But like tell ‘em something that’ll actually scare them and something that you’re actually going to remember, you know?” Similarly, several women discussed viral videos that focused on melanoma. These videos were described as ‘powerful’, ‘touching’ or ‘frightening’ and were clearly memorable to participants. As one woman recalled, “That one cancer video
on melanoma, it was like a variety of people, so it was mostly like teenagers or older people who had suffered from skin cancer, that was really like touching, and I think if people, like it matters to them – that subject, it might draw their attention more, too.” This woman’s comment suggests that the video was effective partly due to its ability to evoke emotion, and partly because the issue mattered to the viewer—highlighting the importance of personal relevance (see Theme 3, below).

Finally, a subtheme that emerged in relation to materials requiring ‘a hook’ was that incentives would increase engagement. Several men and women indicated that they would participate in an interactive intervention quiz or survey if they were offered an incentive such as coupons for supplements, grocery store gift cards or the chance to win a prize.

**Theme 3: “Personal Relevance is Key”**. A principal theme that emerged among both men and women was the desire for relatable information. Text, statistics and videos were perceived as being more valuable if they were specific and personally relevant. One educational tool that participants viewed favorably was personal feedback—presumably because this strategy increases the relevance of the information presented. Participants felt that individual feedback regarding their vitamin D status might motivate them to increase their intake or to seek more information. Further, personal feedback would help individuals differentiate themselves from others when reading facts or statistics. For instance, without any information about their personal vitamin D status, many participants admitted that they would assume that a given statistic did not apply to them. One man stated, “I’d probably be like . . . I’ll just throw [the statistic] away and [assume]
I’m probably not in that 25%, you know what I mean?” Another man chimed in, “Yeah, I think it would be easy to think that you’re like, special or different than like, the group.” However, several participants acknowledged that if they had access to information regarding their personal vitamin D status, they might pay more attention to their intake. The idea of a web-based or handheld (i.e., mobile) calculator that could estimate your vitamin D status was raised during one focus group, and was a well-received idea in subsequent groups. One man envisioned this idea:

You know, click here and figure out whether you are most likely to... Go to another [web] page, ok, here are all of the [dietary] sources, here’s how much is in them, here’s a little calculator so you can actually put in [the foods you consumed], here’s how much time you spend outside in a week ... Because if I can take less than 5 minutes to figure out, “Ok did I get enough vitamin D last week?” Well, ok. Like that, that would be useful, and then I’ll have a fair idea [of my vitamin D intake/status].

In a discussion regarding this idea, one man explained why a vitamin D calculator might be motivating: “Yeah if it seemed like an alarming disparity between what I’m supposed to be getting and what I’m actually consuming, I think I might actually be concerned.”

A subtheme that emerged was that immediate health outcomes are more relatable than long-term effects. There was an overall consensus among both men and women that it would be most effective to focus on the immediate health benefits of vitamin D. Long-term consequences such as developing osteoporosis or breaking a hip were considered irrelevant and not particularly motivating. As one woman explained, “You can relate more with the immediate effects, like you might not think about, ‘Oh in forty years, what are my bones gonna be like?’ You know, most of us don’t really think about that, so.” One man noted, “I’d say short-term too. Because we’re not really worrying about where
we’re going to be in like our 60s, when we’re just like teens or 20s, right?” Another woman stated, “It just has to be relatable; you just have to be able to relate to them. You’re not gonna relate to a 70 year old… Like I’m… I’m still younger, I’m 20 years old… I’m not worried about when I’m 70 right now. I’m worried about right now.” Evidently, long-term health issues are not relatable to these young adults, who are focused on the here and now. This presents a challenge when it comes to nutrients such as vitamin D, for which health consequences of insufficiency are perceived as remote. Indeed, several participants acknowledged the long-term nature of health outcomes associated with vitamin D deficiency as a foreseeable roadblock when designing materials to target young adults:

*It’s too bad, though that the immediate benefits [of vitamin D] aren’t the ones that are necessarily . . . most appealing to people. Like if it was like, if you were at risk of breaking your bones tomorrow— but at this age, because [if] you had low bone density, people would be like “Oh, well like it’s immediate and it’s scary”— I’d be like “Get on this!” But when it’s like, scary and it’s like, later, well… yeah sure, I don’t really want that to happen to me, but it’s a long way off, so.*

**Theme 4: Credibility is essential.** The credibility of information was very important among this sample of young adults. Statistics and study results were deemed to be useful only if the date and source were identified; further, information should come from a reputable source and not be endorsed by a company with a financial conflict of interest. When asked what they perceive to be a credible information source, one man stated, “Well if it’s like a doctor writing it or someone who knows what they’re talking about. Not just like a random person blogging about it”. Similarly, video information was also perceived as more motivating if was produced by a credible source. Both sexes indicated that they would prefer to receive health information from a health professional, whereas,
video testimonials delivered by an individual of their own age were widely considered to be phony or scripted. As one woman admitted, “Like if it’s some random person – like some random testimonial, you always just feel like [they] were just paid to do this; like it doesn’t mean anything.”

**Theme 5: “A combination of strategies would appeal to a wider audience”**. With the exception of a video testimonial by a young adult actor, which was disliked by the majority of participants, findings regarding the effectiveness of any particular strategy were mixed. Several individuals appreciated statistics; others felt that too many numbers were overwhelming, or dismissed them as irrelevant. These differences in opinion were apparent in discussions on positive versus negative messaging, interactive quizzes, and text versus video messaging. As a result, several participants suggested combining strategies in order to appeal to a wider range of users and personal preferences. One woman explained why a combination of strategies might be effective to disseminate vitamin D information:

*A mix for me, personally. Like, the statistics are good because they kind of draw your attention in, and then some people are more liking to watch it and listen to it, while some people like to read it; so like, a mix of both of those. But I think also pictures would help, and ideas of what—how much of certain [food/beverage] items you would need in a day to actually meet the amount of vitamin D you could actually get. So for example vegetarian-based diets, or even like people who do drink milk or different forms of milk...*

Both sexes also mentioned TED Talks (TED, 2015); these lecture-style videos are informative, credible and entertaining. One woman explained why TED talks would appeal to a wide audience:

*And you had mentioned TED Talks, I think if you did something like that people would be into it as well. Because it’s all there, it’s like 5-10 minutes and then it also gives you stats. Um, and in that presentation you can incorporate foods you would need and well [vitamin D] levels you would need to reach, because they...*
Evidently, the right blend of facts, interest and entertainment is essential for educational materials to be effective among this audience, whose individual preferences vary widely.

**DISCUSSION**

Overall, findings revealed that although individuals preferred different learning strategies, certain characteristics were commonly considered important. According to participant feedback, an effective educational intervention should be short, simple, interesting, personally relevant, credible, and include incentives. Additionally, combining multiple strategies would appeal to a wide range of individual tastes, preferences and learning styles, leading to increased reach of the program. These findings align with previous literature; a systematic review of online intervention programs targeted towards adolescents and young adults found that the combination of several strategies increased intervention exposure (Crutzen et al., 2011). Although the authors of this review were unable to distinguish the effects of each strategy individually, they noted that the combination of personal feedback, reminders and incentives led to higher exposure of internet intervention programs (Crutzen et al., 2011). In addition, focus group discussions generated the idea of a hand-held calculator that provides an estimate of individual vitamin D intake. This concept includes a combination of qualities deemed important by this sample of young adults—including visual components, numeric results, immediate feedback, and personally relevant information, and would allow for individual self-monitoring of vitamin D intake. Given that self-monitoring has been associated with increased effectiveness of healthy eating interventions (Michie, Abraham, Whittington,
McAteer & Gupta, 2009), this idea holds promise as a tool with which to enhance intervention programs that aim to increase intake of vitamin D or other nutrients.

**Limitations**
Participants in this sample were primarily Caucasian and well educated, and findings therefore may not be representative of the larger population of emerging adults, or generalizable to other age groups. In addition, the nature of qualitative analysis focuses on reporting of the lived experience more so than ratings about dimensions of this experience. A qualitative approach, rather than a quantitative survey, was therefore chosen in order to gain a fuller understanding of the preferences and barriers that exist in conveying the importance of vitamin D to young adults.

**Relevance to Practice**
The findings of this research have practical implications. Researchers, dietitians, clinicians and health associations can draw upon the themes generated by these focus groups when designing online materials or programs that aim to promote dietary information to young adults. The strategies identified herein will be especially useful for disseminating information related to vitamin D or other nutrients that affect long-term health; for instance, calcium (which has similar implications for future bone health; NIH, 2013). Finally, Crutzen et al. (2011) previously suggested drawing from findings related to different health behaviors when designing online behaviour change interventions for young adults. Similarly, we feel that many of the themes identified herein could be extended to other health behaviours, especially those with potential health outcomes that occur later in life.
CHAPTER 4: Vitamin D intake among young Canadian adults: validation of a mobile Vitamin D Calculator app

Authors: Samantha Goodman, MSc; Barbara Morrongiello, PhD; Janis Randall Simpson, PhD, RD; Kelly Meckling, PhD

ABSTRACT

Objective: To establish the validity and reproducibility of the dietary component of a mobile Vitamin D Calculator ‘app’.

Methods: Participants entered their dietary intake into the Vitamin D Calculator app on three recording days over one month and underwent subsequent 24-hour dietary recalls.

Results: 50 adults (25 female), 18-25 years (M=22±2). Paired-samples t-tests tested for significant differences (p<0.05) in mean vitamin D and calcium intake between the app and dietary recalls; Bland-Altman plots assessed agreement between the two measures. Intraclass correlations and Wilcoxon-Signed Rank tests assessed reproducibility of intakes estimated by the app. Mean vitamin D (n=50) and calcium (n=48) intakes and risk classifications did not differ significantly between the two measures (p>0.05).

Conclusions & Implications: The Vitamin D Calculator app is a valid classification measure for dietary vitamin D and calcium intake. This tool could be used by the general public to increase awareness and intake of these nutrients.

INTRODUCTION

Vitamin D is essential for the maintenance of bone health, preventing rickets, osteomalacia and bone fractures. It also may be implicated in other chronic diseases and bodily processes, including cancer, cardiovascular disease, diabetes, and immunity (Schwalfenberg, 2007). Vitamin D is available naturally in very few dietary sources, the most significant being fatty fish. Fortified cow’s milk and non-dairy milk alternatives represent the main dietary contributors among Canadians (Vatanparast et al., 2010); however, research suggests that Canadian fortification levels are too low to prevent insufficiency (Calvo et al., 2004; Calvo & Whiting, 2003; Vieth, 2012). Further, vitamin D synthesis from the sun does not occur above 43°N latitude during the fall and winter months; hence, many Canadians have inadequate vitamin D intake and status, especially during the winter (Langlois, Greene-Finestone, Little, Hidiroglou & Whiting, 2010; Poliquin et al., 2009; Whiting, Langlois, Vatanparast & Greene-Finestone, 2011).

Data from the 2004 Canadian Community Health Survey (CCHS) (Health Canada, 2004) indicated that mean dietary vitamin D in adults (19-50 years) was 204 IU for women and 232 IU for men. This falls well below the Recommended Dietary Allowance (RDA) of 600 IU/day (IOM, 2010). Further, many researchers (Schwalfenberg & Whiting, 2011) and health associations recommend higher amounts; for instance, the Canadian Cancer Society recommends 1000 IU/day for adults (CCS, 2015). Therefore, tools to examine and promote dietary vitamin D are needed for both the general Canadian public and health professionals.
Mobile applications (‘apps’) are promising tools for this purpose. Health apps are one of the most highly used types on the public market, with over 17,000 currently available, (Kratzke & Cox, 2012) and projections of use by 500 million people worldwide by 2015 (Jahns, 2010). Many researchers have successfully incorporated apps into research designs, including interventions to increase physical activity (Kirwan, Duncan, Vandelanotte & Mummery, 2012) or healthy eating (Tsai et al., 2007). Mobile apps also may be useful for dietary counseling or monitoring personal nutrition. A study examining 18 apps designed for dietary assessment and self-monitoring found that mobile apps frequently led to better adherence of self-monitoring behaviours and changes to dietary intake compared to traditional methods (Lieffers & Hanning, 2012).

Most of the diet-related apps on the public market have not been validated. Indeed, MyFitnessPal, one of the most popular and widely used dietary tracking apps has not been assessed for accuracy, validity or reliability (MyFitnessPal, 2014). The Vitamin D calculator app (VDC-app) is a mobile application in which users enter their daily intake of vitamin D and calcium-containing foods and beverages. By providing immediate feedback on intake of these nutrients relative to current recommendations, the VDC-app represents a convenient means of monitoring personal intake. The purpose of this study was to establish the validity and reproducibility of the dietary component of the VDC-app.

**METHODS**
In order to validate the dietary component of the VDC-app, researchers tested agreement between the app and 24-hour dietary recalls. The University of Guelph Research Ethics Board approved this study (#13AP022). Participants consisted of 25 male and 25 female adults aged 18-25, living in Ontario, Canada. A sample size of at least 50 participants has been recommended for the specific analyses being used (Cade, Thompson, Burley & Warm, 2002); a power calculation confirmed that a sample of 50 participants would provide 80% power to detect a significant difference of 8 IU in mean vitamin D intake between data from the VDC-app and dietary recalls. Participants were recruited in February-April 2014 from the University of Guelph and the Guelph community using poster and online advertisements. Inclusion criteria included being age 18-25 years; fluent in English; residing in Canada; and owning an iPhone/iPad/iPod Touch.

Measures

A socio-demographic survey designed by the researchers gathered general demographic information, including age, sex, race, education, and student status. The VDC-app was originally developed by an independent party (Agarwal, 2014; Jacksonville, Florida); the researchers collaborated in updating the app to include Canadian nutrient and UV index data. The app allows users to enter daily intake of vitamin D and calcium-containing foods and beverages, supplements and time spent in sunlight. Immediate feedback is provided by the app regarding participants’ estimated daily vitamin D (IU) and calcium (mg) intake, both in numeric form and in a pie chart displaying percent intake from dietary sources, supplements, and sun exposure (vitamin D only). A bar graph provides visual representation of vitamin D intake; cut-offs are <400 IU, 400-600 IU, and >600
IU, reflecting the current estimated average requirement (EAR) and RDA of 400 IU and 600 IU, respectively (IOM, 2010). Vitamin D from solar UVB is estimated by linking the user’s postal code to the daily UV forecast from Environment Canada (Government of Canada, 2014; data not shown). Average vitamin D and calcium content for each item in the app were identified *a priori* based on the 2010 Canadian Nutrient File (CNF) (Health Canada, 2007). The user manually enters multivitamin/supplement amounts.

**Procedure**

Participants were interviewed on an individual basis by either the primary student investigator or a single trained research assistant. During an initial visit, participants provided informed written consent and completed the paper demographic survey. Each participant received an instruction package and was shown how to use the VDC-app. The participant downloaded the app on his/her personal device in the presence of the researcher, entering a unique subject ID for confidentiality. Three recording days were scheduled over the subsequent month; 1 weekend and 2 weekdays were assigned. On each of the 3 recording days, the participant entered his/her intake of vitamin D and calcium-containing foods, beverages, and supplements. The day following each recording, the participant returned for a study visit in which the research assistant conducted an oral multiple-pass 24-hour dietary recall (Raper, Perloff, Ingwersen, Steinfeldt & Anand, 2004). Measuring cups and food models (Nasco, 2014; Salida, California) helped participants gauge portion sizes. Following the final recall, the participant received a debriefing letter. Participants received $40 in gift cards ($10/visit) as remuneration.
Data Analysis

Data from the dietary recalls were analyzed using ESHA Food Processor version 10.13.1 (ESHA Research, 2013; Salem, Oregon). Two research assistants entered dietary recall data, maintaining a database of items entered to ensure consistency. Whenever possible, Canadian data (i.e., CNF or Canadian brands) were selected. Data entered into the VDC-app were electronically transmitted to a secure database server at the University of Guelph and downloaded by the researcher. Three-day mean vitamin D and calcium intakes were computed for each participant, and statistical analyses were conducted using SPSS version 21.0 (SPSS Statistics, Armonk, NY, IBM Corp., 2012).

In order to assess validity, the Wilcoxon Signed Rank Test (WSRT) and intraclass correlations (ICC) were used to assess the classification of mean intakes by the app versus dietary recall, respectively. Specifically, WSRTs were analyzed using intake quartiles, which were defined *a priori* (vitamin D: ≤200, 201-400, 401-600, ≥601 IU/day; calcium: ≤800, 801-1000, 1001-2500, ≥2501 mg/day). Vitamin D quartiles were based on the 1997 adequate intake of 200 IU/day (IOM, 1997) and the current EAR (400 IU/day) and RDA (600 IU/day) (IOM, 2010); calcium quartiles were based on the current EAR, RDA and tolerable upper intake level of 800, 1000 and 2500 mg/day, respectively (for adults 19-30 years) (IOM, 2010). Quartiles were collapsed to create binary intake categories for ICCs (vitamin D: ≤400, ≥401 IU/day; calcium: ≤1000, ≥1001 mg/day). This determined whether the app and dietary recall were similarly classifying intake into
‘risk’ versus ‘no/low risk’ categories (i.e., failing to meet vs. meeting the EAR of 400 IU/day for vitamin D or the RDA of 1000 mg/day for calcium).

Bland-Altman (BA) plots (Bland & Altman, 2010) were conducted as a secondary test of validity. Three-day mean and difference scores between the app and recall were plotted for calcium and vitamin D separately and limits of agreement were calculated (mean ±2 SD). Differences in mean estimated vitamin D and calcium intake between the app and dietary recalls were analyzed further using paired-samples t-tests and Pearson’s correlations. In order to assess the reproducibility of daily intake estimates over the 3 time-points, quartile mean intakes from the first versus last recording day were compared using WSRT, and binary mean intakes were compared using ICC.

A square-root transformation was applied to correct abnormally distributed and positively skewed raw data (Sheskin, 2003). For ease of interpretation, raw data are used to report means and standard deviations (SD). Results of statistical tests are reported using square root transformed data, with the exception of the BA plots. The log transformation was used for BA plots as it is considered the most appropriate for interpreting abnormally distributed BA plots (Bland & Altman, 1999).

RESULTS

Mean (±SD) age of participants (n=50) was 22(±2) years; participants were 50% female (n=25) (Table 4.1). Two outliers with unattainably high calcium intake values in the app data were removed for statistical tests relating to calcium intake; therefore, final sample
sizes were n=50 for vitamin D and n=48 for calcium. Table 4.2 displays 3-day mean intakes of vitamin D and calcium for the app and dietary recalls.

**Table 4.1: Socio-Demographic Data for 18-25 Year-Old Adults Enrolled in Vitamin D Calculator App Validation Study (n=50)**

<table>
<thead>
<tr>
<th>Variable</th>
<th>% (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sex</strong></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>50% (25)</td>
</tr>
<tr>
<td>Male</td>
<td>50% (25)</td>
</tr>
<tr>
<td><strong>Age (years)</strong></td>
<td></td>
</tr>
<tr>
<td>18-19</td>
<td>12% (6)</td>
</tr>
<tr>
<td>20-21</td>
<td>30% (15)</td>
</tr>
<tr>
<td>22-23</td>
<td>38% (19)</td>
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<tr>
<td>24-25</td>
<td>20% (10)</td>
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<tr>
<td><strong>Race</strong></td>
<td></td>
</tr>
<tr>
<td>White/Caucasian</td>
<td>60% (30)</td>
</tr>
<tr>
<td>Asian, South Asian, Southeast Asian</td>
<td>24% (12)</td>
</tr>
<tr>
<td>Other</td>
<td>16% (8)</td>
</tr>
<tr>
<td><strong>Highest level of education</strong></td>
<td></td>
</tr>
<tr>
<td>Some university, or undergraduate degree</td>
<td>56% (28)</td>
</tr>
<tr>
<td>Some graduate school, or graduate degree</td>
<td>44% (22)</td>
</tr>
<tr>
<td><strong>Student status</strong></td>
<td></td>
</tr>
<tr>
<td>Currently a student</td>
<td>96% (48)</td>
</tr>
<tr>
<td><strong>Nutrition background</strong></td>
<td></td>
</tr>
<tr>
<td>Taken a nutrition course in the past</td>
<td>72% (36)</td>
</tr>
</tbody>
</table>
Table 4.2: Three-Day Mean Intake of Vitamin D & Calcium for Participants using Vitamin D Calculator App and Completing Subsequent 24-Hour Dietary Recall

<table>
<thead>
<tr>
<th>3-Day Mean Source</th>
<th>Vitamin D (IU/d) ((n=50))</th>
<th>Calcium (mg/d) ((n=48))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>App Recall Pearson Correlation</td>
<td>App Recall Pearson Correlation</td>
</tr>
<tr>
<td>Vitamin D (IU/d)</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Food</td>
<td>279</td>
<td>263</td>
</tr>
<tr>
<td>Supplements</td>
<td>229</td>
<td>404</td>
</tr>
<tr>
<td>All Sources</td>
<td>508</td>
<td>483</td>
</tr>
</tbody>
</table>

M indicates mean; SD, standard deviation; r, Pearson’s r; df, degrees of freedom.

Note: Threshold for significance set at \(P < 0.05\). One-way analysis of variance (ANOVA) tests indicated that neither 3-day mean vitamin D nor calcium intake from the app nor 24-hour recall differed significantly by age, gender, race, education level, student status or whether participants had taken a nutrition course in the past (\(P > 0.05\) for all). Likewise, the difference scores between the app and 24-hour recall for mean intakes of vitamin D and calcium did not significantly differ by these same socio-demographic variables (\(P > 0.05\) for all).
Table 4.3: Group Means for 3 Days of Vitamin D & Calcium Intake Data for Participants Using Vitamin D Calculator App and Completing Subsequent 24-Hour Dietary Recall

<table>
<thead>
<tr>
<th>Recording Day</th>
<th>Vitamin D (IU/d) (n=50)</th>
<th>Calcium (mg/d) (n=48)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>App</td>
<td>Recall</td>
</tr>
<tr>
<td>Day 1</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Day 2</td>
<td>624</td>
<td>785</td>
</tr>
<tr>
<td>Day 3</td>
<td>485</td>
<td>530</td>
</tr>
</tbody>
</table>

M indicates mean; SD, standard deviation.

Notes:
1. Quartile mean intakes comparing days 1, 2 and 3 were not significantly different for vitamin D or calcium based on Wilcoxon-Signed Rank Tests (WSRT) (P > 0.05 for all)
2. Intraclass Correlation (ICC) tests (single measures, 2-way mixed, absolute agreement definition) based on binary categorization of intakes ranged from ICC=0.40-0.54 for vitamin D and ICC=0.13-0.25 for calcium. ICC comparisons between days 1-3 were significant (P < 0.05), except for calcium on day 1 compared to day 3 (ICC=0.22; 95%CI=-0.06-0.47, P=0.06) and day 2 (ICC=0.13; 95%CI=-0.17-0.40, P=0.20).
3. ICCs comparing binary classification of 3-day mean intakes for the dietary recall versus the app were ICC=0.88 (95%CI=0.80, 0.93), P < 0.001 for vitamin D and ICC=0.50 (95%CI=0.25, 0.68), P < 0.001 for calcium. WSRT assessing quartile classification of 3-day mean vitamin D and calcium intakes did not differ significantly between the recall and app (Z=-0.50, p=0.62; Z=-0.46, P=0.65, respectively).
Results of the validity assessment indicated that ICCs comparing binary classification of 3-day mean intakes for the dietary recall versus the app were fairly strong. Similarly, WSRT indicated validity in that quartiles did not differ significantly between the recall and VDC-app (Table 4.3). The percentage of points within the limits of agreement on BA plots was 44% for vitamin D and 60% for calcium (data not shown). Three-day mean vitamin D and calcium intakes estimated by the app were significantly positively correlated and not significantly different from the recalls (Table 4.2). Table 4.3 displays mean intakes of vitamin D and calcium for the 3 recording days separately. Results of the reproducibility assessment using WSRT indicated that mean vitamin D and calcium intakes for app recording day 1 did not differ significantly from recording day 3 (\(Z=-1.19, p=0.24\); \(Z=-1.76, p=0.08\), respectively). For both nutrients, recording days 1 vs. 2 and 2 vs. 3 also were not statistically significantly different (\(p>0.05\) for all; Table 4.3). ICC analyses comparing app recording day 1 vs. 3 for mean vitamin D and calcium intakes resulted in ICC=0.40 (95%CI=0.14, 0.61), \(p=0.002\) and ICC=0.22 (95%CI=-0.06, 0.47), \(p=0.06\), respectively.

**DISCUSSION**

This study validated a mobile app for the purpose of classifying vitamin D and calcium intake. While previous studies have assessed energy intake and utilized photograph analyses (Sharp & Allman-Farinelli, 2014), this study validated the nutrient-centered app, VDC-app. Results from several different analyses suggested that the VDC-app is a valid and strong classification measure of dietary vitamin D and calcium intakes. Reproducibility analyses were less consistent, with WSRT suggesting good reproducibility.
of mean intake estimates, whereas ICCs, although statistically significant, were fair for vitamin D and poor for calcium (Table 4.3). These inconsistent results for validity and reproducibility are not surprising given the high inter- and intra-individual variation in dietary intake (Tarasuk & Beaton, 1992), especially of vitamin D and calcium. Indeed, although 3 days of intake data have been commonly collected by researchers examining nutrient intake (Kumanyika et al., 2003; Ritter-Gooder, Lewis, Heidal & Eskridge, 2006), it has been suggested that a mean of 7-10 days is required to estimate true average calcium intake for groups (Basiotis, Welsh, Cronin, Kelsay & Mertz, 1987). Further, vitamin D is available in very few natural food sources and thus dietary intake tends to vary greatly (Calvo et al., 2004; Calvo & Whiting, 2003) unless supplements are taken regularly. Some researchers have suggested that when conducting dietary assessments for vitamin D, a longer period of time (e.g., 3 months) might be needed to adequately capture less commonly consumed foods such as fatty fish (Millen & Bodnar, 2008). Therefore, it is not surprising that the BA plots and the reproducibility of intake estimates, especially in the case of vitamin D were not optimal.

On a positive note, although day-to-day intakes of study participants varied considerably, mean estimates seem reasonable given that they are comparable to intakes from food sources from the 2004 CCHS for vitamin D (M=236 IU) and calcium (M=1107 mg) (adults 19-30 years) (Health Canada, 2004). In addition, while BA plots yielded a wide spread of data points using individual intake values, comparing 3-day means from the app against the recalls suggests that the app is correctly classifying intake into risk categories.
Given that the app aims to assist users with self-monitoring of vitamin D and calcium intake, this classification has practical significance.

Although the app tracks daily rather than weekly/monthly dietary intake, similar to a Food Frequency Questionnaire (FFQ), the app allows users to enter their daily intake by selecting specific vitamin D and calcium-containing foods from a prescribed list. The FFQ was originally designed to provide descriptive qualitative information about usual food-consumption patterns (Gibson, 1990). Similarly, the VDC-app does not aim to measure exact intake or to appraise vitamin D or calcium status; it can be considered a qualitative tool that provides feedback regarding one’s intake compared to dietary standards. A previous Canadian study assessed the validity of FFQs versus a 7-day food diary to estimate dietary vitamin D intake and found that mean vitamin D estimates from the FFQ were significantly higher than from the food diary. The authors speculated that participants might have overestimated intake when given a prescribed list of serving sizes in the FFQ (Wu et al., 2009). In the case of the VDC-app, there was no difference between the vitamin D intakes from the app versus the recall. The VDC-app therefore has an advantage over the traditional FFQ in that participants manually enter the amount of each item consumed (e.g., 1.5 cups) rather than choosing from pre-set serving sizes (e.g., small, medium or large). This is similar to a 7-day food diary or 24-hour recall in which participants are asked to estimate amounts of each item consumed; the VDC-app might therefore be considered a hybrid of the FFQ and 24-hour recall.

**Limitations**
The VDC-app is limited in that it only contains foods and beverages that are significant sources of vitamin D and/or calcium; certain foods with insignificant amounts of these nutrients (e.g., mayonnaise) were not included. This could have led to an underestimation of vitamin D or calcium intake compared to the dietary recall, which captured all items consumed by the participant; however, significant differences were not found. Similarly, the values for vitamin D and calcium used in the app were based on averages for selected representative foods and may have differed somewhat from dietary recall items entered into ESHA (Health Canada, 2007). However, as both were based on the CNF and/or Canadian brand data, it is not expected that altering the values used in the app would change study results. Indeed, mean intakes derived by the app and dietary recalls were quite similar. Although SDs were large, this could have resulted as a function of the large inter-individual variations in calcium and vitamin D intakes.

Although criterion validity of the dietary component of the app has been suggested, estimates were not analyzed in relation to blood concentrations of 25(OH)D (vitamin D₃) nor to vitamin D from solar UVB. Thus, while providing a valid classification of dietary vitamin D intake, the app is not a measure of overall vitamin D status. Blood tests of 25(OH)D would capture not only changes in vitamin D from dietary intake and the sun, but also inter-individual metabolic differences that lead to changes in vitamin D status. Finally, the VDC app is currently available for select Apple devices only and was validated in a self-selected, convenience sample of 18-25 year-old adults in Ontario. Therefore, results may not necessarily be generalized to other populations, including those from other cultures whose dietary habits may differ.

**IMPLICATIONS FOR RESEARCH AND PRACTICE**
Given that estimated mean vitamin D intake has not increased meaningfully in the past decade since the 2004 CCHS (Health Canada, 2004) there is a clear need for initiatives to increase vitamin D intake in Canadians. The VDC-app is a valid measure of intake classification and could be used in future studies that aim to compare intake of vitamin D and/or calcium to current recommendations. The app provides immediate dietary intake feedback and is available for handheld devices, making it convenient for daily use. Members of the general public may find this app to be a valuable self-monitoring tool for tracking personal intake. Future updates of the app might include expanding its compatibility to other platforms (e.g., Android) to increase public access. Lastly, the app represents a useful tool that physicians or dietitians could use in clinical counseling to aid patients in increasing their intake of vitamin D and/or calcium.

ACKNOWLEDGMENTS

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CONFLICT OF INTEREST

The authors have not stated any conflicts of interest.
CHAPTER 5: A randomized controlled trial evaluating the efficacy of an online intervention targeting vitamin D knowledge and intake among young adults

Authors: Samantha Goodman, MSc, PhD Candidate; Barbara Morrongiello, PhD, C.Psych.; Janis Randall Simpson, PhD, R.D.; Kelly Meckling, PhD

ABSTRACT

Background: It is well documented that vitamin D plays a key role in bone health, preventing rickets in children and osteomalacia in adults. Consuming adequate vitamin D and calcium during young adulthood is especially important because peak bone mass is established during late adolescence and early adulthood. Despite its importance, many Canadian adults do not meet the Recommended Dietary Allowance of 600 IU/day for vitamin D. This study aimed to examine and improve the knowledge, dietary intake and blood concentrations of vitamin D among a sample of young adults living in Canada.

Methods: This study used a pre-post intervention and control group design. Participants were 90 adults (38 men, 52 women), aged 18-25 years living in Ontario, Canada. Participants were randomly assigned to the intervention or control group. All participants filled out a socio-demographic survey, a food frequency questionnaire at pre- and post-test, and a vitamin D knowledge questionnaire at three time-points. The intervention group watched a video and received online information about vitamin D and used the mobile “Vitamin D Calculator” application to track vitamin D intake for 12 weeks. A sub-sample of participants completed blood vitamin D$_3$ tests at pre- and post-test. (ClinicalTrials.gov registration: NCT02118129).
**Results:** Total mean vitamin D intake increased significantly from pre-test (M=407, SD=460 IU) to post-test (M=619, SD=655 IU), $t(88)=5.37, p<0.001$. Experimental group had a significant effect on the change in vitamin D intake after controlling for sex and education, $F(1, 85)=4.09, p<0.05$, such that intake increased more in the intervention than the control group. Mean blood vitamin D$_3$ increased significantly from pre-test (M=28, SD=16 nmol/L) to post-test (M=43, SD=29 nmol/L), $t(53)=11.36, p<0.001$, but did not differ significantly between groups. The increase in vitamin D knowledge from baseline to follow-up was significantly higher in the intervention group than the control ($t(88)=2.26, p=0.03$). Finally, while perceived importance of vitamin D supplementation increased in both groups over time, the intervention group (M=3.52, SE=0.13) had higher agreement overall than the control group (M=3.16, SE=0.12), $F(1, 88)=4.38, p=0.04, \eta_p^2=0.05$.

**Conclusions:** Vitamin D intake and status in this sample were below national recommendations at baseline; receiving a behavioural intervention led to increased vitamin D intake, knowledge, and perceived importance of supplementation. Participation in the intervention did not improve vitamin D status.

**Key Words:** nutrition, vitamin D intake, vitamin D status, mobile app, behaviour change, intervention, emerging adulthood.

**BACKGROUND**

Vitamin D is crucial for bone health, including the prevention of rickets, osteomalacia, falls and fractures (IOM, 2010). Sufficient serum vitamin D concentrations may also be protective against a range of other disease states, including cancer, cardiovascular disease, type I and II diabetes, and multiple sclerosis, and may enhance functioning of the immune
system (Schwalfenberg, 2007). In 2010, the Institute of Medicine (IOM) set the Estimated Adequate Requirement (EAR) and Recommended Dietary Allowance (RDA) for vitamin D at 400 IU/day and 600 IU/day, respectively, for adults up to 70 years. This corresponded to a serum vitamin D (25(OH)D) concentration of 50 nmol/L (IOM, 2010). More recent recommendations indicate that intakes of at least 1000 IU/day and a serum vitamin D$_3$ concentration of at least 75 nmol/L may be needed in order to achieve optimal health (Dawson-Hughes et al., 2005; Vieth, 2011).

National data indicate that the vitamin D status of Canadian adults falls short of the IOM recommendations. The 2012-2013 Canadian Health Measures Survey (CHMS) indicated a mean plasma vitamin D$_3$ concentration of 61.1 nmol/L among adults aged 20-79 (Statistics Canada, 2015b). Poor vitamin D status is especially an issue among young adults, since peak bone mass is reached before age 30 and cannot be significantly increased after this age (Abrams, 2003). Unfortunately, young adults are not meeting the recommendations either. Data from the 2004 Canadian Community Health Survey (CCHS) indicate that, on average, women and men aged 19-30 years consume only 188 IU and 236 IU of vitamin D from food, respectively (Health Canada, 2004), falling well below the EAR and RDA. Further, the 2012-2013 CHMS indicates that young adults aged 18-25 had a mean plasma vitamin D concentration of 60.1 nmol/L (95% CI: 52.4-67.7; Statistics Canada, 2015a). Given that young adulthood is a critical period for the development of long-term health behaviours (Nelson, Story, Larson, Neumark-Sztainer & Lytle, 2008), the formation of healthy habits—including adequate consumption of vitamin D for the formation of peak bone mass, is crucial during this time (Heaney et al., 2000). Unfortunately, few studies
have examined what young adults know (i.e., Boland, Irwin & Johnson, 2015) or believe about vitamin D, or how to target them with regards to increasing vitamin D intake and status.

Theories do exist to predict health behaviours among young adults. The Theory of Planned Behaviour (TPB; Azjen, 1991) has been used widely in health behaviour literature (Armitage & Conner, 2001), and the more recent Prototype Willingness Model (PWM; Gibbons, Gerrard, Blanton & Russell, 1998) holds promise as a theory with which to predict health behaviours among adolescents (Gerrard, Gibbons, Houlihan, Stock & Pomery, 2008). However, it can be quite difficult to engage young adults on health-related issues, due to the feelings of invincibility that often accompany this life stage. Indeed, some researchers have used the term “young invincibles” (Bibbins-Domingo & Burroughs Peña, 2010) to describe young adults, who may have a general disregard for future health consequences. This concept may be especially relevant to vitamin D and its importance for bone health, since bone-related issues such as osteoporosis, osteomalacia and fractures typically occur later in life (IOM, 2010). In previous qualitative research involving focus groups, the authors found that young adults aged 18-25 were not generally worried about bone health, since potential consequences were perceived as being too far in the future to be a present concern (Chapter 3; Goodman & Sheeshka, in preparation). Analysis of focus group data identified several themes related to engaging young adults in the importance of vitamin D, one of which was the importance of immediate, personally relevant health information when using an online intervention (Goodman & Sheeshka, in preparation). The concept of using a mobile app to track personal vitamin D intake emerged during one
focus group discussion (Goodman & Sheeshka, in preparation) and was used to inform the
design of the current study, which utilizes an online survey platform and a mobile vitamin
D-tracking application (‘app’).

The use of a web-based platform is not new to health research; several studies have used
online surveys to examine health-related knowledge, perceptions and/or behaviours
(Bolton-Maggs et al., 2012; Dawkins, Turner, Roberts & Soar, 2013; Hoffman, Stallings,
Bessinger & Brooks, 2013; Prochaska et al., 2011; Storey et al., 2012; Westmaas et al.,
2012). The growing popularity of smartphones (Statista, 2015) and health apps (Kratzke &
Cox, 2012) has also led to the increasing incorporation of mobile health apps in research
studies (i.e., Fukuoka et al., 2012; Kirwan, Duncan, Vandelanotte & Mummery, 2012).
Mobile apps have the advantage of enabling researchers to utilize online technology whilst
engaging and/or communicating with participants directly, and at any time through their
handheld devices. This technology holds promise as a tool with which to engage young
adults on health and nutrition issues (Holzinger, Dorner, Födinger, Valdez & Ziefle,
2010), especially since young adults aged 18-29 look up health or medical information on
mobile phones more often than adults of any other age group (Fox & Duggan, 2012).
Further, although a few researchers have conducted interventions to increase vitamin D
and/or calcium intake in non-elderly populations (Bohaty, Rocole, Wehling & Waltman,
2008; Debar et al., 2006; Jamal et al., 1999; Lv & Brown, 2011), none of these included
young adults of both sexes, or used mobile apps in their study designs. The current study
thus aimed to improve vitamin D intake, blood levels, knowledge and perceptions among
young men and women aged 18-25, using a mobile Vitamin D Calculator app (Agarwal, 2014).

**Study Objectives**

1. To measure vitamin D intake and status (i.e., dietary intake and blood levels) among a sample of young adults living in Ontario, Canada.

2. To describe the underlying knowledge of and perceptions towards vitamin D in this sample.

3. To determine whether a behavioural intervention involving the use of a mobile Vitamin D Calculator app produces changes in intake, blood concentrations, knowledge, and/or perceptions of vitamin D among a sample of young adults living in Ontario.

**METHODS**

**Subjects & Recruitment**

The sample consisted of 90 adult men and women aged 18-25 years. The study was advertised as a “Healthy Living Study” and did not specifically mention vitamin D. Participants were recruited during fall 2014 from the University of Guelph and throughout Ontario using poster and online advertisements (e.g., Kijiji, Craigslist and theCannon.ca). In order to be eligible for the study, participants were required to: be 18-25 years of age, be fluent in English, currently live in Ontario, and own an iPhone, iPad or iPod Touch (running iOS 7.0 or higher). Participants were randomly assigned to either the intervention or control group using a single blind technique; the primary student investigator recruited participants and assigned them to groups based on a spreadsheet that was sequentially numbered with subject ID numbers and group allocations *a priori*. The primary student
investigator recruited participants, assigned them to groups and implemented the study. Quota sampling was conducted via an initial email-screening questionnaire in order to ensure that at least half of the sample was female and that approximately 50% identified as a race other than Caucasian. Given that non-Caucasians tend to have darker skin pigmentation than Caucasians, and that individuals with darker skin pigmentation (i.e., more melanin) are at a higher risk for vitamin D insufficiency (Hall, 2009), quota sampling ensured a diverse sample of skin types.

Study Design

This study was an RCT and followed a pre-post intervention and control group design. The control group consisted of a waitlist control group who did not receive the intervention but had the opportunity to receive the intervention after the study was over, if desired. Both groups received a pre-test at time 1 (baseline) and post-tests at times 2 and 3, which consisted of online surveys. The intervention consisted of a short video about vitamin D followed by some online educational slides, vitamin D newsletters and use of the Vitamin D Calculator app. Blood spot tests were self-administered by participants at pre-and post-test in order to measure 25(OH)D (blood vitamin D₃ concentrations). The study was pilot tested with 5 participants. This study received approval from the University of Guelph Research Ethics Board (#14MY027). See Figure 5.1 and 5.2 for a CONSORT diagram (CONSORT, 2010) and overview of the study design.
Figure 5.1: Intervention Study CONSORT Flow Diagram (CONSORT, 2010)
Figure 5.2: Intervention Study Design

<table>
<thead>
<tr>
<th>Time 1 (“Baseline”)</th>
<th>Time 2 (1 week later)</th>
<th>Recording period (12 weeks)</th>
<th>Time 3 (“Follow-up”) (M=128 days from baseline)</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>Intervention video</td>
<td>Vitamin D Tips &amp; Tricks newsletters</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Vitamin D information slides</td>
<td>App recordings</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Goal setting</td>
<td>Goal setting check-in email</td>
<td></td>
</tr>
</tbody>
</table>

**Intervention components (intervention group only)**

- None
- Intervention video
- Vitamin D information slides
- Goal setting
- Vitamin D Tips & Tricks newsletters
- App recordings
- Goal setting check-in email

**Measures conducted**

- Socio-demographic survey
- Vitamin D survey
- FFQ
- Blood spot test (optional)

- Vitamin D survey
- FFQ
- Feedback survey (intervention group only)
- Blood spot test (optional)

**Procedure**

After expressing interest in the study, participants were contacted via email and answered screening questions to ensure eligibility in the study. Eligible participants were sent the link to the first online survey and asked to complete it within one week; participants were sent email reminders periodically if they had not completed the survey. Upon opening the survey platform, participants were asked to read and agree to the terms of an online consent form. Participants were then prompted to complete the questionnaires included in the online pre-test survey, which included a socio-demographic questionnaire, a vitamin D survey, and a food frequency questionnaire (FFQ) measuring vitamin D intake. The survey was administered via LimeSurvey version 1.91+ (LimeSurvey, 2012); data were stored on a secure SSL-enabled server at the University of Guelph.
Participants were given the choice to participate in the blood test component of the study, and were told that the test measured blood levels of specific nutrients but did not specifically mention vitamin D. Participants who chose to participate were either mailed a blood spot test kit, or asked to pick it up from the University of Guelph if they lived locally. The blood spot test kit included an addressed, postage-paid return envelope and instructions to administer the blood test and return it to the researchers as soon as possible, or within one week of receiving it by mail. Participants received reminders by email if they had not mailed the blood spot test back within this timeframe. Baseline blood tests were completed between September-December 2014, depending on participant start date. One week after completion of the first online survey (or upon return of the blood spot test kit, if applicable), participants were sent a link to the second online survey. For intervention participants, this link included a video about vitamin D, which was embedded in the online platform. A few informational slides followed this video; intervention participants were also asked to set a goal related to their vitamin D intake (see Measures, below), before completing the second online survey. The second online Vitamin D Survey was the same survey administered at baseline, and was identical for both intervention and control participants. The Fitzpatrick Skin Type questionnaire was also included as part of the second online survey. Waitlist-control participants completed the Vitamin D Survey questions only (i.e., video, information slides and goal setting were not shown before the second survey, as in the intervention group).

Upon completion of the second online survey, intervention participants were emailed instructions outlining how to download and use the free Vitamin D Calculator app on their
device (i.e., iPhone, iPad or iPod Touch). Intervention participants were instructed to fill in the profile screen with their unique subject ID number and Fitzpatrick Skin Type and to use the app for the next 12 weeks (intervention ‘recording’ period). Waitlist-control participants were not informed of the app nor instructed to use it at this time. Intervention participants were instructed to record their dietary intake and time spent in sunlight into the app. Participants were asked to record three times per week and were given a choice of recording on Tuesday, Thursday and Sunday or Monday, Wednesday and Saturday. These combinations ensured that participants recorded on two weekdays and one weekend day each week (to capture a variety of dietary habits), while allowing for some consistency so that it was easier for participants to remember their recording days. Thirty-six recording days were assigned in total (12 weeks x 3 days per week). Every three weeks during this recording period, participants were emailed reminders to complete their recordings and a PDF newsletter that contained some easy vitamin D and calcium-containing recipes, tips and information about vitamin D.

At the end of the 12-week period, participants from both groups were emailed a link to the final online survey (‘post-test’; time 3). The final post-test included the same Vitamin D Survey that was included at times 1 and 2, as well as the FFQ that was administered at time 1, in order to measure changes in vitamin D knowledge, perceptions and intake before and after the intervention. A short Feedback Survey regarding experiences, influence and usability of the vitamin D app and intervention components was also included for intervention participants only. After completion of the third online survey, participants who were participating in the blood testing were mailed or asked to pick up
their second blood test kit. Post-intervention blood tests were completed between December-March 2015. After completion of the third online survey (or after the blood spot test kit was returned, if applicable), participants were mailed compensation and a debriefing form that explained the purpose of the study. Waitlist-control participants were instructed to email the researchers if they wished to view the intervention video and/or download the Vitamin D Calculator app. Compensation consisted of a $50 grocery gift card; those who participated in the blood tests received an extra $20 compensation ($10 x 2 tests; totalling $70).

Measures

1. **Socio-demographic Survey.** This questionnaire was developed by the researchers and measured general demographic factors including age, sex, race, height, weight, level of education, student status, etc. (See Appendix J for complete questionnaire). Three items were used to assess physical activity (i.e., as a general indicator of health); these consisted of a brief two-item physical activity assessment which was developed and validated by Marshall, Smith, Bauman and Kaur (2005) and used previously to measure moderate and vigorous physical activity (Smith, Marshall & Huang, 2005). The third item was related to weight-bearing physical activity, and was developed and included by the researchers due to the importance of weight-bearing physical activity on bone health. The socio-demographic survey was administered at the first online survey. This survey has not been externally validated but was used for the purposes of collecting demographic information only.
2. Vitamin D Survey. This online survey was developed by the researchers and consisted of 41 questions that examined vitamin D intake habits, knowledge and perceptions of vitamin D, as well as items from the TPB (Azjen, 1991) and PWM (Gibbons, et al., 1998), administered by Rivis et al. (2006), and adapted for vitamin D. Specifically, the first 33 questions were designed by the researchers to examine what young adults know about vitamin D, their current intake habits, perceived importance of vitamin D supplements, milk consumption and sun exposure, and habits related to the sun. The last nine questions include the TPB and PWM items, which examine the following eight latent variables: behavioural expectations, behavioural intentions, subjective norms, perceived behavioural control, descriptive norms, past behaviour, prototype evaluation and prototype similarity in regards to behaviours that affect vitamin D intake. See Appendix K for complete item wordings. The Vitamin D Survey was administered as part of all three online surveys rather than only at baseline and follow-up in order to test effects of the intervention on vitamin D knowledge, perceptions and TPB/PWM items after two phases of the intervention separately (i.e., immediately after vitamin D video and information slides; and after newsletters and app recording period).

3. Fitzpatrick Skin Type Questionnaire. This questionnaire was developed and validated by Fitzpatrick (1988) to classify six skin types according to reactivity to the sun. Participants’ scores on these measures were used to determine their Fitzpatrick Skin Type (I-VI), which was then entered into the app to estimate vitamin D from UV exposure. This questionnaire was administered as part of the online survey, and used as an indicator of participant skin type (see “Fitzpatrick Skin Type”; Appendix K).
4. **Blood spot test kit.** A subset of participants opted in to blood testing; participants self-administered blood spot tests at home and returned them to the researchers. The blood spot (‘finger prick’) test kits consisted of a lancet, blood spot test card, alcohol swab, bandage and instructions outlining how to administer the finger prick test (Appendix L). Blood spot test kits were provided by GrassrootsHealth and were analyzed using liquid chromatography–tandem mass spectrometry by ZRT Laboratory to determine participants’ blood 25(OH)D$_3$ levels (ZRT Laboratory, 2015). The vitamin D blood spot test method was highly correlated with serum 25-hydroxyvitamin D in measurements conducted by this laboratory (ZRT Laboratory, 2008) and has shown good agreement with serum measurements in previous research (Larkin et al., 2011).

5. **Intervention Video.** The intervention video was embedded in the second online survey (for intervention participants only) and shown immediately before administration of the second Vitamin D Survey. The video was a short (2:08 minutes) video produced by a popular Canadian news source that includes key facts about vitamin D explained by Leslie Beck, R.D. (The Globe and Mail, 2014). Immediately after the video, additional key facts were displayed on text screens as part of the online survey platform. The video and information screens served to educate participants on eight key information points related to vitamin D. These included: (1) the key dietary sources of vitamin D (including fish and cow’s milk/fortified milk alternatives); (2) vitamin D is synthesized in the skin from solar UV exposure after approximately 15-30 minutes of exposure to bare skin; (3) the fact that our bodies cannot make vitamin D from the sun in the fall/winter months in Canada and correspondingly, the importance of taking vitamin D supplements and/or consuming adequate amounts of vitamin D.
from foods and beverages in the fall/winter months; (4) recommended intakes for adults (by the IOM: RDA=600 IU and UL=4,000 IU and higher intakes suggested by vitamin D researchers – i.e., ≥1000 IU/day) and the fact that many Canadians fall short of these recommendations; (5) why we need vitamin D (i.e., to absorb calcium, effects on bone health and a brief summary of other potential diseases/health outcomes associated with vitamin D insufficiency); (6) the fact that vitamin D\textsubscript{3} is the form we receive from the sun and most supplements; (7) factors that affect vitamin D status, including age, sex, weight, cloud cover, clothing, sunscreen, season/UV index, location and skin pigmentation; and, (8) the fact that skin pigmentation/race affects vitamin D status and that those with darker skin pigments may be at risk of vitamin D insufficiency.

6. **Goal Setting.** After watching the intervention video and reading the information screens, participants were also asked to set a ‘SMART’ goal. They were given an example (see “Goal Setting”; Appendix K) asked to enter their goal into a text box in the online survey platform. Nine weeks into the intervention, participants received an email reminder about their recordings and were asked to respond to two goal-setting questions by email (see “Goal Setting Check-in Email”; Appendix K). If participants did not respond to the goal setting questions within the next three weeks before they received the third survey link, they received a reminder by email.

7. **Vitamin D Calculator app.** The intervention group used the Vitamin D Calculator app (Agarwal, 2014) during the 12-week recording period. After completion of the second online survey, participants received instructions outlining how to download and use the app (see Appendix M). The app allowed intervention participants to enter their
intake of vitamin D and calcium-containing foods and beverages, vitamin D and calcium supplements and time spent in sunlight. The app provided users with immediate feedback regarding their estimated vitamin D and calcium intake in relation to current recommendations (i.e., EAR of 400 IU and RDA of 600 IU per day). The feedback screen also included a pie chart illustrating the proportion of vitamin D or calcium the participant consumed from each dietary source (Dairy & Eggs, Fruits & Vegetables, Fish & Meat, Cereals, Seeds & Nuts). The app was used as the primary intervention tool during the intervention period and aimed to motivate participants to increase their vitamin D intake by providing immediate feedback on intake levels. The app was previously validated as a measure of dietary vitamin D intake (Goodman, Morrongiello, Randall Simpson & Meckling, 2015) and is available at: https://itunes.apple.com/us/app/vitamin-d-calculator/id484286798?mt=8&ign-mpt=uo%3D4

8. **Goal Setting & Feedback Survey.** At the end of the third online survey, intervention participants completed a short goal setting and feedback survey. The goal setting questions asked: whether participants remembered their SMART goal, and if so, what their original goal was; whether they made changes to their goal throughout the study, and if so, what their new goal was; and finally, how well they did at meeting their goal (1=not at all – I did not meet any aspects of my goal, 5=very well – I met my goal completely). The feedback questions asked participants to indicate how much the video, online information, and newsletters influenced them to: make changes to their intake of vitamin D, make changes to their intake of calcium, take a supplement/multivitamin containing vitamin D, or spend more time in the sun (1=did
not influence me at all, 4=influenced me very much). They were also asked how many newsletters they read (did not read any, read 1-2, or read all 3). Next, participants were asked to rate their experiences with the app, based on how much they liked using the app, how easy it was to use, and how much it influenced them to: make changes to their intake of vitamin D, make changes to their intake of calcium, take a supplement/multivitamin containing vitamin D, or spend more time in the sun (1=did not influence me at all, 4=influenced me very much). The last three questions were open-ended and asked participants one thing they liked about using the app, one thing that could be improved about the app, and to provide feedback and/or concerns regarding their experiences with the app. See Appendix N for complete survey.

9. **Food Frequency Questionnaire for Vitamin D and Calcium.** The FFQ was previously validated by Wu et al. (2009) to assess self-reported vitamin D and calcium intake. The FFQ includes one open-ended question on nutritional supplement use, and 37 items relating to specific foods or food categories that contain vitamin D and/or calcium. Respondents were asked to select the frequency of consumption (ranging from never or less than 1 per month to 2+ per day) and serving size for each item: medium (defined), small (half a medium serving) or large (twice a medium serving). Serving sizes are described within, and correspond to typical household measures (e.g., cups, tablespoons, slices) for each item (Wu et al., 2009). This survey was administered as part of the first and third online surveys; see Appendix O.

10. **Vitamin D ‘Newsletters’.** Throughout the 12-week recording period, intervention participants were emailed three “Vitamin D Tips and Tricks” newsletters by email attachment at weeks 3, 6, and 9. The newsletters were developed by the researcher and
included key facts relating to vitamin D, as well as recipes and tips for including vitamin D in your diet. The major topics for the three “newsletters” were as follows: (1) “Meet your vitamin D needs in one simple step” (i.e., vitamin D supplementation) as well as a summary of the available brands of vitamin D-fortified orange juice, cereal and yogurt in Canada; (2) “How to get vitamin D naturally” (i.e., oily fish, sunlight); and (3) “Dairy (and non-dairy) goodness” (i.e., easy ways to include milk, eggs and milk alternatives in your diet); see Appendix P.

Data Analysis

Survey data were exported from LimeSurvey to SPSS. Vitamin D Calculator App data were downloaded from the secure online database into Microsoft Excel and exported to SPSS. Vitamin D intake data from the FFQ were analyzed using a Microsoft Excel template provided by the developer (S. Whiting, personal communication, May 16, 2014). Vitamin D intake data were analyzed using PC-SIDE version 1.0 (PC-SIDE, Ames, IA, Department of Statistics, Iowa State University of Science and Technology). Statistical analyses were performed using SPSS version 22.0 (SPSS Statistics, Armonk, NY, IBM Corp., 2013).

Coding of variables. Body mass index (BMI) was calculated using reported height and weight (kg/m²) and the World Health Organization international classification of BMI cut-offs (WHO, 2015) were used to determine weight classification. Fitzpatrick Skin Type was determined by summing the ten Fitzpatrick skin type questions and assigning a score of I-VI according to the Fitzpatrick Skin Type Questionnaire (Fitzpatrick, 1988). The number of data entries participants submitted using the Vitamin D Calculator app were summed to form an “adherence” score, defined as the number of app recordings completed
(control participants received a score of zero). A “vitamin D knowledge” score (max. score=9) was computed by summing the score from the following nine questions: (1) According to Health Canada, what is the recommended daily intake of vitamin D for adults of your age group? This is also known as the "Recommended Dietary Allowance" or RDA. (Open-ended; responses of 600 IU or 15 μg were coded as 1= correct; all other responses coded as 0=incorrect); (2) Which of the following nutrients does your body need in order to absorb calcium? (Categorical; selecting vitamin D was coded as 1=correct; all other responses coded as 0=incorrect); (3) Which of the following are good dietary sources of vitamin D? Check any that apply. (Presented with a list of food categories; computed a proportion correct score where 1.0=max. score); (4) Do you know of any non-dietary sources of vitamin D (aside from foods, beverages or supplements)? (Open-ended; responses related to sun/sunlight/UVB/rays/skin synthesis were coded as 1=correct; all other responses coded as 0=incorrect); (5) Vitamin D comes in more than one form. Do you know which form comes from the sun and is also found in most vitamin D supplements? (Categorical; selecting vitamin D₃ was coded as 1=correct; all other responses coded as 0=incorrect); (6) According to Health Canada, what is the maximum amount of vitamin D that adults should consume per day from dietary sources (including foods, beverages and supplements)? This is also known as the “Tolerable Upper Limit” or UL. (Open-ended; responses of 4000 IU or 100 μg were coded as 1=correct; all other responses coded as 0=incorrect); (7) How much time in direct sunlight is needed in order for our bodies to make vitamin D in the skin? Please type a number in the box below to indicate the minimum number of minutes you think is needed. (Open-ended; responses of 10 through 30 minutes were coded as 1=correct; all other responses coded as 0=incorrect);
(8) Which of the following factors influence our body’s ability to make vitamin D from the sun? Check any that apply. (Presented with a list of factors; computed a proportion correct score where 1.0=max. score); and (9) Which of the following nutrients affect your bone health? Check any that apply. (Presented with a list of nutrients; analyzed responses to calcium, vitamin D and phosphorus only; computed a proportion correct score wherein a perfect score of 1.0 was achieved if all three nutrients were selected). Finally, “vitamin D intake change” and “blood vitamin D₃ change” variables were computed to examine the change in vitamin D intake and status before and after the intervention (change = post-test level – pre-test level).

Statistical analyses. Differences between the control and intervention group on socio-demographic factors and key outcomes at baseline were tested using student’s t-tests, chi-squared tests and univariate analyses of variance (ANOVA) for binary, categorical and continuous outcomes, respectively. Bivariate Pearson’s correlations were used to test for significant associations between variables; a cut-off of $r>0.6$ was used for inclusion of variables within models. Univariate ANOVAs were used to test for differences between the control and intervention groups in the change from baseline to follow-up (time 3) in both vitamin D intake from the FFQ and blood vitamin D₃ measured by blood spot test. A power calculation conducted a priori indicated that a sample size of 84 participants (n=42 per group) would provide 80% power to detect a 5% difference in intake (approximately 8 IU) between the control and intervention groups. Repeated-measures ANOVAs were used to test for differences between the control and intervention group (between-subjects factor) in survey items across the three survey time points (within-subjects factor), including: vitamin D knowledge, perceived importance of behaviours relating to vitamin D, as well
as TPB and PWM items. Paired samples t-tests were used to confirm significant differences in outcomes at pre- and post-intervention. Linear and binary logistic regression models were used to predict mean vitamin D intake (IU; continuous) and supplement use (yes/no; binary), respectively from the FFQ at time 3. Nagelkerke $R^2$ values are reported for logistic regression models.

**RESULTS**

As shown in the CONSORT diagram (Figure 5.1), the original sample consisted of 109 adult men and women; however, 17% of participants (n=19) were lost to follow-up. The final sample thus consisted of N=90 adults aged 18-25 (M=22, SD=2.0) years; 42% were men (n=38) and 58% were women (n=52). Approximately half of the sample identified as non-Caucasian (49%). Men were significantly more likely to drop out of the study compared to women (27% vs. 9%, respectively), $F=30.03$, $t(107)=2.55$, $p=0.01$. Attrition rates did not significantly differ for Caucasians vs. non-Caucasians ($p>0.05$); however, individuals in the intervention group were significantly more likely to drop out compared to those in the control group (31% vs. 2%, respectively), $F=152.93$, $t(107)=4.18$, $p<0.001$. Of those who dropped out, two participants had technical difficulties with their Apple device (i.e., broken iPhone or iPad) and the remaining participants stopped responding to survey reminders or emails from the researcher. The final sample thus consisted of 46% (n=41) intervention participants and 54% (n=49) control participants. Of those who remained in the study at time 3 (n=90), the mean length to follow-up was 128 days (SD=31), or approximately 4 months. Student’s t-tests (two-tailed), chi-squared and univariate ANOVAs were conducted to test for differences between test groups on socio-demographic variables (N=90). Results indicated that there were no significant differences
between the intervention and control group on any of the following variables: sex, age, race, BMI, education level, employment status, student status, mean daily vitamin D intake, reported use of vitamin D supplements, or being employed or in a school program related to health or nutrition; \( p > 0.05 \) for all (data not shown). Detailed sample characteristics are listed in Table 5.1.

Table 5.1: Sample Characteristics of Participants in Intervention Study (n=90)

<table>
<thead>
<tr>
<th>Socio-demographic Characteristics</th>
<th>Intervention (n=41)</th>
<th>Control (n=49)</th>
<th>Total (n=90)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>34% (14)</td>
<td>49% (24)</td>
<td>42% (38)</td>
</tr>
<tr>
<td>Female</td>
<td>66% (27)</td>
<td>51% (25)</td>
<td>58% (52)</td>
</tr>
<tr>
<td>Age (years)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M (SD)</td>
<td>22.0 (2.1)</td>
<td>22.0 (2.0)</td>
<td>22.0 (2.0)</td>
</tr>
<tr>
<td>18-19</td>
<td>24% (10)</td>
<td>8.1% (4)</td>
<td>16% (14)</td>
</tr>
<tr>
<td>20-21</td>
<td>20% (8)</td>
<td>39% (19)</td>
<td>30% (27)</td>
</tr>
<tr>
<td>22-23</td>
<td>32% (13)</td>
<td>22% (11)</td>
<td>27% (24)</td>
</tr>
<tr>
<td>24-25</td>
<td>24% (10)</td>
<td>31% (15)</td>
<td>28% (25)</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White/Caucasian</td>
<td>46% (19)</td>
<td>55% (27)</td>
<td>51% (46)</td>
</tr>
<tr>
<td>Asian, South Asian, Southeast Asian</td>
<td>17% (7)</td>
<td>12% (6)</td>
<td>14.5% (13)</td>
</tr>
<tr>
<td>European</td>
<td>7% (3)</td>
<td>8% (4)</td>
<td>8% (7)</td>
</tr>
<tr>
<td>Middle Eastern/Arab</td>
<td>7% (3)</td>
<td>2% (1)</td>
<td>4% (4)</td>
</tr>
<tr>
<td>African/Caribbean</td>
<td>7% (3)</td>
<td>2% (1)</td>
<td>4% (4)</td>
</tr>
<tr>
<td>Mixed ancestry</td>
<td>5% (2)</td>
<td>6% (3)</td>
<td>6% (5)</td>
</tr>
<tr>
<td>Other (Aboriginal, Latin/Central American, Filipino, other)</td>
<td>10% (4)</td>
<td>14% (7)</td>
<td>12% (11)</td>
</tr>
<tr>
<td>Highest level of education</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Some high school, or high school diploma</td>
<td>24% (10)</td>
<td>10% (5)</td>
<td>17% (15)</td>
</tr>
<tr>
<td>Some college, college diploma or professional certificate</td>
<td>12% (5)</td>
<td>14% (7)</td>
<td>13% (12)</td>
</tr>
<tr>
<td>Some university, or undergraduate degree</td>
<td>56% (23)</td>
<td>63% (31)</td>
<td>60% (54)</td>
</tr>
<tr>
<td>Some graduate school, or graduate degree</td>
<td>7% (3)</td>
<td>12% (6)</td>
<td>10% (9)</td>
</tr>
<tr>
<td>Student status</td>
<td>Intervention (n=41)</td>
<td>Control (n=49)</td>
<td>Total (n=90)</td>
</tr>
<tr>
<td>------------------------</td>
<td>---------------------</td>
<td>----------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Currently a student</td>
<td>76% (31)</td>
<td>61% (30)</td>
<td>68% (61)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Employment status</th>
<th>Intervention (n=41)</th>
<th>Control (n=49)</th>
<th>Total (n=90)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not employed</td>
<td>37% (15)</td>
<td>35% (17)</td>
<td>36% (32)</td>
</tr>
<tr>
<td>Part-time</td>
<td>42% (17)</td>
<td>35% (17)</td>
<td>38% (34)</td>
</tr>
<tr>
<td>Full-time</td>
<td>22% (9)</td>
<td>29% (14)</td>
<td>26% (23)</td>
</tr>
<tr>
<td>Prefer not to say</td>
<td>0% (0)</td>
<td>2% (1)</td>
<td>1% (1)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nutrition Background</th>
<th>Intervention (n=41)</th>
<th>Control (n=49)</th>
<th>Total (n=90)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Has taken a nutrition course in the past</td>
<td>32% (13)</td>
<td>41% (20)</td>
<td>37% (33)</td>
</tr>
<tr>
<td>Employment or program of study related to health or nutrition</td>
<td>22% (9)</td>
<td>26.5% (13)</td>
<td>24% (22)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Food Purchasing Responsibility</th>
<th>Intervention (n=41)</th>
<th>Control (n=49)</th>
<th>Total (n=90)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete responsibility, or primary shopper but someone else contributes</td>
<td>46% (19)</td>
<td>55% (27)</td>
<td>51% (46)</td>
</tr>
<tr>
<td>Shared equally with another person</td>
<td>24% (10)</td>
<td>20% (10)</td>
<td>22% (20)</td>
</tr>
<tr>
<td>Someone else is primarily responsible or has complete responsibility</td>
<td>29% (12)</td>
<td>24.5% (12)</td>
<td>27% (24)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Frequency of 30 mins of Moderate Physical Activity</th>
<th>Intervention (n=41)</th>
<th>Control (n=49)</th>
<th>Total (n=90)</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>7% (3)</td>
<td>8% (4)</td>
<td>8% (7)</td>
</tr>
<tr>
<td>1-2 times/week</td>
<td>29% (12)</td>
<td>26.5% (13)</td>
<td>28% (25)</td>
</tr>
<tr>
<td>3-4 times/week</td>
<td>46% (19)</td>
<td>43% (21)</td>
<td>44% (40)</td>
</tr>
<tr>
<td>≥5 times/week</td>
<td>17% (7)</td>
<td>22% (11)</td>
<td>20% (18)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Frequency of 20 mins of Vigorous Physical Activity</th>
<th>Intervention (n=41)</th>
<th>Control (n=49)</th>
<th>Total (n=90)</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>12% (5)</td>
<td>31% (15)</td>
<td>22% (20)</td>
</tr>
<tr>
<td>1-2 times/week</td>
<td>46% (19)</td>
<td>35% (17)</td>
<td>40% (36)</td>
</tr>
<tr>
<td>≥3 times/week</td>
<td>41.5% (17)</td>
<td>35% (17)</td>
<td>38% (34)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Frequency of Weight-Bearing Physical Activity</th>
<th>Intervention (n=41)</th>
<th>Control (n=49)</th>
<th>Total (n=90)</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>39% (16)</td>
<td>41% (20)</td>
<td>40% (36)</td>
</tr>
<tr>
<td>1-2 times/week</td>
<td>24% (10)</td>
<td>29% (14)</td>
<td>27% (24)</td>
</tr>
<tr>
<td>3-4 times/week</td>
<td>29% (12)</td>
<td>24.5% (12)</td>
<td>27% (24)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BMI Classification</th>
<th>Intervention (n=41)</th>
<th>Control (n=49)</th>
<th>Total (n=90)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underweight (&lt;18.5)</td>
<td>5% (2)</td>
<td>6% (3)</td>
<td>6% (5)</td>
</tr>
<tr>
<td>Normal weight (18.5-24.9)</td>
<td>70% (28)</td>
<td>55% (27)</td>
<td>62% (55)</td>
</tr>
<tr>
<td>Overweight (25.0-29.9)</td>
<td>20% (8)</td>
<td>18% (9)</td>
<td>19% (17)</td>
</tr>
<tr>
<td>Obese (≥30)</td>
<td>5% (2)</td>
<td>20% (10)</td>
<td>13.5% (12)</td>
</tr>
</tbody>
</table>
Are young adults currently meeting the recommendations for vitamin D?

Baseline data from the FFQ and blood spot tests were compared to current vitamin D recommendations in order to assess the vitamin D intake and status of this sample.

**Dietary vitamin D intake.** Normality testing indicated that daily vitamin D intake data from the FFQ were positively skewed. The natural logarithm transformation [ln(x)] was used to correct normality of total vitamin D intake at baseline and time 3. Transformed data were used in subsequent analyses involving this variable and reported herein unless otherwise noted; means and standard deviations (SD) for vitamin D intake are reported for untransformed data, for ease of interpretation. Results from the FFQ administered at baseline indicate that the mean vitamin D intake of this sample (N=90) was 229 IU (SD=245) from food sources and 178 IU (SD=396) from supplements, equaling a total mean intake of 407 IU (SD=460) per day. Men consumed more vitamin D than women in total (M=491, SD=518 vs. M=346, SD=407), from foods and beverages (M=283, SD=332 vs. M=190 vs. 145) and from supplements (M=208, SD=443 vs. M=157, SD=361); however, independent samples t-tests indicated that these differences were not statistically significant (p>0.05 for all). Among individuals who reported taking vitamin D supplements at baseline (n=21), mean intake values were 214 IU (SD=212) from food sources and 764 IU (SD=476) from supplements; summing to a total mean intake of 978 IU (SD=524) per day. Among those who reported no vitamin D supplement use at baseline (n=69), mean daily intake from food sources was 234 IU (SD=255). The mean daily vitamin D intake of supplement users vs. non-supplement users was not significantly different at baseline, p>0.05. Total daily vitamin D intake also did not differ significantly between Caucasians and non-Caucasians, and there were no significant effects of age,
education or BMI ($p>0.05$ for all).

EAR cut-point analysis using the Iowa State method was conducted using the PC-SIDE program. Results indicated that only 9% (SE=0.05) of women and 17% (SE=0.07) of men had vitamin D intakes above the EAR (400 IU/day) from dietary sources (i.e., food and beverages). When examining total vitamin D intake (intake from supplements plus foods and beverages), a quarter of women (25%, SE=0.06) and over a third of men (38.2%, SE=0.07) exceeded the EAR. In addition, 91% (SE=0.08) of supplement users exceeded the EAR compared to 14% (SE=0.05) of non-supplement users.

**Vitamin D status.** Normality testing indicated that blood vitamin D$_3$ concentrations at baseline were normally distributed. A subsample of participants ($n=58$) completed the optional blood spot test at baseline. Chi-square tests indicated that participants who chose to complete the blood test were not significantly different from those who completed the blood test on any of the following variables: study group, sex, race (Caucasian vs. non-Caucasian), student status, education, employment status, having taken a nutrition course, or BMI status ($p>0.05$). An independent samples $t$-test also indicated that those who completed vs. did not complete the blood test did not differ significantly by age ($p>0.05$).

Results indicated that the mean 25(OH)D blood concentration among this subsample was 27 nmol/L (SD=15.7) at pre-test. Descriptive statistics using cut-points indicated that 56.9% ($n=33$) of participants fell below the cut-point of 25 nmol/L, 70.7% ($n=41$) were below 30 nmol/L, 91.4% ($n=53$) were below 50 nmol/L and 100% ($n=58$) fell below 75
nmol/L. These cut-points correspond with the 25(OH)D thresholds for deficiency (25-30 nmol/L) and sufficiency (50 nmol/L) set by the IOM (2010) and the more recent recommendation of 75 nmol/L for optimal health (Vieth, 2011). Independent \( t \)-tests indicated that baseline 25(OH)D did not differ significantly between the control (\( n=34, M=26, SD=16 \) nmol/L) and intervention groups (\( n=24, M=29, SD=16 \) nmol/L), \( F=0.04, t(56)=0.79, p=0.43 \). Concentrations also did not differ significantly between men (\( M=28, SD=15 \) nmol/L) and women (\( M=27, SD=16 \) nmol/L), \( F=0.001, t(56)=0.20, p=0.85 \), or Caucasians (\( n=31, M=29, SD=16 \) nmol/L) and non-Caucasians (\( n=27, M=25, SD=16 \) nmol/L), \( F=0.14, t(56)=0.97, p=0.34 \). Univariate ANOVAs indicated no significant effects of age, education, BMI or Fitzpatrick Skin Type on blood vitamin D\(_3\) (\( p>0.05 \) for all). Finally, bivariate correlations indicated that blood vitamin D\(_3\) was not significantly correlated with vitamin D intake from the FFQ at baseline, \( p>0.05 \).

What are the underlying perceptions, behaviours and knowledge levels of young adults regarding vitamin D?

Responses to the Vitamin D Survey at baseline (time 1) provided a snapshot of the perceptions, behaviours and knowledge of young adults in relation to vitamin D supplements, milk consumption and sun-related behaviours; survey responses are summarized in Tables Q.1, Q.2, and Q.3 (Appendix Q). Overall, vitamin D knowledge was low to moderate. Few participants were able to correctly state the RDA of 600 IU/day (5.6%, \( n=5 \)) or the UL of 4000 IU/day (9.0%, \( n=8 \)). Interestingly, a greater proportion of participants (19%; \( n=17 \)) identified the RDA as 1000 IU/day, which is consistent with recommendations by public health associations (i.e., Canadian Cancer Society, 2015). When presented a list of nutrients and asked to identify which enables calcium absorption,
more than half (61%; n=55) of participants correctly selected vitamin D; however, only half of participants (50%; n=45) selected both calcium and vitamin D when asked to select nutrients that affect bone health. When asked if they knew of any non-dietary sources of vitamin D, 66% (n=58) correctly listed the sun/UV rays. Finally, only 32% (n=29) correctly selected vitamin D₃ as the form of vitamin D that we get from the sun and that is usually found in supplements.

In terms of perceptions and behaviours related to vitamin D, only 13% of participants reported always taking vitamin D supplements, while another 20% reported taking them “sometimes, or when I remember”. Of those who reported taking vitamin D supplements, more than three quarters (77%) reported taking them year-round. Over two-thirds of participants (69%) agreed or strongly agreed with the statement, “It is important for me to take vitamin D supplements in the fall/winter months in Canada”; however, only 39% of participants agreed or strongly agreed to the statement, “It is important for me to regularly take vitamin D supplements or multivitamins containing vitamin D”. This finding suggests that participants are aware of the importance of vitamin D supplementation in the fall/winter months but may not see value in supplementing year-round. When asked their primary reason for not taking vitamin D, about 19% of non-supplement users indicated that they get enough vitamin D from either their diet or the sun, and another 17% indicated that they prefer not to take supplements or vitamins. Additionally, about half (49%) indicated “no reason/never thought about it”, suggesting that vitamin D supplementation is not on the radar of many young adults. Participants were more in favour of drinking milk; over 78% agreed or strongly agreed with the statement, “It is important for me to consume
milk, dairy, and/or fortified non-dairy alternatives every day”, although it is unclear whether this perceived importance was related to consuming adequate vitamin D or calcium (or due to other factors). Participants also acknowledged the importance of sunlight for health and wellbeing: the majority (85%) agreed or strongly agreed with the statement, “It is important for me to get some sun exposure every day”. Further, when asked, “When you consider sun exposure, how much do you think about each of the following…” 58% responded “somewhat, a fair amount, or very much” in relation to “getting adequate sunlight for vitamin D production”, and three quarters (76%) responded the same way in relation to “getting adequate sunlight for overall mood and wellbeing”. Overall, it seems that the drinking milk and getting sun exposure are perceived as slightly more important among young adults than is vitamin D supplementation.

**Efficacy of the Intervention**

Student’s *t*-tests indicated no significant differences between the control and intervention groups on the following socio-demographic variables: sex, age, race, education or BMI (*p*>0.05 for all); these variables were therefore not entered as covariates in analyses testing efficacy of the intervention.

**Influence of the intervention on vitamin D intake.**

Results from the FFQ administered at time 3 indicate that the mean daily vitamin D intake of the sample (n=89) was 247 IU (SD=280) from food sources and 369 IU (SD=619) from supplements, equaling a total mean intake of 619 IU (SD=655) per day. A paired-samples *t*-test indicated that the mean daily vitamin D intake increased significantly from pre- to post-test in both groups combined, *t*(88)=5.37, *p*<0.001. Among those who reported taking
vitamin D supplements at time 3 (n=33), mean intake values were 191 IU (SD=137.8) from food sources and 1005 IU (SD=638.1) from supplements, summing to a total mean intake of 1196 IU (SD=654) per day. Among those who reported no vitamin D supplement use at time 3 (n=56), mean daily intake from food sources was 280 IU (SD=347). An independent-samples t-test indicated that at time 3, the mean daily vitamin D intake of supplement users was significantly higher than that of non-supplement users, \(F(86.9)=6.89, t=11.09, p<0.001\). Although group means cannot be compared to the RDA (Barr, Murphy & Poos, 2002), when examining individuals it is notable that 19% of participants met the RDA of 600 IU/day at baseline, compared to 38% at post-test (total from dietary sources plus supplements). Examining the study groups separately, the number of intervention participants who met the RDA increased by 27% (12% at baseline vs. 39% at time 3), whereas the control group increased by 12% (from 25% at baseline to 37% at time 3).\(^4\) Results of EAR cut-point analysis indicated that when examining vitamin D intake from dietary sources (i.e., food and beverages), only 8% (SE=0.06) of women exceeded the EAR at time 3, compared with 24% (SE=0.07) of men. An independent-samples t-test confirmed that men consumed significantly more vitamin D intake from dietary sources at time 3 (M=333 IU, SD=402) than women (M=185 IU, SD=145), \(F(42.74)=9.39, t=2.14, p=0.04\). Total vitamin D intake and vitamin D intake from supplements did not differ significantly between men and women (\(p>0.05\) for both).

\(^4\) These values are proportions only and are not meant to express prevalence of inadequacy.
When examining the results by study group, the proportion of intervention participants whose total vitamin D intake exceeded the EAR increased by about 22% from pre-test (29%, SE=0.07) to post-test (50%, SE=0.06). In comparison, the proportion of control participants with total intakes above the EAR increased by about 12% from pre-test (33%, SE=0.06) to post-test (44%, SE=0.06). An independent samples t-test indicated that at baseline, total vitamin D intake did not differ significantly between the intervention (M=394, SD=494) and control group (M=418, SD=434), F(88)=0.06, t=-0.52, p=0.60, nor did vitamin D intake from supplements or dietary sources (p>0.05 for both). At time 3, the intervention group had a higher total vitamin D intake on average (M=702 IU, SD=714) than the control group (M=549 IU, SD=598), as well as a higher vitamin D intake from supplements (M=458 IU, SD=657) than the control group (M=294 IU, SD=582), although these differences were not statistically significant (p>0.05 for both).

A univariate ANOVA was conducted to test for a significant difference between study groups in the change in vitamin D intake from pre- to post-intervention. Given that dietary vitamin D intake differed significantly by sex at time 3 (t(42.74)=2.14, p=0.04) and that intervention adherence was significantly correlated with education level (r(39)=0.31, p<0.05), these variables were entered as covariates in the ANOVA. Results indicated that after controlling for the effects of sex and education (p>0.05 for both; ηp²=0.01 and ηp²=0.03, respectively), there was a significant effect of study group on the change in total vitamin D intake from pre- to post-test, F(1, 85)=4.09, p<0.05, ηp²=0.05. Post-hoc paired-samples t-tests indicated that in the intervention group, total vitamin D intake increased significantly from baseline (M=394 IU, SD=494) to time 3 (M=702 IU, SD=714),
As did vitamin D intake from supplements (M=191 IU, SD=473 at baseline vs. M=458 IU, SD=658 at time 3), $t(40)=3.37, p<0.01$. In contrast, in the control group, there were no significant differences in total vitamin D intake at baseline (M=423 IU, SD=438) vs. time 3 (M=549 IU, SD=598), $t(47)=0.98, p=0.33$. Similarly, there was no significant difference in vitamin D from supplements from baseline (M=168 IU, SD=322) to time 3 (M=294 IU, SD=582), $t(48)=0.17, p=0.10$. The difference in vitamin D intake from dietary sources (i.e., foods and beverages) from baseline to time 3 was not significantly different in either the control ($t(47)=-0.07, p=0.95$) or intervention group ($t(40)=0.80, p=0.43$). In summary, total and supplemental vitamin D intake was significantly improved among intervention participants, while the increase observed in the control group was smaller and non-significant.

**Influence of the intervention on vitamin D status.** Normality testing indicated that blood 25(OH)D data were positively skewed at time 3. The natural logarithm transformation [$\ln(x)$] was used to correct normality of this variable, and log-transformed data are therefore reported for time 3 data and used in subsequent analyses. Means and standard deviations are reported for untransformed data, for ease of interpretation. At time 3, the mean 25(OH)D of the sample (n=56) was 43 nmol/L (SD=28). An independent samples $t$-test indicated that time 3 blood concentrations were not significantly different between the intervention group (M=46 nmol/L, SD=31) and control group (42 nmol/L, SD=27), $t(54)=0.73, p=0.47$, or between men (M=28 nmol/L, SD=19) and women (M=48 nmol/L, SD=33), $F(54)=0.47, t=-0.76, p=0.45$. However, 25(OH)D concentrations of supplement users (n=24; M=58 nmol/L, SD=34) were significantly higher than those of non-supplement users (n=32; M=32 nmol/L, SD=16) at time 3, $F(54)=0.003, t=3.80$, p<0.01.
Finally, bivariate correlations indicated that total vitamin D intake and blood concentrations at time 3 were significantly positively correlated, \( r(53) = 0.46, p < 0.001 \).

A paired-samples \( t \)-test indicated that mean 25(OH)D of the sample increased from baseline to time 3; \( t(53) = 11.36, p < 0.001 \). An independent samples \( t \)-test indicated that this change in 25(OH)D did not differ significantly between men and women, \( F(52) = 0.001, t = -0.15, p = 0.88 \). A univariate ANOVA was used to test the difference between groups in the change in 25(OH)D concentrations. As noted earlier, the intervention and control groups did not differ in 25(OH)D at baseline \((p > 0.05)\). Results of a \( \chi^2 \) test indicated that Fitzpatrick Skin Type was not significantly different between the control and intervention groups, \( \chi^2(5) = 3.62, p = 0.61 \). Further, baseline 25(OH)D did not differ significantly across sex, age, race, education level, BMI, or Fitzpatrick Skin Type \((p > 0.05\) for all). Baseline 25(OH)D was significantly correlated with frequency of moderate physical activity \( r(57) = 0.31, p = 0.01 \), vigorous physical activity \( r(57) = 0.45, p < 0.001 \), and weight-bearing activity \( r(57) = 0.31, p = 0.02 \). Results of an unadjusted model indicated no significant effect of study group on the change in 25(OH)D concentrations, \( F(1, 52) = 0.48, p = 0.49 \). Subsequent analyses indicated that study group remained non-significant after adjusting for sex, age, education, race, BMI, or Fitzpatrick Skin Type, as well as supplement use at baseline and time 3 (the effects of which were also non-significant). The effect of study group also remained non-significant after adjusting for physical activity levels and baseline blood concentrations (data not shown). Finally, seasonality was adjusted for by entering the months in which each participant completed the blood tests as covariates in the ANOVA. All participants completed pre-tests between September-December, and all
post-tests were completed between December-March (with the exception of one participant in May). When adjusting for seasonality, study group remained non-significant, \( F(1, 50)=0.61, p=0.44, \eta^2=0.01 \). The effect of post-test month was also non-significant, \( F(1, 50)=0.36, p=0.55, \eta^2<0.01 \); however, the effect of pre-test month was significant, \( F(1, 50)=12.01, p=0.001, \eta^2=0.19 \). Post-hoc tests using the Bonferroni adjustment indicated that baseline 25(OH) concentrations only differed between pre-tests completed in September (\( n=33; M=21.78 \text{ nmol/L, SD}=13.69 \)) compared to November (\( n=6; M=44 \text{ nmol/L, SD}=17 \)), \( p<0.01 \). Given that blood concentrations were lower in September than November, it appears that 25(OH) concentrations were not carried over from the summer; this significant difference was likely due to chance, given that only six participants completed the pre-test in November (i.e., small cell size).

**Influence of the intervention on knowledge and perceived importance of vitamin D.**

A student’s \( t \)-test indicated that the control and intervention groups did not differ on baseline vitamin D knowledge, \( p>0.05 \). Adherence to the intervention was not significantly correlated with vitamin D knowledge at baseline (\( p>0.05 \)); however, it was significantly positively correlated with knowledge at time 2 (\( r(88)=0.42, p<0.001 \)) and time 3 (\( r(88)=0.32, p<0.01 \)). A repeated-measures ANOVA examining knowledge at baseline vs. time 2 only was used to test improvements in knowledge between groups after the first phase of the intervention (i.e., after the intervention video and information screens were shown to the intervention group). Significant main effects of time \( F(1, 88)=47.29, p<0.001, \eta^2=0.36 \) and study group, \( F(1, 88)=7.14, p<0.01, \eta^2=0.08 \), and a significant interaction between time and study group, \( F(1, 88)=32.53, p<0.001, \eta^2=0.27 \) were found,
whereby the knowledge score (maximum score=9) was higher overall in the intervention group (M=5.02, SE=0.22) than the control group (M=4.21, SE=0.21), and the intervention group increased more from baseline to time 2 (+1.88) than the control group (+0.19). A second repeated-measures ANOVA was used to test for differences in vitamin D knowledge between the control and intervention group (between-subjects factor) across all three survey time points (within-subjects factor). This ANOVA examined the pattern of responses after the first (i.e., video and information screens) and second phases of the intervention (i.e., newsletters and app recordings). Significant main effects of time $F(2, 176)=25.52, p<0.001$, $\eta^2_p=0.23$ and study group, $F(1, 88)=6.13, p=0.02$, $\eta^2_p=0.07$, and a significant interaction between time and study group, $F(2,176)=17.03, p<0.001$, $\eta^2_p=0.16$ were found. An independent samples t-test confirmed that the net increase in mean vitamin D knowledge from baseline to follow-up (time 3) was significantly higher in the intervention group (+0.91) than the control group (+0.25), $t(88)=2.26, p=0.03$. However, when adherence (i.e., number of app recordings) was added as a covariate, the effect of study group became non-significant ($p>0.05$). However, the main effect of adherence was significant, $F(1,87)=4.03, p<0.05$, $\eta^2_p=0.04$.

In order to explore the relationship between vitamin D knowledge and app use during the intervention period (time 2 to time 3), an additional analysis was conducted among intervention participants only ($n=41$). Intervention participants were classified into two groups: no/low app use (<20 recordings; $n=24$) or frequent app use (≥20 recordings; $n=17$). An independent samples t-test indicated that the vitamin D knowledge score of the two groups was non-significant at baseline ($p>0.05$), but significantly different at time 2
(t(39)=−2.15, p=0.04) and time 3 (t(39)=−3.39, p<0.01). Thus, an ANOVA was conducted that examined the change in vitamin D knowledge from time 2 to 3, with the time 2 knowledge score entered as a covariate. Significant main effects of time 2 knowledge ($F(1,38)=16.35, p<0.001$, $\eta_p^2=0.30$) and frequency of app use ($F(1,38)=6.01, p<0.02$, $\eta_p^2=0.14$) were found. Specifically, the vitamin D knowledge of both groups decreased from time 2 to time 3, but frequent app users had higher scores at both time points and a smaller decrease in vitamin D knowledge (-0.69) compared to those who used the app infrequently or not at all (-1.17).

In summary, the increase in vitamin D knowledge from pre- to post-intervention was significantly greater in the intervention group compared to the control, with the greatest increase observed at time 2, immediately following the intervention video and information screens. Vitamin D knowledge decreased somewhat from time 2 to time 3 in the intervention group, and although a small net increase was observed from baseline to follow-up, the effect of study group was not significant after controlling for adherence to the app. It seems that while the intervention video and information screens had a positive effect on vitamin D knowledge, more frequent use of the Vitamin D Calculator app was required in order to counteract the decrease in vitamin D knowledge that was observed after the recording period.

Six items relating to the perceived importance of vitamin D-related behaviours were measured; mean agreement at each of the three survey time points are listed in Table Q.4 (Appendix Q). A repeated-measures ANOVA was conducted to test for differences
between the control and intervention group over the three survey time points on the perceived importance of taking vitamin D supplements. This subscale was made up of 3 items (range 1-5; 1=strongly disagree; 5=strongly agree): “From a health perspective, it is important for me to take vitamin D supplements in the spring/summer months in Canada”, “From a health perspective, it is important for me to take vitamin D supplements in the fall/winter months in Canada”, and “From a health perspective, it is important for me to regularly take vitamin D supplements or multivitamins containing vitamin D”. These items were significantly correlated ($p<0.001$) and showed good internal consistency reliability using Cronbach’s alpha ($\alpha=0.81$). A student’s $t$-test indicated no significant differences at baseline between the two groups on response to this item ($p>0.05$). Results of the repeated-measures ANOVA indicated significant main effects of time $F(1.83, 161.23)=3.34$, $p=0.04$, $\eta_p^2=0.04$, and study group, $F(1, 88)=4.38$, $p=0.04$, $\eta_p^2=0.05$, whereby agreement increased in both groups over time, and the intervention group had higher agreement overall ($M=3.52$, $SE=0.13$) compared to the control group ($M=3.16$, $SE=0.12$).

**Influence of intervention on TPB and PWM items.** The following items from the TPB and PWM were examined at all three survey waves and included in repeated-measures ANOVAs: behavioural expectations, subjective norms, descriptive norms, perceived behavioural control, behavioural intentions, past behaviour, prototype evaluation, and prototype similarity (see Appendix K for full description). Normality testing indicated that all items were normally distributed except for the “descriptive norms” item for the following behaviour: “taking a vitamin D supplement every day”. The square root
transformation $[\sqrt{x+1}]$ was applied to reduce positive skew and correct the normality of this item at all three survey waves. Student’s $t$-tests indicated that the control and intervention groups did not respond significantly differently on any of the items at baseline, $p>0.05$, except for the “subjective norms” item for the following behaviour: “drinking at least two cups of cow’s milk or enriched non-dairy alternative such as soy/almond/coconut/goat’s milk) per day”. The intervention group (M=3.68, SD=1.49) responded significantly more favorably to this item than the control group (M=3.05, SD=1.44), $t(88)=2.07, p=0.04$. For consistency, all repeated-measures ANOVAs using the TPB and PWM items were therefore conducted with the baseline response to each item (i.e., from survey 1) entered as a covariate; time was entered as the within-subjects factor with 2 levels (i.e., responses to surveys 2 and 3), and study group as the between-subjects factor. ANOVAs were also run with adherence (i.e., number of app recordings) entered as a second covariate. Bivariate correlations between the four health behaviours were conducted for each construct. None of the behaviours were correlated at $r>0.6$, therefore separate ANOVAs were conducted for each of the four health behaviours. This approach (i.e., running health-protective behaviours in separate models to test TPB/PWM items) was also taken by Rivis et al. (2006). Results for the four health-protective behaviours were as follows:

1) **Taking a vitamin D supplement every day.** Table 5.2 displays the mean responses for each item across the three time points. Results indicated that there was no main effect of study group or time on items related to expectations, descriptive norms, or prototype similarity. For subjective norms, there were no significant main effects before or after adjusting for adherence, but there was a significant interaction between time and
adherence $F(1, 86)=12.94, p=0.001, \eta_p^2=0.13$, whereby after adjusting for adherence, responses increased from time 2 to 3 in the control group but decreased in the intervention group. For perceived behavioural control related to taking a vitamin D supplement every day, there was a significant main effect of time $F(1, 87)=4.48, p=0.04, \eta_p^2=0.05$ and baseline response, $F(1, 87)=48.09, p<0.001, \eta_p^2=0.36$, and a significant interaction between time and baseline response, $F(1, 87)=5.40, p=0.02, \eta_p^2=0.06$ whereby after controlling for baseline response, responses became more favourable in the control group and less favourable in the intervention group from time 2 to 3. For intentions to take a vitamin D supplement every day, there was a significant main effect of study group, $F(1, 87)=6.26, p=0.01, \eta_p^2=0.07$ and baseline response, $F(1, 87)=66.01, p<0.001, \eta_p^2=0.43$, whereby the intervention group had higher intentions overall compared to the control group. After adjusting for adherence, the main effect of baseline response remained significant ($F(1, 86)=67.72, p<0.001, \eta_p^2=0.44$), but the main effect of study group became non-significant, whereas there was a significant interaction between time and adherence, $F(1, 86)=4.90, p=0.03, \eta_p^2=0.05$. In relation to past behaviour regarding taking a vitamin D supplement every day, there was a significant main effect of time, $F(1, 87)=4.93 p=0.03, \eta_p^2=0.05$ and baseline response, $F(1, 87)=110.71 p<0.001, \eta_p^2=0.56$, and a significant interaction between time and study group, $F(1, 87)=5.33, p=0.02, \eta_p^2=0.06$, whereby reported vitamin D supplementation in the intervention group was lower than the control group at time 2 but surpassed the control group at time 3. After adjusting for adherence, only significant main effects of baseline response ($F(1, 86)=118.15, p<0.001, \eta_p^2=0.58$) and adherence ($F(1, 86)=4.69, p=0.03, \eta_p^2=0.05$) remained significant; responses in both
groups increased to similar levels at time 3. Finally, in relation to prototype evaluation related to taking a vitamin D supplement every day, there was a significant main effect of baseline response $F(1, 87)=79.92, p<0.001$, $\eta_p^2=0.48$ and study group, $F(1, 87)=12.62, p=0.001$, $\eta_p^2=0.13$ whereby responses were higher overall in the intervention group than the control group at both time points; these effects remained significant after adjusting for adherence.

Table 5.2: Mean responses to theoretical constructs over time in relation to the following behaviour: "Take a vitamin D supplement every day" (n=90)

<table>
<thead>
<tr>
<th>Item</th>
<th>Survey Time Point</th>
<th>Intervention Group M (SD)</th>
<th>Control Group M (SD)</th>
</tr>
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<tbody>
<tr>
<td>Behavioural expectations</td>
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<tr>
<td>(Range 1-4)</td>
<td>1</td>
<td>3.29 (1.45)</td>
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<td></td>
<td>2</td>
<td>3.39 (1.34)</td>
<td>3.16 (1.36)</td>
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<tr>
<td></td>
<td>3</td>
<td>3.44 (1.43)</td>
<td>3.04 (1.46)</td>
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<td>Subjective norms</td>
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<td>2.57 (1.40)</td>
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<td></td>
<td>2</td>
<td>2.88 (1.54)</td>
<td>2.61 (1.38)</td>
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<td></td>
<td>3</td>
<td>2.95 (1.36)</td>
<td>2.59 (1.40)</td>
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<td>21.71 (16.19)</td>
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<td></td>
<td>3</td>
<td>18.85 (15.49)</td>
<td>20.86 (16.58)</td>
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<td></td>
<td>3</td>
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<td>4.00 (1.28)</td>
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<td></td>
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<td>1.82 (1.29)</td>
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<td>2.02 (1.38)</td>
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<tr>
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<td>2.16 (1.43)</td>
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<td>1.87 (1.79)</td>
<td>1.92 (2.32)</td>
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<tr>
<td></td>
<td>2</td>
<td>2.44 (1.55)</td>
<td>1.80 (2.23)</td>
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<td>2.78 (1.67)</td>
<td>1.55 (2.09)</td>
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<td>Prototype similarity</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>(Range 1-5)</td>
<td>1</td>
<td>2.44 (1.18)</td>
<td>2.31 (1.33)</td>
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<tr>
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<td>2</td>
<td>2.56 (1.32)</td>
<td>2.39 (1.32)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>2.66 (1.37)</td>
<td>2.51 (1.39)</td>
</tr>
</tbody>
</table>

2) **Eating one to two servings of fish per week.** Table 5.3 shows the mean responses for each item across the three time points. Results indicated that there was no main effect of study group or time on items related to expectations, perceived behavioural control, intentions, past behaviour, or prototype evaluation. For subjective norms, there were
no significant main effects in the unadjusted model, but after adjusting for adherence there were significant main effects of adherence $F(1, 86)=4.37, p=0.04, \eta_p^2=0.05$ and baseline response $F(1, 86)=37.10, p<0.001, \eta_p^2=0.30$. Similarly, for descriptive norms, although no significant effects were observed in the initial model, after adjusting for adherence there were significant main effects of baseline response $F(1, 86)=10.10, p=0.02, \eta_p^2=0.11$ and study group $F(1, 86)=4.08, p<0.05, \eta_p^2=0.05$; whereby responses were higher in the control group than the intervention group. For prototype similarity, there was a main effect of baseline response $F(1, 87)=135.05, p<0.001, \eta_p^2=0.61$ and a significant interaction between time and baseline response, $F(1, 87)=4.65, p=0.03, \eta_p^2=0.05$.

Table 5.3: Mean responses to theoretical constructs over time in relation to the following behaviour: “Eat one or two servings of fish per week” (n=90)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Survey Time Point</th>
<th>Intervention Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Behavioural expectations</td>
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</tr>
<tr>
<td>1</td>
<td>3.68 (1.39)</td>
<td>3.31 (1.50)</td>
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<tr>
<td>2</td>
<td>3.49 (1.47)</td>
<td>3.20 (1.51)</td>
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</tr>
<tr>
<td>3</td>
<td>3.39 (1.38)</td>
<td>3.14 (1.43)</td>
<td></td>
</tr>
<tr>
<td>Subjective norms</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>(Range 1-5)</td>
<td></td>
<td></td>
<td></td>
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<td>3.41 (1.45)</td>
<td>2.90 (1.48)</td>
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<td>3.27 (1.40)</td>
<td>2.94 (1.42)</td>
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<td>3</td>
<td>3.00 (1.18)</td>
<td>3.04 (1.47)</td>
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<tr>
<td>Descriptive norms</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>(Range 0-100)</td>
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<td></td>
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</tr>
<tr>
<td>1</td>
<td>30.45 (21.17)</td>
<td>31.16 (21.77)</td>
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<td>28.61 (17.53)</td>
<td>34.51 (20.04)</td>
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<tr>
<td>3</td>
<td>31.15 (22.07)</td>
<td>36.29 (22.57)</td>
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<td>Perceived behavioural control</td>
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<td>(Range 1-5)</td>
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<td>1</td>
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<td>3.24 (1.36)</td>
<td>3.27 (1.46)</td>
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<td>Behavioural intentions</td>
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<td>(Range 0-100)</td>
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<td>46.78 (36.19)</td>
<td>45.04 (36.81)</td>
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<tr>
<td>(Range 1-5)</td>
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<td>1</td>
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<td>2.76 (1.28)</td>
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<td>3</td>
<td>2.66 (1.22)</td>
<td>2.69 (1.37)</td>
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<td>Prototype evaluation</td>
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<td></td>
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<tr>
<td>(Range -5 to 5)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>1</td>
<td>2.66 (1.64)</td>
<td>2.53 (1.43)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2.93 (1.59)</td>
<td>2.41 (1.59)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2.61 (1.99)</td>
<td>2.49 (1.68)</td>
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</tr>
<tr>
<td>Prototype similarity</td>
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<tr>
<td>(Range 1-5)</td>
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<td></td>
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<tr>
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<td>3.02 (1.31)</td>
<td>2.92 (1.35)</td>
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<tr>
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<td>2.93 (1.40)</td>
<td>2.92 (1.35)</td>
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<tr>
<td>3</td>
<td>2.98 (1.41)</td>
<td>2.76 (1.28)</td>
<td></td>
</tr>
</tbody>
</table>
3) **Drinking at least two cups of cow’s milk or enriched non-dairy alternative (such as soy/almond/coconut/goat’s milk) per day.** Table 5.4 shows the mean responses to each item across the three survey time points. Results indicated that there was no main effect of study group or time on items related to perceived behavioural control, intentions, prototype evaluation or prototype similarity. For behavioural expectations surrounding drinking milk, after adjusting for adherence, there were significant main effects of baseline response \( F(1, 86)=122.34, p<0.001, \eta_p^2=0.59 \) and study group \( F(1, 86)=4.77, p=0.03, \eta_p^2=0.05 \), whereby responses were higher in the control than intervention group. The effect of adherence bordered on significance, \( F(1, 86)=3.79, p=0.06, \eta_p^2=0.04 \). For subjective norms, there was a main effect of baseline response \( F(1, 87)=33.27, p<0.001, \eta_p^2=0.28 \) and a significant interaction between time and study group, \( F(1, 87)=6.42 p=0.01, \eta_p^2=0.07 \), whereby responses in the intervention group decreased from time 2 to 3 and those in the control group increased. These effects remained significant after adjusting for adherence, which was also significant \( (F(1, 86)=4.07, p<0.05, \eta_p^2=0.05) \). For descriptive norms, there was a main effect of baseline response \( F(1, 87)=13.22, p<0.001, \eta_p^2=0.13 \) and a significant interaction between time and baseline response, \( F(1, 87)=5.07 p=0.03, \eta_p^2=0.06 \). These effects remained significant after adjusting for adherence, which was non-significant \( (p>0.05) \). However, significant interactions between time and adherence \( (F(1, 86)=10.39, p<0.01, \eta_p^2=0.11) \), and time and study group \( (F(1, 86)=8.80, p<0.01, \eta_p^2=0.09) \) emerged in the adjusted model, whereby responses in the intervention group decreased from time 2 to 3 while those in the control group increased. For past behaviour related to drinking milk, although no significant main effects were observed
in the first model, after adjusting for adherence there were significant main effects of baseline response $F(1, 86)=124.45, p<0.001, \eta_p^2=0.59$, adherence $F(1, 86)=4.20, p=0.04, \eta_p^2=0.05$ and study group $F(1, 86)=5.52, p=0.02, \eta_p^2=0.06$, whereby responses in the control group were higher than those in the intervention group.

Table 5.4: Mean responses to theoretical constructs over time in relation to the following behaviour: “Drink at least two cups of cow’s milk (or enriched non-dairy alternative such as soy/almond/coconut/goat’s milk) per day”

<table>
<thead>
<tr>
<th>Variable</th>
<th>Survey Time Point</th>
<th>Intervention Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
</tr>
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<td>(Range 1-4)</td>
<td>2</td>
<td>3.76 (1.28)</td>
<td>3.92 (1.22)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>3.71 (1.29)</td>
<td>3.78 (1.25)</td>
</tr>
<tr>
<td><strong>Subjective norms</strong></td>
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<td>3.68 (1.49)</td>
<td>3.04 (1.44)</td>
</tr>
<tr>
<td>(Range 1-5)</td>
<td>2</td>
<td>3.66 (1.37)</td>
<td>3.04 (1.41)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>3.12 (1.05)</td>
<td>3.22 (1.34)</td>
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<tr>
<td><strong>Descriptive norms</strong></td>
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<td>4.14 (1.21)</td>
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<td>3</td>
<td>60.17 (35.17)</td>
<td>70.06 (31.82)</td>
</tr>
<tr>
<td><strong>Past behaviour</strong></td>
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<td>3.29 (1.21)</td>
<td>3.45 (1.29)</td>
</tr>
<tr>
<td>(Range 1-5)</td>
<td>2</td>
<td>3.02 (1.13)</td>
<td>3.41 (1.29)</td>
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<tr>
<td></td>
<td>3</td>
<td>3.29 (1.08)</td>
<td>3.53 (1.29)</td>
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<tr>
<td><strong>Prototype evaluation</strong></td>
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<td>2.20 (1.65)</td>
<td>2.39 (1.84)</td>
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<td>(Range -5 to 5)</td>
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<td>2.32 (1.59)</td>
<td>2.06 (1.72)</td>
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<td>2.24 (1.71)</td>
<td>2.35 (1.74)</td>
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<tr>
<td><strong>Prototype similarity</strong></td>
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<td>3.43 (1.17)</td>
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<td>(Range 1-5)</td>
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<td>3.57 (1.26)</td>
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<tr>
<td></td>
<td>3</td>
<td>3.20 (1.17)</td>
<td>3.49 (1.19)</td>
</tr>
</tbody>
</table>

4) **Spending 15-30 minutes in the sun without sunscreen, with at least some skin exposed, twice per week.** Table 5.5 shows the mean responses to each item across the three survey time points. Results indicated that there was no main effect of study group or time on items related to expectations, subjective norms, prototype evaluation, or prototype similarity. For descriptive norms related to spending time in the sun, after
adjusting for adherence, there were significant main effects of baseline response, $F(1, 86)=25.90, p<0.001, \eta^2_p=0.23$ and study group, $F(1, 86)=6.32, p=0.01, \eta^2_p=0.07$, whereby overall responses were higher in the control than intervention group. The main effect of adherence bordered on significance, $F(1, 86)=3.58, p=0.06, \eta^2_p=0.04$. For perceived behavioural control, after adjusting for adherence, there were significant main effects of time, $F(1, 86)=4.00, p<0.05, \eta^2_p=0.04$, baseline response, $F(1, 86)=22.61, p<0.001, \eta^2_p=0.21$ and adherence, $F(1, 86)=4.20, p=0.04, \eta^2_p=0.05$. There were also significant interactions between time and adherence, $F(1, 86)=21.92, p<0.001, \eta^2_p=0.20$, and time and study group, $F(1, 86)=4.48, p=0.04, \eta^2_p=0.05$, whereby mean responses were lower in the intervention group at both time points, but increased from time 2 to 3 in the intervention and decreased in the control group. For intentions related to spending time in the sun, an initial significant main effect of study group became non-significant ($p>0.05$) after controlling for adherence. For past behaviour, after controlling for adherence there were significant main effects of baseline response, $F(1, 86)=50.96, p<0.001, \eta^2_p=0.37$ and adherence, $F(1, 86)=16.74, p<0.001, \eta^2_p=0.16$, and a significant interaction between time and adherence, $F(1, 86)=6.48, p=0.01, \eta^2_p=0.07$; whereby responses decreased overall from time 2 to 3.

Table 5.5: Mean responses to theoretical constructs over time in relation to the following behaviour: “Spend 15-30 minutes in the sun without sunscreen, with at least some skin exposed, twice per week” (n=90)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Survey Time Point</th>
<th>Intervention Group M (SD)</th>
<th>Control Group M (SD)</th>
</tr>
</thead>
<tbody>
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<td>4.12 (0.90)</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>4.07 (1.13)</td>
<td>3.92 (1.27)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>3.98 (0.96)</td>
<td>3.98 (1.05)</td>
</tr>
<tr>
<td>Subjective norms (Range 1-5)</td>
<td>1</td>
<td>3.05 (1.41)</td>
<td>2.98 (1.32)</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>3.20 (1.50)</td>
<td>2.98 (1.44)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>2.98 (1.17)</td>
<td>3.14 (1.46)</td>
</tr>
<tr>
<td>Descriptive norms</td>
<td>1</td>
<td>66.12 (20.99)</td>
<td>60.24 (28.98)</td>
</tr>
</tbody>
</table>
In summary, after adjusting for both adherence and baseline response, the change in response to these theoretical constructs differed significantly by study group in only a few instances, and in many cases responses were higher in the control group. For instance, behavioural expectations and descriptive norms related to eating fish 1-2 times per week were higher in the control group than the intervention group, as were descriptive norms related to spending time in the sun twice per week. Similarly, reported past behaviour of drinking ≥2 cups of milk per day was higher in the control group than in the intervention group, and both subjective and descriptive norms related to drinking milk increased in the control group while decreasing in the intervention group from time 2 to 3. On the other hand, prototype evaluations of the type of person who takes a vitamin D supplement every day were higher overall in the intervention than the control group, and PBC related to spending time in the sun increased from time 2 to 3 in the intervention group while decreasing in the control group. Although various interactions between adherence, baseline response and time were observed for the four behaviours (as described above),
study group did not significantly influence responses to the remaining constructs after controlling for the effect of intervention adherence.

**Adherence to Intervention Components**

**Use of Vitamin D Calculator.** About 66% (n=27) of intervention participants submitted at least one app recording to the online database. Including the 34% (n=14) of intervention participants who did not submit app recordings, a mean of 14 (SD=16) recordings were submitted. Among those who submitted recordings, the average number of submissions was 21 (SD=15; range=1-63). An independent samples t-test indicated that the number of app submissions (‘adherence’) did not differ significantly between men and women in the intervention group, \(p>0.05\). However, adherence was significantly positively correlated with education level, \(r(39)=0.31, \ p<0.05\). Adherence was also significantly positively correlated with the change in vitamin D knowledge from baseline to follow-up, \(r(39)=0.47, \ p<0.01\) and with the change in perceived importance of regularly taking vitamin D supplements from time 2 to 3 \(r(39)=0.42, \ p<0.01\). Adherence was not significantly correlated with the change in mean vitamin D intake or status \(p>0.05\).

**Newsletters.** Over half (51%, n=21) of intervention participants indicated that they read one or two of the three Vitamin D Tips & Tricks newsletters, and another 29% (n=12) indicated that they read all three. A fifth (20%, n=8) indicated that they did not read any of the newsletters.

**Goal Setting.** All intervention participants (n=41) set a SMART goal during survey 2, and few failed to use the SMART format; two participants simply indicated the quantity of vitamin D (IU) they would like to consume (i.e., “1500”), and one indicated “eat more
salmon”; these participants did not indicate a timeframe or how they planned to achieve their goals. Participants also received a goal-setting email during the intervention period; 54% (n=22) of intervention participants responded to this email. When asked “Did seeing your vitamin D results in the feedback page of the app lead you to increase your commitment to your goal?”, 75% (n=15) of participants who responded to the email said “yes”. When asked, “Did seeing your vitamin D results lead you to modify or change your goal?” 62% (n=13) of participants who responded to the email said “yes”. Responding to the goal setting email was significantly positively correlated with adherence (i.e., number of app recordings submitted), $r(39)=0.67, p<0.001$ and with change in vitamin D intake from supplements from pre- to post-test, $r(39)=0.40, p=0.01$. Responses regarding commitment or changing the goal were not significantly associated with adherence or change in vitamin D intake, $p>0.05$. When asked at survey 3 if they remembered the SMART goal they had set, 39% (n=16) of intervention participants indicated that they remembered their goal (and 15 of these typed their goal into the textbox provided); over half (54%, n=22) indicated that they did not remember their goal, and 7% (n=3) indicated that they had not set a goal. About a third (34%, n=14) of intervention participants indicated that they made changes to their original goal after receiving feedback regarding personal vitamin D intake from the app. When asked how well they did at meeting their goal (goal assessment), over half (59%, n=24) selected “not-applicable”. Of those who responded, 77% (n=13) indicated that they did “somewhat” or “fairly well” at meeting their goal, and 12% (n=2) selected “very well – I met my goal completely”. Another 12% (n=2) indicated that they did “a little well”, and no participants selected, “not at all – I did not meet any aspects of my goal”. Goal assessment was significantly negatively correlated
with having taken a formal nutrition course, \( r(15)=0.52, p=0.04 \). An independent samples \( t \)-test confirmed that intervention participants who had not taken a formal nutrition course assessed their goal ascertainment significantly more positively (\( n=11, M=4.0, SD=0.7 \)) compared to those who reported having taken a formal nutrition course (\( n=6, M=3.0, SD=0.89 \)), \( F(15)=0.48, t=2.32, p=0.04 \). Goal assessment was not significantly correlated with any other socio-demographic variables, number of app submissions, baseline vitamin D knowledge, or mean vitamin D intake from the app or the FFQ at time 3. However, higher goal ascertainment was significantly positively correlated with change from pre- to post-test in vitamin D intake from supplements, \( r(15)=0.63, p<0.01 \), and was also a predictor of change in supplemental vitamin D intake (\( \beta=0.63, p<0.01; R^2=0.40, F(1, 15)=10.01, p<0.01 \)).

**Intervention Feedback**

Detailed results of the feedback survey are shown in Table Q.5 (Appendix Q) including perceived influence of the intervention components on behaviour change. In regards to the Vitamin D Calculator app, approximately half of intervention participants reported that they liked using the app “somewhat” or “very much” (46%), and that it was “somewhat” or “very” easy to use (54%). The other half of participants responded that they did not use the app, or that they did not like it “very much” or “at all”/found it “somewhat” or “very” difficult to use. Adherence was significantly positively correlated with liking the app, \( r(39)=0.57, p<0.001 \) and reported ease of using the app, \( r(39)=0.43, p<0.01 \).
Non-parametric tests were used to compare mean ratings of perceived influence of the intervention video, information screens, Vitamin D Tips & Tricks newsletters, and Vitamin D Calculator app to: (a) make changes to dietary intake of vitamin D; (b) make changes to dietary intake of calcium; (c) take a multivitamin or supplement containing vitamin D; and, (d) spend more time in the sun. Mean ratings are shown in Table 5.6; overall, mean influence ratings tended to be higher for the newsletters and information screens, followed by the app and video. The Friedman test indicated that perceived influence of the four intervention components did not significantly differ in relation to making changes to dietary intake of vitamin D ($\chi^2(3)=4.65, p=0.20$) or calcium ($\chi^2(3)=0.87, p=0.83$), or taking a multivitamin/supplement containing vitamin D ($\chi^2(3)=2.95, p=0.40$). There was a statistically significant difference between intervention components in perceived influence of spending more time in the sun, $\chi^2(3)=14.93, p<0.01$. Post-hoc analyses with Wilcoxon-Signed Rank Tests were conducted with a Bonferroni correction applied, resulting in a significance level set at $p<0.008$. There was a statistically significant difference in perceived influence of the app compared to the newsletters in regards to spending more time in the sun ($Z=-2.77, p=0.006$).

**Table 5.6: Mean rankings of intervention components on perceived influence of behaviour change (Feedback Survey, n=41)**

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Intervention Components</th>
<th>Intervention video M (SD)</th>
<th>Information slides M (SD)</th>
<th>Tips &amp; Tricks newsletters M (SD)</th>
<th>Vitamin D Calculator app M (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Make changes to dietary intake of foods containing vitamin D (n=25)</td>
<td>2.48 (0.82)</td>
<td>2.80 (1.00)</td>
<td>2.80 (0.91)</td>
<td>2.76 (1.05)</td>
<td></td>
</tr>
<tr>
<td>Make changes to dietary intake of foods containing calcium (n=24)</td>
<td>2.50 (0.83)</td>
<td>2.67 (0.82)</td>
<td>2.67 (0.82)</td>
<td>2.58 (1.10)</td>
<td></td>
</tr>
<tr>
<td>Take a supplement or multivitamin containing vitamin D (n=25)</td>
<td>2.36 (1.00)</td>
<td>2.52 (1.05)</td>
<td>2.60 (1.04)</td>
<td>2.36 (1.22)</td>
<td></td>
</tr>
</tbody>
</table>
In order to test the influence of the intervention components on actual behaviour change, separate regression models were used to predict vitamin D intake and supplement use from the FFQ at post-test. Bivariate correlations were run between socio-demographic factors and reported influence of the intervention components on the following two outcomes: making changes to dietary intake of foods containing vitamin D, and taking a multivitamin/supplement containing vitamin D. Responses to the item “how much would you say the [intervention component] influenced you to make changes to your dietary intake of foods containing vitamin D?” were used to predict mean vitamin D intake at post-test, using separate stepwise linear regressions. Baseline dietary vitamin D intake and any socio-demographic factors that were significantly correlated at \( p<0.05 \) were entered in the first block. Response to the item above was entered in the second block. Reported influence of the four intervention components (i.e., video, information screens, newsletters, or app) at making changes in dietary intake of foods containing vitamin D did not significantly predict mean vitamin D intake at time 3 (\( p>0.05 \) for all). Secondly, responses to the item “how much would you say the [intervention component] influenced you to take a supplement or multivitamin containing vitamin D?” were used to predict supplement use at time 3, using separate stepwise logistic regressions. Baseline supplement use and any socio-demographic factors that were significantly correlated at \( p<0.05 \) were included in the first block, and response to the item above was entered in the second block. None of the socio-demographic factors emerged as significant predictors. Results indicated that those who used vitamin D supplements at baseline (OR=18.65, 95% CI=1.79-194.68, \( p=0.01 \)) and reported greater influence of the intervention video at taking

<table>
<thead>
<tr>
<th>Spend more time in the sun (n=26)</th>
<th>2.65 (0.98)</th>
<th>2.58 (1.03)</th>
<th>2.69 (1.05)*</th>
<th>2.08 (1.09)*</th>
</tr>
</thead>
</table>

*Significantly different at \( p<0.008 \)
a supplement or multivitamin containing vitamin D (OR=2.28, 95% CI=1.03-5.06, \( p=0.04 \)) were significantly more likely to take a vitamin D supplement at post-test, \( R^2=0.43 \). The information slides, newsletters and app did not significantly predict vitamin D supplement use at time 3 (\( p>0.05 \) for all).

**DISCUSSION**

This study had many important findings; one being that vitamin D intake and status in this sample of young adults was low. At baseline, the sample had a mean daily vitamin D intake of only 229 IU from foods and beverages, with fewer than 9% of women and 17% of men meeting the EAR of 400 IU/day from food and beverage sources alone. When examining total dietary vitamin D intake (including vitamin D from supplements), the mean intake was 407 IU/day; however, 75% of women and 62% of men still failed to meet the EAR. This is concerning, given that the recommendations set by the IOM in 2010 (EAR and RDA of 400 and 600 IU/day, respectively) have been criticized for being too low (Schwalfenberg & Whiting, 2011) and that many health organizations now recommend intakes of 1000 IU/day or higher (CCS, 2015). It seems that the Canadian food supply may not currently provide enough vitamin D for most young adults to meet recommendations based on current dietary habits. This finding is in line with past research by Calvo & Whiting (2004), which found that current fortification levels in Canada and the USA were insufficient to prevent vitamin D insufficiency, and suggested that vitamin D supplements show some promise in helping to prevent insufficiency. The importance of supplemental vitamin D is clear; in the current study, participants who reported taking vitamin D supplements were much more likely to have a total vitamin D intake that met the recommendations. In fact, 91% of supplement users exceeded the EAR at baseline.
compared to only 14% of non-supplement users. Unfortunately, the impact of supplements currently has low reach in this population; about two-thirds (66%) of individuals indicated that they did not currently take supplements/multivitamins containing vitamin D at baseline. These findings are similar to those of Boland et al. (2015) who found that 61% of their undergraduate student sample did not take supplements containing vitamin D.

Vitamin D status, based on blood concentrations of 25(OH)D, at baseline was similarly low (M=27 nmol/L), falling well below the recommended concentrations of 50 nmol/L for bone health (IOM, 2010) and 75 nmol/L for optimal health and disease prevention (Dawson-Hughes et al., 2005; Vieth, 2011). These concentrations may place individuals at risk for negative health outcomes. Indeed, the IOM’s most recent review of dietary vitamin D and calcium stated, “this committee’s review of data suggests that persons are at risk of deficiency relative to bone health at serum 25OHD levels of below 30 nmol/L (12 ng/mL). Some, but not all, persons are potentially at risk for inadequacy at serum 25OHD concentrations between 30 and 50 nmol/L (12 and 20 ng/mL)” (IOM, 2010, p. 13). The mean blood vitamin D₃ concentration in this sample was much lower than the national average; the CHMS reported a mean of approximately 60 nmol/L among adults aged 18-25 (Statistics Canada, 2015a). However, it is important to note that a subsample of fewer than 60 participants completed the blood test, and a larger sample may have produced different results. Additionally, the CHMS participants were sampled from August 2009-November 2011 (Janz & Pearson, 2013); therefore, the mean vitamin D concentration reported in the 2012-2013 CHMS was likely higher due to the fact that blood samples were taken yearround rather than from September-March, as in the current study.
The mean blood vitamin D₃ concentrations in our sample (approximately 27 nmol/L at baseline and 43 nmol/L at post-test) were more similar to that of a study conducted by Gozdzik et al. (2008), who reported a mean 25(OH)D concentration of 39.4 nmol/L in their sample of young adults aged 18-30 living in Toronto, Ontario. As in the current study, Gozdzik and colleagues sampled based on ethnic background; however, given their more comprehensive sampling technique (including personal, parental, and grandparental places of birth, race, language, migration history, and current residence), these researchers were able to divide their sample into three population groups (European, East Asian and South Asian) and found significantly lower 25(OH)D concentrations in the non-European (31-35 nmol/L) compared to European participants (56 nmol/L). Gozdzik et al. (2008) had a larger sample size of 107 participants complete their blood test (versus 58 participants in the current study); given that we observed only a 4 nmol/L difference between our Caucasian and non-Caucasian samples, it is unsurprising that we had inadequate power to detect significant differences between groups. It is also of note that Gozdzik et al. (2008) reported a substantially lower mean total vitamin D intake (172 IU/day) than was found in the current study (407 IU/day at baseline). Given that the two studies had similar sample characteristics, this discrepancy may have been due to differences in the measurement of vitamin D intake; namely, the use of a FFQ in the current study versus a 7-day food diary by Gozdzik et al. (2008). Due to the large intra-individual variability in vitamin D intake, use of a food diary may have produced lower vitamin intake estimates than the FFQ. For instance, if an individual often consumes fish but did not consume it during the week they completed the 7-day food diary, their average vitamin D intake would have been
underestimated. On the other hand, an individual might overestimate their usual intake of foods containing vitamin D (such as fatty fish or milk) when completing a FFQ.

In terms of demographic differences in the current study, on average, a greater proportion of men met the vitamin D intake recommendations than did women. Given that the FFQ used in this study does not provide information on energy intake, it is unclear whether these trends can be attributed to a higher daily caloric intake in men (i.e., it is plausible that men consume more vitamin D incidentally due to a higher food and beverage intake), or other factors. Additionally, blood vitamin D₃ concentrations did not differ significantly by sex. Neither vitamin D intake nor status differed significantly in Caucasian vs. non-Caucasians, or by age, education level, Fitzpatrick Skin type or BMI, despite previous findings suggesting that vitamin D status tends to be lower among obese individuals and those who have darker skin pigmentation (NIH, 2011). This discrepancy in findings regarding vitamin D status may be due to a small sample size (i.e., a subset of 58 individuals completed the blood test). A *post hoc* sample size calculation was conducted to determine the sample size needed to adequately detect the observed difference in serum vitamin D₃ concentrations between Caucasians and non-Caucasians found in this study (4 nmol/L); results indicated that approximately 220 participants per group would have been required to detect a difference this small.

Comparing baseline to post-test results, we observed modest improvements in vitamin D intake. Examining total vitamin D intake across time, a statistically significant increase from pre- to post-intervention was observed in the intervention but not the control group.
Similarly, the proportion of participants in the intervention group who met the EAR of 400 IU/day at baseline vs. time 3 increased by almost double the amount in the control group (+22% vs. +12%, respectively), resulting in a greater proportion of intervention than control participants meeting the EAR at post-test (50% vs. 44%, respectively). Further, while the change in vitamin D intake increased from pre- to post-test in both groups, the effect of experimental group was significant. The mean increase in total vitamin D intake was approximately 43% greater in the intervention group (+308 IU/day) than in the control group (+131 IU/day). The additional 177 IU/day vitamin D consumed by intervention participants is roughly equivalent to consuming an extra 1¾ cups of milk or ¾ to 1 serving of oily fish per day\(^5\), an increase we feel is clinically relevant. In addition, the mean vitamin D intake from supplements increased significantly by 267 IU/day in the intervention group, while the control group had a non-significant increase of 126 IU/day. Cumulatively, these results suggest that the intervention model administered herein led to improvements in total vitamin D intake, largely due to increased supplemental vitamin D. These findings contrast those of Bohaty et al. (2008), who did not find significant increases in vitamin D or calcium intake after an educational intervention (which involved a slideshow presentation, group discussion, information packet and follow-up call) relating to calcium, vitamin D and osteoporosis. The additional components of our intervention (i.e., goal setting, plus self-monitoring and receiving personal feedback regarding intake via a mobile app) may have added to our relative success.

\(^5\) Vitamin D content of fish varies considerably by type and source.
It is also important to acknowledge the (non-significant) increases in vitamin D knowledge and intake among control participants. Although study advertisements and blood test materials did not specifically mention vitamin D, all participants completed three online surveys that contained questions related to vitamin D. Thus, a “study effect” may have existed, in which participants personally sought out more information about vitamin D after responding to questions relating to this topic. This may partly explain the findings among control participants, whose vitamin D knowledge and intake increased slightly despite the fact that they were not exposed to intervention materials. Alternatively, external factors may partially attribute to the increase in vitamin D intake in both groups, since vitamin D has been featured in the media in recent years (e.g., Beck 2015; Gillinov, 2014; Mercola, 2014; Picard, 2015). The increase in vitamin D knowledge may also have been influenced by the survey vehicle, since participants may have looked up information on the internet while completing the online survey (although they were instructed not to do so). Nevertheless, it is important to note that while the intervention and control groups had equal access to the internet and other external factors (e.g., media reports on vitamin D), significant differences were observed between the two groups. Thus, we can conclude that a genuine increase in vitamin D knowledge and intake did occur in the intervention group.

Similar to the increase observed in vitamin D intake, vitamin D status improved significantly from blood 25(OH)D concentrations of 27 nmol/L at baseline to 43nmol/L at post-test. Two assumptions regarding this increase are worth noting: (1) blood vitamin D concentrations at pre-test did not appear to be inflated by carryover from summer UVB (as noted above); and, (2) concentrations in the winter are expected to be equal to, or even
lower than those in the fall. Given that the change in status was not significantly different between the control and intervention groups, we can conclude that participation in the intervention alone did not appear to significantly influence 25(OH)D concentrations. This is unsurprising given that: a) we did not have adequate power to detect small differences in blood concentrations between groups; and, b) a multitude of factors affect circulating vitamin D concentrations. These include amount of sun exposure (which was recorded in the app but not measured empirically), and other environmental factors that affect UVB radiation levels, such as cloud cover, ozone levels, and amount of surface reflection (Webb & Engelsen, 2006). Perhaps most importantly, the amount of dietary vitamin D required to raise blood vitamin D concentrations (i.e., dose-response curve) differs widely across individuals (Aloia et al., 2008). Thus, even a consistent increase in intake (which was observed in the current study) would not uniformly raise serum levels. However, given that an increase from time 1 to 3 in both vitamin D intake and blood concentrations was observed in both groups, and intake and blood concentrations were positively correlated at post-test, participation in the vitamin D survey may have had an overall positive effect on vitamin D status (similar to the “study effect” mentioned above in relation to vitamin D knowledge and intake). This conclusion is supported by the fact that the demographic factors that typically affect vitamin D status (i.e., race, skin type, BMI) did not have significant effects on the change in blood vitamin D3, and that seasonality also had little effect.

Results also suggest that the intervention led to improved knowledge and perceptions of the young adults in this study. Initial vitamin D knowledge was fairly poor, as
demonstrated by the fact that only 6% of participants knew the recommended daily intake and 9% knew the upper limit for vitamin D at baseline. These findings align with those of the vitamin D knowledge survey conducted by Boland et al. (2015), in which 8% of participants correctly identified the recommended intake of vitamin D. Vitamin D knowledge in the current study increased over time in the intervention group, and only marginally in the control group; the net increase from baseline to follow-up was significantly higher in the intervention group than the control. Given that the increase in the intervention group was largest at time 2, the intervention video and vitamin D information slides seem to have had the greatest effect on knowledge among intervention participants. These findings are similar to those of Bohaty et al. (2008), who found increased knowledge of vitamin D, calcium and osteoporosis after an educational intervention (consisting of an educational slideshow, discussion and information packet). However, our findings extend those of Bohaty et al. (2008), whose study design did not include a control group. It is also important to note that the decrease in vitamin D knowledge from time 2 to time 3 was more drastic for intervention participants who used the app infrequently or not at all. This finding suggests that more frequent use of the app served to temper the decrease in vitamin D knowledge that occurred over time (i.e., from viewing of the video at time 2 to follow-up 12 weeks later). Lastly, when asked about the importance of taking vitamin D supplements, agreement was greater among the intervention group than the control group, suggesting that the intervention components had the intended effect of increasing perceived importance of vitamin D supplementation.
The intervention had only a modest effect on responses to items from the TPB and PWM. Intentions to take vitamin D supplements every day were higher at all time points in the intervention group. However, the effect of study group did not remain after adjusting for adherence, suggesting that use of the app may have influenced intentions to take vitamin D supplements. Secondly, prototype evaluations of the type of person who takes a vitamin D supplement every day were more positive at all time points and increased more from time 2-3 in the intervention group, suggesting that perceptions of vitamin D supplement users became more positive during and after the intervention period. In addition, reported consumption of at least 2 cups of milk per day increased more from time 2-3 in the intervention than the control group; however, in the adjusted model, there was a significant effect of adherence, and means were higher overall among the control group. This increase in ‘past behaviour’ may therefore have resulted from dietary tracking using the app; when this effect was controlled for, the effect of group disappeared. Comparing our findings to previous literature, Rivis et al. (2006) found that attitudes, past behaviour and perceived behavioural control were the strongest TPB predictors of health behaviour intentions, and that including prototype similarity and prototype evaluation (PWM) extended the model’s ability to predict intentions. Similarly, Pawlak et al. (2008) used the TPB to examine attitudes towards multivitamin use among college-aged women, and found that two attitudinal beliefs and one control belief significantly predicted intentions to take multivitamins. The current study was unique in that it measured changes in response to these items over time, and extends the findings of these studies to suggest that behavioural intervention may lead to changes in intentions, prototype evaluation and reported past behaviour. However, it is also important to note that after adjusting for
intervention adherence (i.e., number of app recordings) and baseline response, responses to certain constructs were higher in the control than intervention group and responses to a few constructs increased from time 2-3 in the control group while decreasing in the intervention group. This may reflect an increase in responses to these items from baseline to time 2 (immediately after intervention participants were shown the video and information slides on vitamin D), followed by a decrease at time 3, at which point some of this initial effect may have faded. This finding also highlights the importance of considering adherence when examining the effects of an intervention; perhaps factors other than experimental group (such as a study effect) contributed to higher responses in the control group.

In assessing the efficacy of the intervention, it is important to acknowledge that intervention adherence was less than ideal. Although participants were asked to record their intake in the app 3 times/week for 12 weeks (36 recordings), over a third of intervention participants did not submit any recordings. Among those who participated, the average adherence rate was about 58% (M=21 submissions out of the 36 requested). Overall, 66% of intervention participants submitted at least one app recording, and about 54% responded to the goal setting “check-in” email. Approximately 81% also reported reading at least one electronic vitamin D newsletter—although this was a self-report measure. Given that there is no gold standard for measuring adherence to different health behaviour interventions and that authors typically define adherence according to their study and the behaviour being examined (Vitolins, Rand, Rapp, Ribisl & Sevick, 2000), it is difficult to make cross-study comparisons regarding adherence. However, a systematic
review found that dietary adherence typically ranges from 13-78% (Burke & Dunbar-Jacob, 1995); our adherence rates fall within this range. Although our study was not a diet program *per se*, our intervention adherence rates are also comparable to those of other internet-based intervention programs targeting dietary behaviours. For instance, an online intervention study that aimed to prevent weight gain in undergraduate students reported an adherence rate of about 69% in their internet intervention group (Gow, Trace & Mazzeo, 2010). Similarly, an online fracture-risk intervention that assessed vitamin D intake reported that 59% of intervention participants completed all study components (online tutorials), while 38% completed less than 50% of the tutorials during the last three months of their study (Drieling et al., 2011). Thirdly, Hebden et al. (2014) conducted a mobile health program among young adults and reported overall improvements in body weight, fruit and vegetable intake, and sugar-sweetened beverage consumption; however, these changes did not significantly differ between the control and intervention groups. The authors suggested that low engagement with the intervention (web-based smartphone app, text messages and internet forums) might have contributed to the small effect of the intervention. Furthermore, as in the current study, all three studies reported lower retention rates in the intervention than control groups (Drieling et al., 2011; Gow et al., 2010; Hebden et al., 2014), suggesting that our findings are not atypical. Finally, Crutzen et al. (2011) conducted a systematic review of strategies to increase exposure to online behaviour change interventions targeting young adults and adolescents. The authors found that interventions that combined tailored communication (i.e., personalized feedback), reminders and incentives had higher exposure. All three strategies were elements of the
current intervention; our modest “exposure” rates (use of app, reach of newsletters, etc.)
might have been lower had these elements not been included.

Examining intervention components individually, we observed that app adherence was
higher among those with higher education levels. This finding is in line with previous
research in which individuals with higher education levels were more likely to adhere to a
dietary intervention (Hu et al., 2013). Somewhat surprisingly, the following variables
related to compliance were not significantly correlated with change in vitamin D intake, or
with vitamin D intake at time 3: number of app recordings submitted, number of
newsletters read, liking the app, or finding the app easy to use. However, the number of
app recordings completed among intervention participants was positively correlated with
the change in vitamin D knowledge from baseline to time follow-up and the change in
perceived importance of supplements from time 2-3, suggesting that using the app did
have a positive effect on outcomes related to knowledge and perceptions of vitamin D.
Goal setting also seemed to have a positive impact on behaviour change. Responding to
the goal setting “check-in” email was associated with an increase in vitamin D intake from
supplements, and higher ratings of goal ascertainment significantly predicted change in
supplemental vitamin D intake from pre- to post-test. It seems that setting a goal and
sticking to it may have increased participants’ motivation to take vitamin D supplements,
or to increase the amount of their current supplement.

Results of the feedback survey shed further light on the overall influence of the
intervention. Surprisingly, participants tended to rate the newsletters and information
slides as marginally more influential overall compared to the Vitamin D Calculator app and intervention video. These findings may point to a slight preference for text-based information when receiving nutrition information. Regardless, it is important to highlight the fact that higher reported influence of both the app and the intervention video predicted behaviour; namely, vitamin D supplement use at post-test. This finding suggests that non-print media and interactive tools are most useful for promoting behaviour change among those who are receptive to these mediums. Indeed, previous focus groups conducted by the author indicated that young adults vary considerably in their preference for different types of educational material (Goodman & Sheeshka, in preparation). We feel that our intervention model addressed this challenge fairly successfully by combining text, video and interactive app components to appeal to a wider audience.

Finally, examining effect of the intervention overall, we observed “small” to “medium” effects using partial eta squared (Cohen, 1969; as cited in Richarson, 2011) of experimental group for two of the primary outcomes: change in vitamin D intake ($\eta_p^2=0.05$) and vitamin D knowledge ($\eta_p^2=0.07$). Previous meta-analyses have found small effect sizes overall (using Cohen’s $d$ interpretations of effect) among online dietary behaviour change interventions ($d=0.20$, $k=10$, 95%CI=0.02-0.37; Webb, Joseph, Yardley & Michie, 2010) and healthy eating interventions ($d=0.31$, 95%CI= 0.23-0.39; Michie et al., 2009). Although partial eta squared and Cohen’s $d$ cannot be compared directly, it is notable that effect sizes for dietary interventions tend to be small but significant (Webb et al., 2010). Similarly, in the current study, experimental group (i.e., participation in the intervention) accounted for only small proportions of the variance in
the change in vitamin D intake and knowledge (5% and 7%, respectively). Interestingly, the systematic review by Webb et al. (2010) found that online health behaviour change interventions tended to have a greater effect if they incorporated theory—particularly the TPB, and that interventions that employed a greater number of behaviour change techniques tended to have larger effect sizes. In addition, Michie et al. (2009) found that use of more self-regulation strategies was associated with larger intervention effects, and that interventions that utilized self-monitoring plus at least one other technique from control theory (i.e., intention formation, specific goal setting, feedback on performance, self-monitoring, and review of behavioural goals) were significantly more effective than interventions that did not. The current intervention utilized the following self-regulation strategies, which may have added to its modest effects on vitamin D knowledge and intake: goal setting, feedback, self-monitoring, and goal review/assessment. Further, although intention formation was not required of participants, behavioural intentions were assessed at all three survey time points and participants may have subconsciously, or even directly considered their intentions to engage in the behaviours assessed. All in all, we feel that this study included many of the strategies cited as beneficial in behavioural interventions.

**Limitations**
This study was, of course, not without limitations. Firstly, as mentioned above, adherence was fairly low. Only two-thirds of intervention participants submitted recordings using the Vitamin D Calculator app, and just over half responded to goal-setting emails. Low adherence may have been a result of difficulty using the app, a lack of interest in the app or the study, a lack of time, or external factors. Results indicated that lower adherence (i.e., number of app recordings) was associated with dislike of the app and difficulty using
the app; these factors may have dissuaded some participants from regularly submitting recordings. Indeed, 34% of intervention participants did not submit app recordings, while similar numbers of individuals indicated that they did not like the app (39%), or found it difficult to use (37%). Given that intervention participants were also significantly more likely to drop out of the study than control participants, we can speculate that some intervention participants may have found three weekly app recordings to be too arduous or time consuming. Qualitative feedback from participants have been provided to the app developer and may be used in future upgrades to make the app more user-friendly. Future intervention studies using mobile apps might consider requiring participants to use the app less frequently, given that use of the app was lower than expected and that higher adherence was not associated with increased vitamin D intake.

Additionally, the Vitamin D Survey used herein was developed for the purpose of the current study and has not been externally validated. However, at the time of study development, no other vitamin D surveys or knowledge scales had been validated. The study by Boland et al. (2015) was published after our research had commenced, and their vitamin D knowledge scale was not externally validated. Given that vitamin D knowledge and perceptions were secondary outcome measures (our primary outcomes were vitamin D intake and status), externally validating our vitamin D survey was beyond the scope of the current study. As such, we do not propose that the knowledge subscale used herein be used as a standalone test of vitamin D knowledge by other researchers. However, given that we saw between-group differences (i.e., a greater increase in knowledge and higher perceived
importance of vitamin D supplementation in the intervention group), we feel that use of our vitamin D knowledge scale was justified as a measure of intervention efficacy.

Another limitation of the current study was that only 62% of participants completed both optional blood tests, leading to decreased power to detect differences in blood vitamin D₃ concentrations between groups. Future studies could include mandatory, rather than optional blood tests to ensure a larger sample size and increased power. Finally, this study was conducted with a sample of 18-25 year old adults living in Ontario, Canada; 68% of whom were students. Results cannot necessarily be generalized to older adults, or to young adults living in other locales (i.e., due to differences in climate, latitude, culture, food supply or dietary patterns).

**CONCLUSIONS**

This study has several potential public health implications. Firstly, vitamin D knowledge, intake and status in this sample of young adults were quite poor at baseline. Fewer than 10% of participants knew the recommended intakes for vitamin D, and three-quarters of women and over 60% of men failed to meet the EAR, even when accounting for vitamin D from supplements. Vitamin D status at baseline was also suboptimal; none of the participants met the recent recommendation of blood concentrations of 75 nmol/L for optimal health (Dawson-Hughes et al., 2005; Vieth, 2011) at baseline, and only four participants had blood concentrations ≥75 nmol/L at post-test. Even more troublingly, at baseline, only 9% met the more conservative recommendation of 50 nmol/L set by the
IOM (2010) and 71% had blood vitamin D₃ concentrations below 30 nmol/L; the cut-off used to indicate vitamin D deficiency relative to bone health (IOM, 2010).

A behavioural intervention that consisted of information conveyed through an online video, slides, and electronic newsletters, as well as dietary tracking through the mobile Vitamin D Calculator app, was fairly successful at improving intake, knowledge and perceived importance of vitamin D in this sample of young adults. At post-test, the intervention group displayed a significant increase in vitamin D intake from supplements, and an increase in vitamin D intake of 308 IU/day (equivalent to 3 cups of milk, or about 1½ servings of oily fish). Future researchers could adapt this intervention model (noting the limitations mentioned above) to increase knowledge and intake of different foods and nutrients, or to promote other health-protective behaviours. Furthermore, given that daily vitamin D intake among the control group also increased by 131 IU after participating in surveys related to vitamin D, a targeted public health campaign aiming to increase awareness of the importance of vitamin D for health might be sufficient to improve intake among young adults (i.e., without the resources required to administer an intensive intervention). Such a campaign might aim to increase consumption of dietary sources of vitamin D (such as milk or oily fish), or perhaps more appropriately, the use of vitamin D supplements. Vitamin D supplement users in the current study were much more likely to meet the EAR than non-supplement users, pointing to supplemental vitamin D as an important focus for health interventions, and a significant tool with which to help individuals meet their vitamin D requirements.
The findings of this study also have policy implications. The low vitamin D intake and status of young adults in this sample support the need for higher fortification levels in the Canadian food supply. This could occur by increasing current fortification levels (i.e., increasing the amount of vitamin D added to fluid milk and margarine) and requiring equal fortification of all plant-based milk alternatives, to ensure equal access to vitamin D-enriched products among the growing number of individuals who do not drink cow’s milk. Alternatively, vitamin D fortification could be expanded to other dietary staples. Fortified flour (i.e., Lallemand, 2012), bread (i.e., Stonemill Bakehouse, 2015), cereal (i.e., Kellogg’s, 2013), orange juice (e.g., President’s Choice, 2015; Tropicana, 2013) and yogurt (e.g., Danone Activia, 2015) have begun to emerge on the Canadian marketplace, and represent a potential avenue with which to increase dietary vitamin D intake at the population level. A substantial increase in fortification of the food supply could also negate the need for individual vitamin D supplementation. This point is critical given that supplement use was relatively uncommon in our sample and other populations of young adults (i.e., Boland et al., 2015), and that adherence to vitamin supplements tends to be low in general (Vieth, 2012). Lastly, toxicity is always a concern when considering food fortification—especially with fat-soluble vitamins. Thus, future studies should determine the maximum fortification level(s) that would help Canadians safely increase vitamin D intakes to meet current recommendations for optimal health.

**List of Abbreviations**

25(OH)D = 1-25-dihydroxycholecalciferol, or serum vitamin D₃ concentration

ANOVA = Analysis of variance

BMI = Body mass index
CCHS = Canadian Community Health Survey
CHMS = Canadian Health Measures Survey
EAR = Estimated Average Requirement
FFQ = Food frequency questionnaire
IOM = Institute of Medicine
PWM = Prototype Willingness Model
RDA = Recommended Dietary Allowance
SD = Standard deviation
SE = Standard error
TPB = Theory of Planned Behaviour
UL = Tolerable Upper Limit

**Competing Interests**

Blood test materials were provided by public health promotion organization GrassRoots Health (http://www.grassrootshealth.net/) and funded by The Vitamin D Society (http://www.vitamindsociety.org/), both of which are non-profit organizations. As such, neither the authors of this study nor the organizations serve to profit financially from the publication of this manuscript.

**Authors’ Contributions**

SG conceived of the study, developed survey measures, conducted data collection and statistical analysis, and drafted the manuscript. BM and KM guided study design and data analysis and revised the manuscript. JRS participated in the study design and manuscript revisions. All authors read and approved the final manuscript.
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Acknowledgments

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CHAPTER 6: Use of behaviour change theories to predict vitamin D intake among young adults

Authors: Samantha Goodman, MSc; Barbara Morrongiello, PhD; Kelly Meckling, PhD

ABSTRACT

Objective: To determine whether a model including items from the Theory of Planned Behaviour and Prototype Willingness Model could predict health-protective behaviours or intentions related to vitamin D (vitamin D supplementation, eating fish, drinking milk, spending time in the sun).

Methods: An online survey, food frequency questionnaire and blood spot tests were administered to a sample of adults aged 18-25 living in Canada.

Results: The sample consisted of 109 men (48%) and women (52%). Past behaviour, perceived behavioural control (PBC), behavioural expectations, and prototype evaluation significantly predicted intentions. Past behaviour significantly predicted vitamin D intake and supplement use, fish and milk intake; intentions predicted supplement use, and PBC predicted milk consumption (p<0.05 for all). Prototype evaluation predicted blood vitamin D$_3$ concentrations (p<0.05).

Conclusions and Implications: The theoretical model was better at predicting behavioural intentions than actual behaviours. Past behaviour was the most useful predictor of current behaviours related to vitamin D.
INTRODUCTION

Vitamin D is crucial for maintaining adequate bone health, and helps to prevent rickets in children and osteomalacia in adults (IOM, 2010). Beyond this classical function, research suggests that vitamin D plays a critical role in the immune system and that low vitamin D status is associated with an increased risk of cancer, hypertension, cardiovascular disease, diabetes mellitus, multiple sclerosis, and cognitive decline (Scwhalfenberg, 2007). Peak bone mass is reached during the late teens and early twenties and cannot be increased after approximately age 25-30 (Abrams, 2003). Bone density tends to decline with age, and the age-associated decrease in bone mass can lead to bone fractures in later life (Russo et al., 2003). As such, adequate intake of vitamin D and calcium is especially important during young adulthood, a critical window for the accumulation of skeletal mass (Heaney et al., 2000).

The period from 18-25 years of age is sometimes referred to as “emerging adulthood,” a period of increased independence and autonomy that is considered vital for developing patterns of long-term health behaviours (Nelson, Story, Larson, Neumark-Sztainer & Lytle, 2008). This newfound autonomy may be characterized by changes to existing dietary patterns due to the increased freedom to make food-purchasing decisions and/or to eat outside the home. Research has shown changes in food group consumption during the transition from childhood to young adulthood, including increased sugar-sweetened beverage and decreased milk consumption (Demory-Luce et al., 2004). Replacing milk with other beverages at meals could lead to decreased calcium and vitamin D intake, which has implications for bone health. Indeed, women of reproductive age who drank
more carbonated beverages and did not consume milk at dinner had a greater risk of osteopenia and a higher likelihood of bone fractures earlier in life (Sámano et al., 2013).

Despite the fact that habits relating to long-term health are formed during this time (Nelson et al., 2008), young adulthood is also a period often characterized by feelings of invincibility. This includes a lack of consideration for the consequences of risky health behaviours and the sense that one is impervious to negative health outcomes; leading some to coin the term “young invincibles” to describe this age group (Bibbins-Domingo and Burroughs Peña, 2010). In order to supersede these feelings of invulnerability and encourage healthy dietary habits, it is imperative to explore the factors that predict behaviour and risk-taking among young adults.

The Theory of Planned Behaviour (TPB; Azjen, 1991) is a widely used theory in health behaviour research. The TPB theorizes that attitudes, subjective norms, and perceived behavioural control are all important predictors of behavioural intentions, and that perceived behavioural control influences intentions and behaviours (Azjen, 1991). The Prototype Willingness Model (PWM; Gibbons et al., 1998) addresses the fact that individuals engage in certain behaviours (especially risky ones) despite a lack of intention. This is especially true among adolescents and young adults, who may be driven more by willingness to engage in a behaviour than by conscious intention (Gerrard, Gibbons, Houlihan, Stock & Pomery, 2008a). Risk prototypes (i.e., perceptions of people who engage in risky behaviours) are influenced more by intuition than by logical reasoning, and predict willingness to engage in a specific behaviour (Gerrard et al., 2008a). Research
indicates that when adolescents have little experience with a particular behaviour, they are less likely to have intentions to engage in it, and willingness becomes the primary predictor of behaviour. However, as adolescents become more familiar with this behaviour, expectations and intentions may become stronger predictors of behaviour than willingness (Gerrard et al., 2008a). Thus, prototype evaluation (which influences willingness) and behavioural expectations, are two additional constructs that influence behaviour (see Figure 6.1).

The TPB has been used to successfully predict intentions to engage in a range of health-protective behaviours, including positive dietary habits such as use of multivitamins (Pawlak et al., 2008) and vitamin D supplements (de Nooijer, Onnink, & van Assema, 2010), intake of vitamin D and calcium (Lv & Brown, 2011) and healthy eating habits (Carson, 2010; Chan & Tsang, 2011; Conner, Bell & Norman, 2002; Middleton, 2007). In contrast, the PWM is most often used to predict willingness of youth or young adults to engage in unhealthy or risky behaviours, including smoking behaviours and initiation (Gerrard, Gibbons, Stock, VandeLune & Cleveland, 2005; Sommer Hukkelberg & Dykstra, 2009). The two models have also been used in conjunction; often to predict risky behaviours such as driving while intoxicated (Rivis, Abraham and Snook, 2011; Todd & Mullan 2011).

Given that its initial focus was on willingness to engage in health-risk behaviours (Gibbons et al., 1998), the PWM has seldom been applied to health-protective behaviours. One study combined the TPB and PWM to predict both risky and health-protective
behaviours among adolescents, and found that the PWM enhanced the predictive effect of the TPB. Specifically, perceived similarity to prototypes (a key element of the PWM) most consistently predicted behavioural intention after accounting for TPB variables (Rivis, Sheeran & Armitage, 2006). The PWM has also been used in a few studies to examining skin protection behaviours (Gerrard et al., 2008b; Matterne et al., 2011). Only recently has the PWM been used in the realm of diet and nutrition; a longitudinal study used the PWM to predict adolescent eating behaviour, and found that it predicted healthy but not unhealthy snack consumption (Dohnke, Steinhilber & Fuchs, 2015). While the TPB has been used to predict the use of multivitamins (Pawlak et al., 2008) and vitamin D intake (de Nooijer et al., 2010; Lv & Brown, 2011), to our knowledge the PWM has not yet been used to predict these health-protective behaviours. The current study therefore aimed to combine elements of the TPB and PWM into one model to predict health-protective behaviours among young adults (see Figure 6.1).

The primary objective was to determine whether this model could be used to predict behavioural intentions or actual behaviour (i.e., vitamin D intake) among young adults living in Canada. Given that vitamin D status (i.e., serum 25(OH)D concentration) is influenced by both dietary intake and exposure to sunlight, we also examined the relationship between TPB and PWM variables and vitamin D status in this population.

**METHODS**

**Participants & Recruitment**

Research participants consisted of young men and women aged 18-25 years. Participants were recruited from the University of Guelph and throughout Ontario using poster and online advertisements. Eligibility criteria included being 18-25 years of age, being fluent
in English, currently living in Ontario and owning an iPhone, iPad or iPod Touch (running iOS 7.0 or higher). Quota sampling was used to recruit equal numbers of males and females and to ensure that about half of the sample was non-Caucasian.

**Procedure**

Participants were recruited for a larger online intervention study (ClinicalTrials.gov registration #NCT02118129) that aimed to increase knowledge, perceptions, intake and status of vitamin D among young adults. This study followed a pre-post control group design and has been described elsewhere (Goodman, Morrongiello, Randall Simpson & Meckling, in preparation). As part of the larger study, participants completed surveys at three time points (n=90); the current study examines the baseline data collected at the first time point, during fall 2014 (N=109). After initial recruitment, participants provided informed consent by agreeing to an online consent form. Participants then completed the first online survey, which consisted of: (1) a socio-demographic questionnaire, (2) a survey that gathered information on knowledge, perceptions and beliefs surrounding vitamin D, and (3) a food frequency questionnaire (FFQ) specific to vitamin D and calcium intake. On the last page of the survey participants indicated whether they agreed to participate in the optional blood-testing component of the study. Those who opted in to this component were sent a blood spot test kit, which was used to assess baseline vitamin D status. Due to the control group design of the larger intervention study, the consent form stated that the test measured “blood levels of specific nutrients”, but did not directly mention vitamin D. Upon completion of the larger study, participants were mailed a debriefing letter and received a gift card equal to $50 (or $70 if they participated in the blood testing component). Online surveys were administered via LimeSurvey version
1.91+ (LimeSurvey, 2012), and survey data were stored on a secure SSL-enabled server at the University of Guelph. This study received approval from the University of Guelph Research Ethics Board (#14MY027).

Measures

The socio-demographic questionnaire gathered general demographic information, including age, sex, race, and education level, height and weight. The Vitamin D Survey was developed by the researchers and consisted of 33 questions that examined vitamin D consumption habits, perceptions and behaviours regarding sun exposure, and knowledge of vitamin D. The last section of this survey consisted of nine items adapted from TPB and PWM by Rivis et al. (2006), who measured three health-protective and three risky behaviours. In the current study, four health-protective behaviours related to vitamin D were measured: (a) “take a vitamin D supplement every day,” (b) “eat one to two servings of fish per week”; (c) “drink at least two cups of cow’s milk (or enriched non-dairy alternative such as soy/almond/coconut/goat’s milk) per day”; and (d) “spend 15-30 minutes in the sun without sunscreen, with at least some skin exposed, twice per week”.

The ability of the theoretical model to predict the four health protective behaviours was assessed using the following constructs: behavioural expectations (Gerrard et al., 2008a), behavioural intentions, subjective norms, descriptive norms, perceived behavioural control, past behaviour, prototype evaluation and prototype similarity (Rivis et al, 2006). Complete item wordings are listed in Table 6.1. The definition of a prototype used within the survey and by Rivis et al. (2006) was originally taken from Gibbons, Gerrard, and Boney McCoy (1995, p. 85); the researchers of the current study developed the response options for the item related to prototype evaluation. The FFQ was developed and validated
by Wu et al. (2009) to estimate vitamin D and calcium intake. The FFQ asks participants to indicate how much (if any) of each item they consume in a typical month, and to list any nutritional supplements they currently take. The blood spot test kits consisted of a lancet (“finger prick”), a blood spot test card, an alcohol swab, a bandage, and instruction sheet. Participants self-administered the finger prick test at home and returned it to the researchers.
Figure 6.1: Theoretical Model

- Past Behaviour
- Prototypes
  - Behavioural Willingness
- Expectations
- Subjective Norms
  - Normative Beliefs
  - Control Beliefs
- Perceived Behavioural Control
  - Behavioural Intentions
    - Behaviour

**Note:** Concepts with solid lines are directly measured in the current study; latent concepts are indicated with dash lines.
Table 6.1: Theoretical Construct Survey Items (used in Intervention Study)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Item Wording and Sub-Questions</th>
<th>Response Options and/or Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Behavioural expectations</strong></td>
<td>Now we are going to ask a few questions regarding your attitudes towards a list of behaviours. Please indicate your responses on the scale beside each question.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>To what extent would you be <strong>likely</strong> to do each of the following behaviours, if the opportunity arose?</td>
<td>5-point Likert scale: 1. Not at all likely 2. A little likely 3. Somewhat likely 4. Fairly likely 5. Very likely</td>
</tr>
<tr>
<td></td>
<td>a. Take a vitamin D supplement every day</td>
<td></td>
</tr>
<tr>
<td></td>
<td>b. Eat one to two servings of fish per week</td>
<td></td>
</tr>
<tr>
<td></td>
<td>c. Drink at least two cups of cow’s milk (or enriched non-dairy alternative such as soy/almond/coconut/goat’s milk) per day</td>
<td></td>
</tr>
<tr>
<td></td>
<td>d. Spend 15-30 minutes in the sun without sunscreen, with at least some skin exposed, twice per week</td>
<td></td>
</tr>
<tr>
<td><strong>2. Subjective norms</strong></td>
<td>How much do people who are important to you think you should do each of the following over the next month?</td>
<td>5-point Likert scale: 1. Not at all; they wouldn’t care if I did this 2. A little 3. Somewhat 4. A fair amount 5. A lot; they would want me to do this</td>
</tr>
<tr>
<td></td>
<td>a. Take a vitamin D supplement every day</td>
<td></td>
</tr>
<tr>
<td></td>
<td>b. Eat one to two servings of fish per week</td>
<td></td>
</tr>
<tr>
<td></td>
<td>c. Drink at least two cups of cow’s milk (or enriched non-dairy alternative such as soy/almond/coconut/goat’s milk) per day</td>
<td></td>
</tr>
<tr>
<td></td>
<td>d. Spend 15-30 minutes in the sun without sunscreen, with at least some skin exposed, twice per week</td>
<td></td>
</tr>
</tbody>
</table>
| **3. Descriptive norms (2 items)** | (A) What **percentage** of people your age do you think do each of the following? Please type a number between 0 and 100%.  
(b) What **percentage** of people your age that you know do you think do each of the following? Please type a number between 0 and 100%. | Enter a number from 0-100 |
<p>|                                 | a. Take a vitamin D supplement every day                                                       |                                                                                                 |
|                                 | b. Eat one to two servings of fish per week                                                     |                                                                                                 |
|                                 | c. Drink at least two cups of cow’s milk (or enriched non-dairy alternative such as soy/almond/coconut/goat’s milk) per day |                                                                                                 |</p>
<table>
<thead>
<tr>
<th></th>
<th>soy/almond/coconut/goat’s milk) per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>d.</td>
<td>Spend 15-30 minutes in the sun without sunscreen, with at least some skin exposed, twice per week</td>
</tr>
</tbody>
</table>

4. Perceived behavioural control

<table>
<thead>
<tr>
<th></th>
<th>How easy would it be for you to do each of the following over the next month?</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>Take a vitamin D supplement every day</td>
</tr>
<tr>
<td>b.</td>
<td>Eat one to two servings of fish per week</td>
</tr>
<tr>
<td>c.</td>
<td>Drink at least two cups of cow’s milk (or enriched non-dairy alternative such as soy/almond/coconut/goat’s milk) per day</td>
</tr>
<tr>
<td>d.</td>
<td>Spend 15-30 minutes in the sun without sunscreen, with at least some skin exposed, twice per week</td>
</tr>
</tbody>
</table>

5-point Likert scale:
1. Not at all easy
2. A little easy
3. Somewhat easy
4. Fairly easy
5. Very easy to do if I wanted to

5. Behavioural Intentions

On a scale of 1 to 100, where 0=I do not intend to do this at all and 100=I definitely intend to do this...

How much do you intend to do each of the following over the next month? Please type a number between 0 and 100%.

<table>
<thead>
<tr>
<th></th>
<th>Take a vitamin D supplement every day</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td></td>
</tr>
<tr>
<td>d.</td>
<td></td>
</tr>
</tbody>
</table>

Enter a number from 0-100

6. Past Behaviour

How often have you done each of the following over the last month?

<table>
<thead>
<tr>
<th></th>
<th>Taken a vitamin D supplement every day</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td></td>
</tr>
<tr>
<td>d.</td>
<td></td>
</tr>
</tbody>
</table>

5-point Likert scale:
1. Never
2. Rarely
3. Sometimes
4. Frequently
5. Every day/each time

The following questions concern your images of people. For example, we all have ideas about what typical movie stars are like or what the typical grandmother is like. We might think of the typical movie star as being pretty or rich, and the typical grandmother as sweet and frail. We are not saying that all movie stars or all grandmothers are exactly alike, but rather that many of them share certain characteristics.
7. Prototype Evaluation

Think about the **type of person** who does each of the following behaviours.

Pick from the following words to describe **YOUR impression of this type person**, including any negative or positive thoughts that go through your mind as you think about this type of person.

a. Takes a vitamin D supplement every day
b. Eats one to two servings of fish per week
c. Drinks at least two cups of cow’s milk per day (or non-dairy alternative such as fortified soy/almond/coconut/goat’s milk)
d. Spends 15-30 minutes in the sun without sunscreen, with at least face, arms, leg or back exposed, twice per week

Select all that apply from the following list of adjectives (randomized):

- Smart
- Foolish
- Worrier
- Control freak
- Conscientious
- Healthy
- Wasting their time and/or money
- Fit
- Health conscious
- Diet-obsessed

8. Prototype Similarity

In general, how **similar are you** to the **type of person your age** who does the following? *(Please think for a moment about the type of person that does each behaviour before indicating your response).*

a. Takes a vitamin D supplement every day
b. Eats one to two servings of fish per week
c. Drinks at least two cups of cow’s milk per day (or non-dairy alternative such as fortified soy/almond/coconut/goat’s milk fortified with vitamin D)
d. Spends 15-30 minutes in the sun without sunscreen, with at least face, arms, leg or back exposed, twice per week

5-point Likert scale:
1. Not at all similar to me
2. A little similar to me
3. Somewhat similar to me
4. Fairly similar to me
5. Very similar to me
Data Analysis

Mean vitamin D intake for each participant was computed using a Microsoft Excel template provided by the FFQ developer (S. Whiting, personal communication, May 16, 2014). Blood spot test cards were analyzed using liquid chromatography-tandem mass spectrometry (ZRT Laboratory, 2015) to assess participants’ baseline vitamin D₃ concentrations. Statistical analyses were performed using SPSS version 22.0 (SPSS Statistics, Armonk, NY, IBM Corp., 2013). All variables were continuous with the exception of sex and race; race was recoded from a categorical to a binary variable (1=Caucasian, 0=Non-Caucasian). Body mass index (BMI) was calculated using reported height and weight (kg/m²). The World Health Organization international classification of BMI cut-offs (WHO, 2015) was used to determine weight status. Bivariate correlations were used to examine the association between the independent variables (IVs; behavioural expectations, subjective norms, descriptive norms, behavioural intentions, perceived behavioural control (PBC), past behaviour, prototype evaluation and prototype similarity) dependent variables (DV; vitamin D₃ concentration and mean daily vitamin D intake), and socio-demographic factors (i.e., sex, age, race, education level and BMI) for each of the four health-protective behaviours.

Separate linear regression models were used to test whether any of the aforementioned TPB or PWM variables were predictors of behavioural intentions, vitamin D consumption (i.e., mean vitamin D intake from FFQ) or status (i.e., vitamin D₃ from blood spot test). Separate binary logistic regression models were conducted to test whether TPB and PWM items referring to taking a vitamin D supplement every day, eating at least 1-2 servings of
fish per week, or drinking at least 2 cups of milk per day were predictive of the following dietary behaviours from the FFQ: reported use of vitamin D supplements, consumption of ≥1 serving of fish/week, and consumption of ≥2 cups of milk/day, respectively. Use of vitamin D supplements was coded as a binary variable (0= no reported supplement use, 1= reported supplement use ≥1 IU). Total fish intake (IU) was computed by summing intake of the following six FFQ items: canned salmon, canned tuna, sardines, salmon steak, white fish, and other oily fish. Total milk intake (IU) was computed by summing intake of the following seven FFQ items: milk, chocolate milk, fortified soy milk, unfortified soy milk, other plant-based milks, milk in coffee or tea, and milk on cereal. These variables were then recoded into binary variables related to the survey items: consuming ≥1 serving of fish/week (0= 0-27.99 IU, 1= ≥28 IU) and drinking ≥2 cups of milk/day (0= 0-195.99, 1= ≥196 IU). Intake values from the FFQ were used to determine the cut-points for these binary variables; one serving of oily fish on the FFQ was equal to 196 IU (1 serving/week= 196 IU/7 days=28 IU/week), and one serving of milk on the FFQ was equal to 98 IU (two servings/day= 98 IU x 2= 196 IU/day). Nagelkerke $R^2$ values are reported for logistic regression models. Finally, a sub-group analysis was conducted with control participants only (n=49), using data from both baseline and follow-up (M=110 days, SD=21) from the larger study (chapter 5; Goodman et al., in preparation). Intervention participants were excluded due to expected effects of the behavioural intervention described in chapter 5. Intentions of engaging in the four health behaviours at time 1 were entered into separate stepwise regression models predicting the following behaviours at time 3: vitamin D intake (linear regression), vitamin D$_3$ concentrations (linear regression) and vitamin D supplement use (binary logistic regression).
RESULTS

Sample characteristics

The sample consisted of 109 participants: 48% (n=52) men and 52% (n=57) women. The mean age was 21.8 (SD=2.1) years; 65% were students and approximately half (52%) the sample was Caucasian. Sample characteristics are listed in Table 6.2. Normality testing indicated that vitamin D intake data were positively skewed; the natural logarithm transformation successfully corrected the normality of the mean vitamin D intake variable. Transformed data were used in analyses involving this variable and are reported herein; means and SDs for daily intake are reported using untransformed data, for ease of interpretation. Data from the FFQ (n=109) indicated that the mean daily vitamin D intake (supplements plus food and beverages) was 450 IU (SD=510). Among the 58% of participants (n=63; 24 men and 39 women) who completed the optional blood test at baseline, the mean blood 25(OH)D level was 27 (SD=16) nmol/L. Blood vitamin D₃ levels did not significantly differ across sex, age, race, BMI, or education level (p>0.05 for all). Additional information regarding the vitamin D intake and status of this sample over the three survey time points (n=90) are outlined in chapter 5 (Goodman, Morrongiello, Randall Simpson & Meckling, in preparation).

Table 6.2: Baseline Sample Characteristics of Young Adults aged 18-25 (n=109)

<table>
<thead>
<tr>
<th>Socio-demographic Characteristics</th>
<th>% (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sex</strong></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>48% (52)</td>
</tr>
<tr>
<td>Female</td>
<td>52% (57)</td>
</tr>
<tr>
<td><strong>Age (years)</strong></td>
<td></td>
</tr>
<tr>
<td>18-19</td>
<td>18% (20)</td>
</tr>
</tbody>
</table>
Predicting vitamin D-related behaviours using the theoretical model

Bivariate correlations between IVs, DVs and socio-demographic factors are displayed in Table Q.6 (Appendix Q). Results indicated that none of the socio-demographic variables (age, sex, race, BMI, education) were significant predictors in stepwise linear regression models predicting behavioural intentions, mean daily vitamin D intake, or blood vitamin D₃ (p>0.05). Independent samples t-tests indicated that the three dietary behaviours

| 20-21 | 27% (29) |
| 22-23 | 27.5% (30) |
| 24-25 | 27.5% (30) |
| **Race** | |
| Caucasian | 52.3% (57) |
| Non-Caucasian | 47.7% (52) |
| **Highest level of education** | |
| Some high school, or high school diploma | 19% (21) |
| Some college, college diploma or professional certificate | 14% (15) |
| Some university, or undergraduate degree | 58% (63) |
| Some graduate school, or graduate degree | 9% (10) |
| **Student status** | |
| Currently a student | 65% (71) |
| **Employment status** | |
| Not employed | 36% (39) |
| Part-time | 38.5% (42) |
| Full-time | 25% (27) |
| Prefer not to say | 1% (1) |
| **Nutrition Background** | |
| Has taken a nutrition course in the past | 37% (40) |
| Employment or program of study related to health or nutrition | 24% (26) |
| **Food Purchasing Responsibility** | |
| Has complete responsibility, or is the primary shopper | 51% (56) |
| Shared equally with another person | 21% (23) |
| Someone else is primarily responsible or has complete responsibility | 28% (30) |
| **BMI Classification** | |
| Underweight (<18.5) | 6% (6) |
| Normal weight (18.5-24.9) | 57% (62) |
| Overweight (25.0-29.9) | 23% (25) |
| Obese (≥30) | 14% (15) |
(vitamin D supplement use, consuming at least one serving of fish/week, and/or drinking at least two cups of milk/day) did not differ significantly by sex or race, and were not significantly correlated with any of the following socio-demographic factors: sex, age, race, education or BMI ($p>0.05$). Therefore, no demographic factors were entered as covariates of stepwise logistic regression models; all TPB and PWM variables were entered into the models.

**Taking a vitamin D supplement.** For survey items relating to taking a vitamin D supplement every day, past behaviour ($\beta=0.61$, $p<0.001$), behavioural expectations ($\beta=0.25$, $p=0.001$) and PBC ($\beta=0.14$, $p=0.04$) accounted for 68.3% of the variance in intentions to take a vitamin D supplement ($R^2=0.68$, $F(3, 105)=75.26$, $p<0.001$). When examining behavioural outcomes, past behaviour was the only significant predictor of mean daily vitamin D intake, $\beta=0.56$, $p<0.001$ and accounted for 31.2% of the variance in this model ($R^2=0.31$, $F(1, 107)=48.51$, $p<0.001$). No items significantly predicted vitamin D$_3$ concentrations. Those who reported more frequent past vitamin D supplementation (past behaviour; OR=1.88, 95% CI=1.07-3.30, $p=0.03$) and higher behavioural intentions (OR=1.03, 95% CI=1.01-1.05, $p=0.01$) were significantly more likely to take a vitamin D supplement, $R^2=0.53$.

**Eating fish.** A model consisting of behavioural expectations ($\beta=0.37$, $p<0.001$), past behaviour ($\beta=0.27$, $p=0.001$), PBC ($\beta=0.21$, $p=0.02$), descriptive norms (B) ($\beta=0.12$, $p=0.04$), and prototype evaluation ($\beta=0.12$, $p=0.04$) accounted for 73.8% of the variance in intentions to eat fish 1-2 times/week ($R^2=0.74$, $F(5, 103)=58.11$, $p<0.001$). Although no survey items related to eating fish significantly predicted actual mean vitamin D intake,
prototype evaluation was a significant predictor of vitamin D₃ concentrations, β=0.25, p=0.04; although it accounted for only 6.5% of the variance in the model (R²=0.07, F(1, 61)=4.22, p=0.04). Similarly, those with more positive prototype evaluations towards eating fish were somewhat more likely to consume at least one serving of fish/week (as per the FFQ); however, this trend was non-significant (p=0.09). Those who reported more frequently consuming 1-2 serving of fish/week in the past (i.e., past behaviour) were significantly more likely to consume at least one serving of fish/week, OR=2.31, 95% CI=1.53-3.50, p<0.001, R²=0.24.

Drinking milk. Past behaviour (β=0.45, p<0.001), behavioural expectations (β=0.39, p<0.001) and prototype evaluation (β=0.20, p<0.001) accounted for 75.2% of variance in intentions to drink ≥2 cups of cow’s milk (or milk alternatives) per day (R²=0.75, F(3, 105)=105.92, p<0.001). Past behaviour was a significant predictor of actual mean vitamin D intake, β=0.42, p<0.001 and accounted for 17.2% of the variance in the model (R²=0.17, F(1, 107)=22.24, p<0.001). No items significantly predicted vitamin D₃ concentrations. Those who reported more frequently consuming ≥2 cups milk/day in the past (i.e., past behaviour; OR=7.89, 95% CI=3.12-19.95, p<0.001) and reported higher PBC (OR=0.43, 95% CI=0.20-0.92, p=0.03) were significantly more likely to drink at least 2 servings of milk/day, R²=0.43.

Spending time in the sun. Lastly, PBC (β=0.41, p<0.001), past behaviour (β=0.33, p<0.001), and behavioural expectations (β=0.16, p=0.04) accounted for 48.2% of the variance in intentions to spend time in the sun for 15-30 minutes, twice per week without sunscreen (R²=0.48, F(3, 105)=32.59, p<0.001). No survey items related to the sun significantly predicted daily vitamin D intake or vitamin D₃ concentrations.
Do baseline intentions predict future behaviours? Results of a sub-group analysis with control participants only (n=49) indicated that overall, intentions at baseline did not predict future behaviours. Specifically, intentions to engage in any of the four health behaviours were not significant predictors of blood vitamin D$_3$ concentrations at follow-up, and intentions to take vitamin D supplements at baseline did not significantly predict supplement use at follow-up, after controlling for baseline supplement use (data not shown). Of the four health behaviours, only intentions to drink $\geq$2 cups of milk/day significantly predicted mean vitamin D intake at follow-up ($\beta$=0.34, $p$=0.02).

DISCUSSION

The theoretical model used herein was quite useful for predicting behavioural intentions, but less effective at predicting vitamin D intake and status. Specifically, five factors from the theoretical model (past behaviour, PBC, behavioural expectations, prototype evaluation and descriptive norms) predicted behavioural intentions, whereas past behaviour was the sole predictor of intake (and emerged for only two health behaviours), and prototype evaluation related to eating fish was the only predictor of blood vitamin D$_3$ concentrations.

Examining the results individually, we see that behavioural expectations were predictive of intentions to engage in all four health-protective behaviours. This finding is logical; a higher likelihood of engaging in a particular behaviour should correspond with higher intentions to do so. Likewise, the importance of past behaviour in predicting intentions to engage in the four behaviours was unsurprising, as having engaged in a healthy behaviour in the past might lead to higher intentions to do so again. Indeed, those who reported
higher frequency of past vitamin D supplementation, fish and milk consumption (i.e.,
higher reported past behaviour) were significantly more likely to have taken a vitamin D
supplement, consumed at least one serving of fish per week, or drank at least 2 cups of
milk per day, as measured by the FFQ. Additionally, reported past vitamin D
supplementation and milk consumption were predictive of total daily vitamin D intake.

Finally, PBC was a significant predictor of behavioural intentions for three of the four
health behaviours: vitamin D supplementation, eating fish and spending time in the sun.
PBC represents the perceived ease of engaging in a particular behaviour; our results show
that higher levels of control corresponded with higher intentions to engage in these
behaviours. Further, those with higher reported PBC related to drinking milk were
significantly more likely to consume at least 2 servings of milk/day as measured by the
FFQ. The importance of past behaviour and PBC in predicting intentions align with past
literature; Rivis et al. (2006) found that when examining TPB items alone, attitudes and
past behaviour were the most consistent predictors of behavioural intentions, followed by
perceived behavioural control.

Interestingly, although behavioural expectations, past behaviour, and PBC were predictive
of behavioural intentions, intentions themselves were not predictive of total vitamin D
intake, or of the likelihood of consuming 1-2 servings of fish/week or drinking 2 cups of
milk/day. In contrast, those who reported higher intentions to take a vitamin D supplement
every day were significantly more likely to report using supplements. Although the reason
for this discrepancy is unknown, it could be that intentions are a stronger factor for
supplementation because it is a purposeful act (i.e., one must intend to purchase and
consume supplements in order to engage in this behaviour). In contrast, the likelihood of consuming an adequate amount of milk or fish may be influenced by incidental factors (e.g., milk might be consumed incidentally in cereal or coffee, despite low intentions to meet the recommended intake), or barriers that outweigh intentions (e.g., one might intend to eat fish but be unable to afford it, or have a busy schedule that precludes meal planning). Further, a sub-group analysis revealed that with one exception (intentions to drink milk predicted future mean vitamin D intake), intentions at baseline did not predict behaviors at follow-up. Regardless of intentions, it seems that past behaviour plays the strongest role in predicting actual behaviour for all three dietary behaviours, pointing to the importance of forming healthy habits early on.

In terms of vitamin D status, positive prototype evaluation related to eating fish was the only significant predictor of vitamin D<sub>3</sub> concentrations. The fact that reported past behaviour (i.e., for drinking milk, eating fish, or taking supplements) did not predict vitamin D<sub>3</sub> concentrations underscores the absence of a linear relationship between dietary vitamin D intake and blood levels. It could also be that self-reported TPB/PWM measures are insufficient to predict vitamin D<sub>3</sub> concentration, a biometric indicator that is inherently difficult to predict and depends on a multitude of factors beyond those measured in this survey.

Of course, this study was not without limitations. Although we measured prototype evaluation and similarity from the PWM, we did not directly assess willingness; instead, this was considered a latent factor that mediates the relationship between prototype evaluation/similarity and behaviour. Further, the items in this survey taken from previous
work (i.e., Gerrard et al., 2008a; Rivis et al., 2006) and adapted for vitamin D from the researchers; items may therefore not be fully representative of the original TPB and/or PWM items. Finally, this sample consisted of young adults aged 18-25 from Ontario, Canada, and more than half were students; results may therefore not be generalizable to other populations.

**CONCLUSIONS**

Results of this study suggest that the theoretical model used herein—which included items adapted from the TPB and PWM, was more useful at predicting intentions to engage in health-protective behaviors than in predicting actual behaviour. Past behaviour was the greatest predictor of behavioural outcomes, predicting vitamin D intake, supplement use, fish consumption and milk intake. In addition, two items from TPB contributed somewhat to the predictive ability of the model: intentions predicted vitamin D supplement use, while PBC predicted milk intake. However, the remaining TPB items were not predictive of behaviour, suggesting that the health behaviours assessed may have been influenced by factors beyond those measured by TPB. Lastly, use of the PWM for healthful, rather than risky behaviours is relatively novel, and inclusion of prototype evaluations marginally extended the predictive ability of the theoretical model. In future studies, researchers might directly assess willingness to examine its direct effect on intentions and behaviour, above and beyond the influence of prototype evaluation.
CHAPTER 7: INTEGRATIVE DISCUSSION

Summary of Results

This thesis examined the knowledge, perceptions, intake and blood concentrations of vitamin D among a sample of young adults aged 18-25 living in Canada. Results from qualitative focus groups and quantitative online surveys suggest that vitamin D knowledge in this population is fairly low. Many young adults in our study did not know the recommended daily intakes or upper limits of vitamin D, and were unaware of many of the potential health outcomes associated with vitamin D deficiency. As a whole, consuming adequate vitamin D is not an issue of central importance to young adults. Focus group discussions indicated that this population perceives issues related to bone health (e.g., developing osteoporosis, breaking a hip) and other associated health outcomes as being too far in the future to be of primary concern. These young adults are focused on the here-and-now, and not on health issues common in old age. These findings are in line with previous research on adolescents and young adults, who have been referred to as “young invincibles” due to their disregard for future health consequences (Bibbins-Domingo & Peña, 2010).

Based on these findings, it is relatively unsurprising that vitamin D intake and status were also poor among the young adults we sampled. At our baseline measurements, three-quarters of women and over sixty percent of men failed to meet the EAR of 400 IU/day; and the average blood vitamin D$_3$ concentration of our sample was below the threshold associated with risk to bone health (i.e., 30 nmol/L; IOM, 2010). Given that some researchers have suggested that the current dietary (e.g., Schwalfenberg & Whiting, 2011)
and serum (e.g., Vieth, 2011) vitamin D recommendations should be higher than those set out by the IOM (2010), these findings are of grave concern. It is notable that mean vitamin D intakes from foods and beverage sources were comparable to national averages for young adults aged 19-30 (Health Canada, 2004), increasing the confidence of our findings. On the other hand, blood vitamin D levels in our sample were much lower than national estimates reported in the CCHS (Statistics Canada, 2015a); this may have been due to the fact that the CCHS was conducted year-round, as opposed to solely in the fall and winter, as in the current study.

Thematic analysis of focus groups resulted in five central themes related to effective dissemination of vitamin D information to young adults. These themes indicated that an online program related to vitamin D should be: (a) simple and concise; (b) appealing/catchy and interesting; (c) relatable and personally relevant; (d) credible, and (e) involve a combination of educational strategies. Further, effective intervention programs would ideally include incentives and personal feedback to increase motivation. The findings from these focus groups were used to inform our intervention study. Specifically, we utilized a combination of strategies (e.g., visual imagery, statistics, text-based, auditory and video information), and incorporated a mobile app that provides personal feedback and self-monitoring of vitamin D intake.

Results from the intervention study indicated that vitamin D knowledge, intake and perceived importance of vitamin D supplementation increased significantly after participating in the behavioural intervention. These findings lend support to themes
derived from the focus group study and suggest that use of a wide variety of educational methods, as well as goal setting, personal feedback, and self-monitoring are effective techniques with which to disseminate nutrition information to young adults. Previous literature supports these findings. A systematic review by Michie et al. (2009) found that effective healthy eating interventions incorporated self-monitoring plus at least one of the following techniques: intention formation, specific goal setting, feedback on performance, self-monitoring, and goal review. Additionally, Lieffers and Hanning (2012) found that mobile apps more frequently led to better adherence to self-monitoring behaviours and changes to dietary intake compared to traditional dietary assessment methods. Use of the Vitamin D Calculator app certainly enhanced the self-monitoring capabilities of our intervention, and given the greater increase in vitamin D intake among intervention participants, it may have led to increased intake as well.

Although the increase in mean vitamin D intake was significant only in the intervention group, intake also increased modestly among control participants. This increase is notable mainly because it may be partially attributable to participation in the online surveys (i.e., which both groups completed, and that included several questions related to vitamin D). Assuming that the surveys did factor into the increased intake, we can speculate that simply bringing awareness to vitamin D may have increased participants’ attention to it—perhaps influencing them to personally seek out more information and/or make changes to their dietary intake. This finding has important implications; namely, that awareness may be a key motivator when it comes to increasing perceived importance and intake of nutrients.
Finally, although the average blood vitamin D$_3$ concentration of the sample also increased significantly from pre- to post-intervention, it did not differ significantly by study group. We may speculate that participating in the vitamin D surveys led to increased intake and in turn, increased vitamin D concentration in the sample as a whole. Indeed, unlike at baseline, vitamin D intake and blood concentrations were significantly positively correlated post-intervention, lending support to this proposition. However, given that the dose-response curve for vitamin D varies considerably across individuals (Aloia et al., 2008) and that blood vitamin D$_3$ concentrations are influenced by a variety of environmental factors (Webb & Engelsen, 2006), we cannot conclude this with certainty.

**Contributions to the Literature**

Taken together, the studies described herein make several novel contributions to the literature. Firstly, results from the focus group study (Appendix R; Supplementary Data) and online vitamin D surveys (chapter 5) provide qualitative and quantitative information, respectively regarding what young adults know about vitamin D. This topic has been largely undescribed up until this point, with the exception of a recently published quantitative survey of undergraduate students (Boland et al., 2015). Secondly, the focus group study (chapter 3) also provided information regarding which strategies would be most appropriate and effective at disseminating vitamin D information to young adults. These findings are novel given that vitamin D presents fairly unique challenges (i.e., the fact that most health outcomes are long-term and chronic rather than immediate and acute) and could be used by researchers aiming to encourage intake of other nutrients or health-protective behaviours with long-term outcomes. Thirdly, this thesis validated the mobile
Vitamin D Calculator app as a measure of dietary vitamin D intake (chapter 4). This was one of the first studies to validate a publicly available mobile app for the measurements of dietary intake; indeed, some of the most popular diet-tracking apps have not been validated (e.g., MyFitnessPal, 2014), leaving uncertainties as to their accuracy. Further, the Vitamin D Calculator app previously consisted of dietary and UV information specific to the USA. We contributed the Canadian dietary data (Canadian Nutrient File; Health Canada, 2007) and UV information (Environment Canada; Government of Canada, 2014), leading to the development of an updated platform. The Canadian public now has free access to an app that: (a) provides dietary vitamin D data specific to the Canadian food supply, and (b) estimates solar vitamin D using the UV forecast associated with the user’s postal code. Fourthly, we conducted an online, behavioural intervention that was relatively successful at increasing vitamin D intake, knowledge and perceived importance of vitamin D among young adults (chapter 5). Online dietary interventions are still relatively new (e.g., Gow et al., 2010), and while one study assessed vitamin D and calcium intake as outcomes related to fracture risk in older women (Drieling et al., 2011) none to our knowledge have focused on vitamin D in a young adult population. Finally, we tested the effect of items from the TPB and PWM on outcomes related to vitamin D intake and status (chapter 6). Use of the PWM for health-protective behaviours is fairly novel (e.g., Rivis et al., 2006), and to our knowledge, no other studies have combined these theories in relation to vitamin D intake behaviours.

**Implications for Policy and Practice**

This thesis has several implications. Firstly, given that vitamin D intake and status in this population were low, a public health campaign geared towards young adults could aim to
increase awareness regarding: the importance of vitamin D for bone health and other health outcomes, the recommended intakes, safe levels of sun exposure to increase solar vitamin D synthesis in the summer months, dietary sources of vitamin D (i.e., oily fish and fortified milk products), and the importance of supplementation (especially in the fall/winter months). Given that increased awareness of vitamin D seems to have led to increased dietary intake in our study, this might be the first step in targeting this population. An effective campaign might use an online platform (i.e., given the popularity of social media and high internet use among this population), and should draw upon the themes found in our focus groups; noting that information should be disseminated by a credible source (such as a health professional) rather than an actor, messages should be simple, concise and relatable, and that efforts must be taken to make campaigns appealing and attention-grabbing. However, given that our study also highlighted the importance of personally relevant information and individual feedback, other methods may be more successful at instigating behaviour change in this population.

Primary care practitioners (including physicians and dietitians) represent an important avenue with which to disseminate health and nutrition information among young adults. Greater efforts should be placed on preventative healthcare among this population, who indicated that they would place greater trust in information coming from a health professional. Physicians and dietitians could enquire about the vitamin D (and calcium) intake of young adult patients and acknowledge the immediate importance of these nutrients to the development of their peak bone mass. Vitamin D supplementation should
be recommended during the fall and winter months, and blood vitamin D testing could be requested for individuals with suspected vitamin D deficiency.

It is also important to highlight the non-linear relationship between intake and status. In our study, vitamin D intake and blood concentrations were not correlated at baseline. Similarly, previous research indicates that the dose-response relationship for vitamin D differs across individuals (Aloia et al., 2008; Garland, French, Baggerly & Heaney, 2011) and testing basal serum 25(OH)D concentrations is therefore the only way to empirically determine individual intake requirements (GrassrootsHealth, 2015). Given that widespread recommendations (i.e., 600 IU/day for those aged 1-70 years; IOM, 2010) may not raise blood 25(OH)D to desired levels in all individuals, provincial health plans should change their current policies. The cost of 25(OH)D testing should be covered by provincial health care for all patients, rather than only those with specific conditions (i.e., bone and renal diseases, malabsorption disorders, specific medications; Government of Canada, 2010). Greater access to 25(OH)D testing would allow primary care practitioners (i.e., physicians, dietitians) to make well-informed, tailored intake recommendations to their patients.

Another policy implication stemming from this research is the need for higher national recommendations for vitamin D. As described previously, many vitamin D researchers have recommended higher vitamin D intakes (Garland et al., 2011; Schwalfenberg & Whiting, 2011) and called for serum levels of at least 75 nmol/L (Dawson-Hughes et al., 2005; Holick & Chen, 2008; Vieth, 2011) rather than the threshold of 50 nmol/L recommended by the IOM (2010). Results of our study indicated poor vitamin D intake
and status among a sample of young adults living in Canada, and national data indicate
that vitamin D intakes from food sources are below national recommendations (Health
Canada, 2004). It is notable that the mean 25(OH)D levels in our sample were below
50 nmol/L at both pre- and post-test—even among the intervention group, in which we
observed clinically significant increases in vitamin D intake. Given these findings, it is
evident that national recommendations for both vitamin D intake and status are too low.
National recommendations should be increased to help Canadians reach serum levels of at
least 75 nmol/L. The studies conducted in this dissertation did not administer oral vitamin
D, and results therefore cannot be used to recommend a specific dose needed to reach this
blood concentration. However, given the evidence, it seems that current recommendations
could quite easily—and safely, be doubled (i.e., to an RDA of 1200 IU and UL of 8000 IU
per day). Studies have shown that daily vitamin D intakes upwards of 6000-8000 IU are
needed to reach serum 25(OH)D concentrations of 50-75 nmol/L (Garland et al., 2011;
Heaney et al., 2014; Veugelers & Ekwaru, 2014), and that toxicity is unlikely to occur at
intakes below 40,000 IU/day (Garland et al., 2011). While an RDA of 1200 IU seems
quite conservative given this knowledge, reaching the recommended threshold is nearly
impossible with the current UL set at 4000 IU/day (IOM, 2010). Therefore, despite this
relatively small increase in the RDA (+600 IU), doubling the UL might at the very least
make health professionals feel more comfortable recommending higher vitamin D intakes.
Importantly, setting the UL at 8000 IU leaves a margin of error below the range at which
the IOM (2010) has concluded that toxicity may occur (10,000-40,000 IU/day). Of course,
since many young adults are not meeting the current intake recommendations, further
efforts to increase public awareness of the vitamin D recommendations would be required.
Lastly, given that many Canadians are not meeting vitamin D recommendations for intake or status and that blood vitamin D testing is currently not covered in many provinces (Government of Canada, 2010), it is prudent to examine the issue from a broader population health perspective. Doing so presents a potential policy alternative; namely, increased fortification of the Canadian food supply. Previous research indicates that fortification levels in Canada and the USA are too low to prevent vitamin D insufficiency (Calvo & Whiting, 2004), but that increased fortification levels may be effective at raising vitamin D status. For instance, a study in which participants consumed milk powder fortified with calcium and vitamin D at above-average levels (800 IU vitamin D per 100g) successfully increased 25(OH)D levels among Chinese women (Chee, Suriah, Chan, Zaitun & Chan, 2003). Further, a meta-analysis examining vitamin D food fortification reported a 1.2 nmol/L increase in serum vitamin D concentrations for every 1 mg of vitamin D consumed from fortified food, and concluded that vitamin D food fortification has the potential to raise serum vitamin D concentrations at the population level (Black et al., 2012). Indeed, population-level health interventions have great potential at the population level (Rose, 1985) and even small-scale changes can create nationwide change, due to their great reach. As stated by Rose (1985), “a large number of people at a small risk may give rise to more cases of disease than a small number at high risk” (p. 431). Thus, in some cases it can be more effective from both a health and an economic standpoint to make changes that will affect health at the population level. This is arguably the case for vitamin D in Canada. Although the incidence of rickets (i.e., representing extreme deficiency) is relatively rare (2.9 cases per 100,000; Ward et al., 2007) a large
proportion of the population has insufficient vitamin D status for optimal health (<75 nmol/L), with mean plasma 25(OH)D levels hovering around 60 nmol/L among adults aged 18-79 (Statistics Canada, 2015a; 2015b). Importantly, population health interventions also negate the need for individual behaviour change, which we have already acknowledged is difficult to promote among young adults. Unlike the need to regularly purchase and consume vitamin D supplements, drink a minimum of six cups of milk per day (i.e., to equal 600 IU), or eat several servings of oily fish each week, consuming vitamin D through fortified food staples requires no conscious effort on the part of the consumer. Further, fortification of the food supply would be relatively inexpensive in comparison to the cost for most or all of Canadians to regularly purchase supplements. This is especially true given that those who require vitamin D the most, and those who are at greatest risk of deficiency (i.e., lower SES, the ill or elderly, adolescents, children) are also the least likely to have sufficient access or funds to purchase supplements. Indeed, nationwide adherence to a recommendation for vitamin D supplementation is likely to be poor. From a public health perspective, further fortification of the food supply is a logical way to combat vitamin D insufficiency in Canada—an argument that has been previously made by other vitamin D researchers (Black et al., 2012; Vieth, 2012).

Limitations & Directions for Future Work

This work was not without limitations; however, shortcomings of the studies described herein can be used to guide future research. To begin, we sampled young adults aged 18-25 living in Ontario, Canada. Results may therefore not be generalizable to young adults from other cultures, or to younger or older Canadians. Future studies could assess vitamin D knowledge, intake and status among other populations to determine whether results are
comparable. Secondly, the findings generated from our focus group study regarding strategies to effectively disseminate vitamin D information may or may not be generalizable to other nutrients. Future research could examine whether the strategies preferred by our sample of young adults are applicable to the dissemination of information regarding other nutrients that have long-term health implications (e.g., calcium, omega-3 fatty acids). Thirdly, in chapter 6 we used elements of the TPB and PWM to predict health-protective behaviours related to vitamin D status. However, we did not directly test the latent concept of behavioural willingness. Future studies could extend our model (which included two elements of the PWM: prototype evaluation and prototype similarity) by directly assessing willingness among young adults. Fourthly, a relatively small sub-sample of participants (<60) completed our optional vitamin D blood test, leading to decreased power. Therefore, although we conducted quota sampling to ensure that half our sample was non-Caucasian, we were unable to detect significant differences between ethnicities (or between the intervention and control groups). Additional blood vitamin D testing among a larger sample of young adults aged 18-25 living in Ontario is needed in order to corroborate our findings. Finally, our behavioural intervention only had a modest adherence rate and effect size, and like in previous studies, attrition was disproportionately higher among the intervention group. Other research groups could draw upon the results of our intervention study (including the responses from our feedback survey) to design an online intervention to which participants are more receptive. An intervention that is more appealing to, and perhaps less demanding of participants could help decrease attrition rates and encourage adherence to the intervention, and might be more effective overall.
Conclusion

In conclusion, this thesis consisted of three research studies that collectively examined the knowledge, perceptions, intake, and status of vitamin D among young adults aged 18-25 living in Ontario, Canada. Vitamin D knowledge, intake and status were low overall, and an online behavioural intervention involving a mobile app was modestly successful at improving vitamin D intake, knowledge and perceived importance of vitamin D supplements in this population. While participation in the intervention did not improve vitamin D status, participation in an online survey related to vitamin D was associated with an increase in vitamin D intake and status in both groups.
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Thank you for participating in this focus group study. Before beginning the group discussion, we have a few general questions for you. Please note that all responses will be kept confidential.

1) What is your gender?
   1. Male
   2. Female
   3. Prefer not to say

2) What is your current age? _______ years

3) Which of these best describes your racial or ethnic background?
   1. White/Caucasian
   2. Japanese, Chinese, or Korean
   3. South East Asian
   4. South Asian
   5. African or Caribbean
   6. European
   7. Middle-Eastern/Arab
   8. Latin American (including Central America)
   9. Filipino
   10. Aboriginal
   11. Mixed ancestry
   12. Other: ______________________
   13. Prefer not to say

4) Are you currently a student (or going back to school in the fall)?
   1. No
   2. Yes – please indicate your program (e.g. Psychology):
      ______________________
   3. Prefer not to say

5) What is the highest level of formal education you have achieved?
   1. Some high school
   2. High school
3. Apprenticeship/Professional Certificate
4. Some college
5. College diploma
6. Some university
7. Undergraduate university degree
8. Graduate university degree
9. Other (please specify): ________________________________
10. Prefer not to say

6) What will your employment status be, as of September 2012?
   1. Not employed
   2. Employed part-time
   3. Employed full-time
   4. Prefer not to say

7) Have you ever taken a nutrition course?
   1. Yes
   2. No
   3. Don’t know/prefer not to say

Now we would like to ask you a few questions to determine your skin tone. Please answer to the best of your ability.

8) Which best describes your eye colour?
   0. Light colours
   1. Blue, gray or green
   2. Dark
   3. Brown
   4. Black

9) What is your natural hair colour?
   0. Sandy red
   1. Blond
   2. Chestnut or dark blond
   3. Brown
   4. Black

10) Which best describes your skin colour (in unexposed areas)?
    0. Reddish
    1. Pale
    2. Beige or olive
    3. Brown
    4. Dark brown

11) Which best describes your tendency to get freckles (in unexposed areas)?
    0. Many
1. Several
2. Few
3. Rare
4. None

12) What happens if you stay in the sun too long?
   0. Painful blisters, peeling
   1. Mild blisters, peeling
   2. Burn, mild peeling
   3. Rare
   4. No burning

13) Do you turn brown?
   0. Never
   1. Seldom
   2. Sometimes
   3. Often
   4. Always

14) How brown do you get?
   0. Never
   1. Light tan
   2. Medium tan
   3. Dark tan
   4. Deep dark

15) Is your face sensitive to the sun?
   0. Very sensitive
   1. Sensitive
   2. Sometimes
   3. Resistant
   4. Never have a problem

16) How often do you tan?
   0. Never
   1. Seldom
   2. Sometimes
   3. Often
   4. Always

17) When was your last tan?
   0. +3 months ago
   1. 2–3 months ago
   2. 1–2 months ago
   3. Weeks ago
   4. Days
Appendix B: Focus Group Questions

“Thank you for coming in today. As the information letter explained, the purpose of this focus group is to help us understand your thoughts and understanding of vitamin D and its relation to health. Your feedback will help us to develop a larger study on vitamin D designed for young adults, so we will also ask you some questions about the type and format of information that you think would be most helpful to people your age.”

“To begin, I’ll ask you some general questions.”

General Questions

So I’ll ask you some general questions to start off…

1) Where do you generally get your information on health and nutrition?  
   o E.g. online, school, magazines/books, friends/family, doctor/dietitian?

2) What do you know about bone health?  
   o Are there any specific foods or nutrients that affect your bones?  
   o Link of vitamin D to bone health (preventing osteomalacia, rickets, osteoporosis)

3) What have you heard about nutrients or foods that can help prevent cancer?  
   o Did you know vitamin D has been linked to preventing certain cancers and other chronic diseases (e.g. cancers, M.S., cardiovascular disease, diabetes, autoimmune diseases and infections)

4) What else do you know about vitamin D? (to get a general idea of what they know; more specific questions come next)  
   o Did you know vitamin D helps you absorb calcium?

5) Do you know where we get vitamin D from?  
   o Are you aware of the link between vitamin D and the sun – have you heard the nickname “the sunshine vitamin”?  
   o What are the food sources of vitamin D? (e.g. fatty fish, cod liver oil, egg yolk, liver)  
   o What about fortified foods? Did you know milk and margarine are fortified with vitamin D in Canada? (Other foods and beverages that may be fortified in Canada include goat’s milk, soy beverages, yogurt, cheese, and some calcium-fortified orange juices. Almond milk is only fortified in the USA, not in Canada.)

6) Do you think it’s important to take vitamin D supplements? (Try to get a response from each person in the group – I am particularly interested in this)  
   o If so, what form of supplements do you take?  
   o Do you know the dose?  
   o How often do you take them (e.g. daily, once a week, only in winter, etc.)?
7) Do you know the recommended daily amount of vitamin D recommended by Health Canada?
  o RDA = 600 IU/day (15 ug)
  o UL = 4000 IU/day (100 ug)

![](https://example.com/table)

**Dietary Reference Intakes for Calcium and Vitamin D**

<table>
<thead>
<tr>
<th>Life Stage Group</th>
<th>Estimated Average Requirement (mg/day)</th>
<th>Recommended Dietary Allowance (mg/day)</th>
<th>Upper Level Intake (mg/day)</th>
<th>Estimated Average Requirement (IU/day)</th>
<th>Recommended Dietary Allowance (IU/day)</th>
<th>Upper Level Intake (IU/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infants 0 to 6 months</td>
<td>*</td>
<td>1,000</td>
<td>**</td>
<td>1,000</td>
<td>**</td>
<td>1,000</td>
</tr>
<tr>
<td>Infants 6 to 12 months</td>
<td>*</td>
<td>1,500</td>
<td>**</td>
<td>1,500</td>
<td>**</td>
<td>1,500</td>
</tr>
<tr>
<td>1-3 years old</td>
<td>500</td>
<td>700</td>
<td>2,500</td>
<td>400</td>
<td>600</td>
<td>2,500</td>
</tr>
<tr>
<td>4-6 years old</td>
<td>800</td>
<td>1,000</td>
<td>2,500</td>
<td>400</td>
<td>600</td>
<td>2,500</td>
</tr>
<tr>
<td>9-12 years old</td>
<td>1,000</td>
<td>1,200</td>
<td>3,000</td>
<td>400</td>
<td>600</td>
<td>4,000</td>
</tr>
<tr>
<td>14-18 years old</td>
<td>1,100</td>
<td>1,300</td>
<td>3,000</td>
<td>400</td>
<td>600</td>
<td>4,000</td>
</tr>
<tr>
<td>19-30 years old</td>
<td>1,000</td>
<td>1,000</td>
<td>2,500</td>
<td>400</td>
<td>400</td>
<td>4,000</td>
</tr>
<tr>
<td>31-50 years old</td>
<td>800</td>
<td>1,000</td>
<td>2,500</td>
<td>400</td>
<td>600</td>
<td>4,000</td>
</tr>
<tr>
<td>51-70 years old males</td>
<td>800</td>
<td>1,000</td>
<td>2,000</td>
<td>400</td>
<td>600</td>
<td>4,000</td>
</tr>
<tr>
<td>51-70 years old females</td>
<td>1,000</td>
<td>1,200</td>
<td>2,000</td>
<td>400</td>
<td>600</td>
<td>4,000</td>
</tr>
<tr>
<td>&gt;70 years old</td>
<td>1,000</td>
<td>1,200</td>
<td>2,000</td>
<td>400</td>
<td>600</td>
<td>4,000</td>
</tr>
<tr>
<td>14-18 years old, pregnant/lactating</td>
<td>1,100</td>
<td>1,300</td>
<td>3,000</td>
<td>400</td>
<td>600</td>
<td>4,000</td>
</tr>
<tr>
<td>19-50 years old, pregnant/lactating</td>
<td>800</td>
<td>1,000</td>
<td>2,500</td>
<td>400</td>
<td>600</td>
<td>4,000</td>
</tr>
</tbody>
</table>

*For infants, Adequate Intake is 200 mg/day for 0 to 6 months of age and 260 mg/day for 6 to 12 months of age.

8) Do you think it is important to drink milk and/or consume dairy products every day?
  o Is drinking milk every day a challenge for you?

9) Do you think it is important to expose yourself to the sun every day?
  o How much sun exposure do you think we need every day? *(The U.S. National Institutes of Health suggest spending five to 30 minutes in the sun between 10 a.m. to 3 p.m. at least twice a week with your face, arms, legs or back without sunscreen to boost vitamin D intake.)*

“So we know that exposing yourself to the sun every day is important since the sun is our main source of vitamin D. However, a problem we face in the health and nutrition field is that exposing yourself to the sun may also increase your risk of skin cancer. We were wondering how people your age feel about this issue.”

10) When you think about sun exposure, do you think about getting adequate vitamin D – is this something that ever crosses your mind? Or are you more worried about skin health?
  o Do you regularly wear sunscreen or cover up from the sun?
  o How do you feel about tanning – do you regularly tan or use tanning beds? *(Don’t spend too much time on this; just get a sense of whether it’s common or not – focus should be on vitamin D)*
Questions Relating to Intervention Design

“Ok so as I mentioned before, the study we are designing will examine the knowledge, attitudes and perceptions of young adults in relation to vitamin D. The study will involve an online intervention aimed at increasing knowledge and consumption of vitamin D. Now I’ll ask you some questions that will help us decide on the best approach to use.”

11) If you were to learn about vitamin D through an online program, how would you like to get this information? We have a list of ideas here that we’d like your opinions on. Please let me know whether you think these would be useful for people your age. The first one is…

(go through these separately)

i. Educational messages written out in text
   E.g. The importance of vitamin D to bone health, and the fact that your peak bone mass is reached by age 20-30.

ii. Statistics (written and/or read via audio)
   E.g. “X% of Canadians aged 18-25 are deficient in vitamin D.”
   “X% of young adults do not meet the recommended number of daily servings for milk and alternatives”.

iii. Educational messages delivered by a health professional
   E.g. The importance of vitamin D to your health, explained by a dietitian or doctor.

iv. Short video highlighting about vitamin D, with live testimonials by people your age
   E.g. A short video featuring a 20 year old young man or woman speaking in plain language about the importance of vitamin D and explaining why they take daily supplements.

v. Interactive survey containing educational modules and quizzes
   E.g. each page would have some facts on vitamin D, and you would have to read and click through the pages, and perhaps answer a short quiz at the end to test your knowledge.

“Ok, now we have a few more general questions that would help us design our study”.

12) What would be more helpful: a message that scared you (e.g. a young mother whose baby was born with rickets because she did not consume enough vitamin D during her pregnancy), or a positive message (e.g. adequate vitamin D can help you build strong bones and may prevent certain types of cancer)?

13) What would be most likely to influence you: a message that focused on immediate benefits (e.g. building strong bones for enhanced athletic performance) or long-term effects (e.g. preventing osteoporosis later in life)?

14) Behaviours are often difficult to change because they are so engrained in our daily routines. Keeping in mind that we are planning to deliver our program online, what
do you think we could do that would get you to make changes to your diet - such as drinking more milk or taking vitamin D supplements?

15) Overall, what issues relating to vitamin D would be most relevant to you?
   o Bone health
   o Avoiding cancer and other chronic diseases
   o Increasing calcium absorption
   o Mental health/seasonal affective disorder (i.e., some people think vitamin D improves their mood)
   o Other

16) Is there anything else you’d like to add in general that we haven’t discussed yet?

   “Ok that’s it, thank you for your thoughts and opinions!”
Appendix C: Coding Scheme for Focus Group Transcriptions

### Initial Codes

<table>
<thead>
<tr>
<th>Code #</th>
<th>Code name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Relevant, relatable</td>
</tr>
<tr>
<td>2</td>
<td>Short, concise, importance/value of time</td>
</tr>
<tr>
<td>3</td>
<td>Active searching</td>
</tr>
<tr>
<td>4</td>
<td>Positive attitudes towards statistics</td>
</tr>
<tr>
<td>5</td>
<td>Negative attitudes towards video featuring testimonial by someone of own age (i.e., young adult)</td>
</tr>
<tr>
<td>6</td>
<td>TED talks would be useful/interesting</td>
</tr>
<tr>
<td>7</td>
<td>Materials should be attention grabbing (visually appealing, infographics, interactive, surprising, shocking, interesting, memorable, touching)</td>
</tr>
<tr>
<td>8</td>
<td>Incentives would be a motivator</td>
</tr>
<tr>
<td>9</td>
<td>Credibility is important</td>
</tr>
<tr>
<td>10</td>
<td>A mixture of techniques/methodologies would be ideal/appeal to more people</td>
</tr>
<tr>
<td>11</td>
<td>Immediate effects are more effective than long-term</td>
</tr>
<tr>
<td>12</td>
<td>Simplicity valued</td>
</tr>
</tbody>
</table>

### Final Themes

<table>
<thead>
<tr>
<th>Codes Included</th>
<th>Theme Name</th>
</tr>
</thead>
</table>
| 2, 3, 12       | “Time is of the essence”  
**Subtheme:** “Stress simplicity” |
| 6, 7, 8        | “Intervention materials require ‘a hook’”  
**Subtheme:** “Incentives increase motivation” |
| 1, 11          | “It’s all about me”  
**Subtheme:** “The importance of personal feedback” |
| 5, 9           | “Credibility is essential” |
| 4, 6, 10       | “Two strategies are better than one!” |
LETTER OF INFORMATION ABOUT THE RESEARCH STUDY:

_Vitamin D intake among young Canadian adults: validation of a mobile vitamin D calculator ‘app’._

You are asked to participate in a research study conducted by Dr. Barbara Morrongiello, Dr. Kelly Meckling, Dr. Janis Randall Simpson and Doctoral student Samantha Goodman of the Department of Human Health and Nutritional Sciences at the University of Guelph.

If you have any questions or concerns about the research, or would like a copy of the results of the research, please feel free to contact Dr. Barbara Morrongiello (519-824-4120 ext. 53086), Dr. Kelly Meckling (519-824-4120 ext. 53742), or email vitaminDapp@gmail.com.

PURPOSE OF THE STUDY

The purpose of this study is to determine whether a mobile smartphone application (‘app’) is an accurate measure of dietary vitamin D intake.

STUDY ELIGIBILITY

In order to participate in this study, you must be fluent in English, be currently living in Canada, and own an iPhone, iPad or iPod Touch running IOS 5.1 or higher.

PROCEDURES

If you volunteer to participate in this study, we would ask you to do the following things:

- Sign and date a consent form.
- Fill out a short demographic survey.
- Download a free vitamin D calculator ‘app’ on your device.
- Record your intake of vitamin D and calcium containing foods and beverages into the vitamin D calculator app, on three days over the next month.
- Complete a short initial visit, followed by three study visits in which you will recall your dietary intake from the previous day. These interviews should take no more than one hour each.

PAYMENT FOR PARTICIPATION
You will receive a $10 gift card after completing each interview ($40 in gift cards in total). If you withdraw from the study before completion, you will receive compensation for the study visits you have completed. If you withdraw partway through a visit, you will still receive compensation for that visit. You will not receive gift cards for study visits that have not yet occurred.

If you have any questions regarding the study, scheduling, or how to use the vitamin D app, please email vitaminDapp@gmail.com. If you have questions or comments regarding the research overall, please contact Dr. Kelly Meckling or Dr. Barbara Morrongiello, whose contact information are listed at the top of this page.
CONSENT TO PARTICIPATE IN RESEARCH

Vitamin D intake among young Canadian adults: validation of a mobile vitamin D calculator app.

You are asked to participate in a research study conducted by Doctoral student Samantha Goodman, Dr. Barbara Morrongiello, Dr. Kelly Meckling and Dr. Janis Randall Simpson, through the Department of Human Health and Nutritional Sciences at the University of Guelph. The results of this project will contribute to Samantha Goodman’s PhD dissertation. The Canadian Institutes of Health Research (CIHR) provided funding for this project.

If you have any questions or concerns about the research, please feel free to contact Dr. Barbara Morrongiello (519-824-4120 ext. 53086) or Dr. Kelly Meckling (519-824-4120 ext. 53742) or Samantha Goodman (sgoodm01@uoguelph.ca).

PURPOSE OF THE STUDY

The purpose of this study is to determine whether a mobile smartphone application (‘app’) is an accurate measure of dietary vitamin D intake.

PROCEDURES

If you volunteer to participate in this study, we would ask you to do the following things:

1. During your visit today, you will be asked to read and sign this consent form, and fill out a short demographic survey, which will include general information such as your age, gender, and skin type.

2. You will be asked to download a free app called “Vitamin D calculator” from the Apple Store. You will be given a Letter of Information about the study as well as instructions on how to download the vitamin D calculator app.

3. The research assistant will ask you to choose three recording days over the next month (i.e., in the 30 days), including two weekdays and one weekend day. You will be asked to record your intake of vitamin D containing foods and beverages into the vitamin D calculator app on these specified days. A study visit will be
scheduled for the day after each of these days; so you will complete 3 recording
days and 3 study visits, in addition to your initial visit today. The research assistant
will send you an email to remind you of each of your recording days.

4. On your first recording day, you will be asked to record your intake of all vitamin
D and calcium-containing foods and beverages into the vitamin D calculator app.
Since the app only lists foods and beverages that contain vitamin D and calcium,
you will not need to worry about knowing which foods contain these nutrients.
Foods or beverages that do not contain calcium or vitamin D do not need to be
entered into the app.

5. On the day after your first scheduled recording day, the research assistant will meet
you for the first study visit, which will be conducted in person at the University of
Guelph. The visit should take approximately ½ hour to 1 hour. The research
assistant will ask you to recall out loud everything you ate and drank on the
previous day (i.e., your recording day). The research assistant will record all foods
and beverages that you consumed, including types, brands, cooking methods and
amounts. At the end of the visit, your next recording day will be confirmed.

6. This procedure will be repeated for your second and third recording days.

7. You will receive a $10 gift card after each study visit, totaling $40 if all 4 visits are
completed.

8. If you are interested, you may indicate your desire to be contacted for future
studies using the vitamin D calculator app. Please email the study coordinator at
vitaminDapp@gmail.com or Samantha Goodman at sgoodm01@uoguelph.ca.

9. Study results will become available after publication. If you would like to be
notified when study results become available, please notify Samantha Goodman
(sgoodm01@uoguelph.ca).

**POTENTIAL RISKS AND DISCOMFORTS**

This study should not involve any risks beyond those you would encounter in every day
life. Please note that the vitamin D calculator app is intended for educational purposes
only. It should not be used as a substitute for professional medical advice. You should
consult your health care professional before making any health, medical or other decisions
based on the results of the daily calculations of vitamin D intake provided by this app. The
information provided by this app is not a medical diagnosis. This study is of an
experimental and exploratory nature and no particular results can be guaranteed.

The University of Guelph makes no warranty, express or implied, as to the vitamin D
calculator app including the results or fitness of the Vitamin D calculator app for a
particular purpose.
POTENTIAL BENEFITS TO PARTICIPANTS AND/OR TO SOCIETY

You will benefit from this study by learning about your estimated vitamin D and calcium intake. You may gain valuable information about changes to your diet that would increase your intake of vitamin D or calcium.

This study will benefit the scientific community by establishing the accuracy of a mobile app that could be used in future research studies or by the general public to track individual vitamin D and calcium intake.

PAYMENT FOR PARTICIPATION

As a token of appreciation for participating in this study, you will receive a $10 gift card after completing each interview (totalling $40). If you withdraw from the study before completion, you will receive compensation for the study visits you have completed, but not those that have not occurred. If you withdraw partway through an interview, you will still receive compensation for that visit.

CONFIDENTIALITY

Every effort will be made to ensure confidentiality of any identifying information that is obtained in connection with this study.

You will be assigned a unique personal ID code, which you will be asked to enter into the vitamin D calculator app instead of your name. This ID code will also be used on all surveys and written records taken by the research assistant. Your name will not be used in any data files or included in study results. Please ensure that you do not enter your name in the vitamin D app. If your name is entered rather than your confidential personal ID code, the data you enter will be sent to a server in the United States and thus we cannot ensure the confidentiality of your data.

Electronic data entered into the vitamin D calculator app under your unique ID code will be transmitted to a secure database server at the University of Guelph. This data will be downloaded and stored on a password-encrypted drive; written data will be stored in a locked filing cabinet. Data will be destroyed after 5 years. Only the research assistants and investigators associated with this study will have access to this data. Study results may be published in a scholarly journal. Commercialization of findings is possible; study results may also be referenced and/or made publicly available on the app developer’s website: http://www.vitdcalculator.com. Participant names will not be disclosed.

PARTICIPATION AND WITHDRAWAL

You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences other than loss of financial compensation associated with any study visits that have not yet occurred (see “Payment for
Participation”, above). You may exercise the option of removing your data from the study. If you would like your data to be removed from the study, please inform Samantha Goodman (sgoodm01@uoguelph.ca) or Dr. Kelly Meckling (519-824-4120 ext. 53742), and your data will be destroyed. You may also refuse to answer any questions you don’t want to answer and still remain in the study. The investigator may withdraw you from this research if circumstances arise that warrant doing so.

RIGHTS OF RESEARCH PARTICIPANTS

You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. This study has been reviewed and received ethics clearance through the University of Guelph Research Ethics Board (#13AP022). If you have questions regarding your rights as a research participant, contact:

Director, Research Ethics
University of Guelph
437 University Centre
Guelph, ON N1G 2W1
Telephone: (519) 824-4120, ext. 56606
E-mail: sauld@uoguelph.ca
Fax: (519) 821-5236

SIGNATURE OF RESEARCH PARTICIPANT

I have read the information provided for the study “Vitamin D intake among young Canadian adults: validation of a mobile vitamin D calculator app” as described herein. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

Name of Participant (please print)

_________________________ __________________________ __________________________
Signature of Participant Date

SIGNATURE OF WITNESS

Name of Witness (please print)

_________________________ __________________________ __________________________
Signature of Witness Date
Thank you for participating in the vitamin D calculator validation study. Before beginning the interview today, we have a few general questions for you. Please note that all responses will be kept confidential.

1) What is your gender?
   4. Male
   5. Female
   6. Prefer not to say

2) What is your current age? _______ years

3) Which of these best describes your racial or ethnic background?
   14. White/Caucasian
   15. Japanese, Chinese, or Korean
   16. South East Asian
   17. South Asian
   18. African or Caribbean
   19. European
   20. Middle-Eastern/Arab
   21. Latin American (including Central America)
   22. Filipino
   23. Aboriginal
   24. Mixed ancestry
   25. Other: ____________________
   26. Prefer not to say

4) Are you currently a student?
   4. No
   5. Yes – please indicate your program (e.g. Psychology, Biology):
      ___________________
   6. Prefer not to say

5) What is the highest level of formal education you have achieved?
   11. Some high school
   12. High school diploma
   13. Apprenticeship/professional certificate
   14. Some college
   15. College diploma
   16. Some university
   17. Undergraduate university degree
   18. Some graduate school
   19. Graduate degree
20. Other (please specify): ____________________________________
21. Prefer not to say

6) What is your employment status?
   5. Not employed
   6. Employed part-time
   7. Employed full-time
   8. Prefer not to say

7) Have you ever taken a nutrition course?
   4. Yes
   5. No
   6. Don’t know/prefer not to say

Now we would like to ask you a few questions to determine your skin type. This information will be used to determine your exposure to the sun. Please answer to the best of your ability.

8) Which best describes your eye colour?
   5. Light blue, light gray or light green
   6. Blue, gray or green
   7. Hazel or light brown
   8. Brown
   9. Black

9) What is your natural hair colour?
   5. Red or light blonde
   6. Blonde
   7. Dark blonde or light brown
   8. Dark brown
   9. Black

10) Which best describes your skin colour (in unexposed areas)?
    5. Ivory white
    6. Fair or pale
    7. Fair to beige, with golden undertone
    8. Olive or light brown
    9. Dark brown or black

11) How many freckles do you have in unexposed areas?
    5. Many
    6. Several
    7. Few
    8. Very few
    9. None

12) What happens to your skin if you stay in the sun too long?
    5. Always burns, blisters and peels
    6. Often burns, blisters and peels
    7. Burns moderately
8. Burns rarely, if at all
9. Never burns

13) Does your skin tan?
   0. Never
   1. Seldom
   2. Sometimes
   3. Often
   4. Always

14) How deeply do you tan?
   0. Not at all or very little
   1. Lightly
   2. Moderately
   3. Deeply
   4. My skin is naturally dark

15) Is your face sensitive to the sun?
   0. Very sensitive
   1. Sensitive
   2. Normal/ Sometimes sensitive
   3. Resistant
   4. Very resistant/ Never have a problem

16) How often do you tan (e.g. in the sun or in a tanning bed)?
   0. Never
   1. Seldom
   2. Sometimes
   3. Often
   4. Always

17) When did you last expose your body to the sun or a tanning bed?
   0. +3 months ago
   1. 2–3 months ago
   2. 1–2 months ago
   3. Weeks ago
   4. Days ago
Appendix G: How to Use the App Instructions

HOW TO DOWNLOAD THE VITAMIN D CALCULATOR APP

In order to download the free Vitamin D Calculator app, please follow these steps:

1. Click on the "App Store" icon on your iPhone.
2. Click the "Search" icon. Type "Vitamin D Calculator" in the search bar, and click "Search".
3. The Vitamin D Calculator app should be one of the first results in your search results.
4. If you are using an iPad and you don’t see the app in your results, change the setting at the top of the screen to “iPhone only” and the app should show up. The icon associated with this app should look like the square image with a sun, shown here.
5. Install the app.

GETTING STARTED WITH THE VITAMIN D CALCULATOR APP

1. Under the "Profile" tab, please fill in your unique ID number under the field that says "Name". DO NOT ENTER YOUR NAME. This is VERY important as it ensures that your data is kept confidential. If you enter your name, your information will not be saved in the study database.

   Your ID number: __________________________

2. Please fill in your age, height, weight, and the first 3 digits of your postal code.

3. Under “Skin Type”, please enter Skin Type # ________.

4. Press "Save" to save your profile. You should get a pop-up message that says, "Profile successfully saved". Or, press "Reset" to edit your profile if you made an error. *Note: you must be connected to the internet when you save your profile.

USING THE VITAMIN D CALCULATOR APP

1. Once you have saved your profile, the app will remember your information each time you log in. You do not need to fill out your profile each time. However, if you made an error, you can change this information by clicking on the "Profile" tab, pressing "Reset" and changing the applicable information. Press "Save" to save your changes.

2. On your first recording day, click on the "Calculator" tab to enter the foods and beverages you have consumed that day. You will see a screen that looks like the one pictured here. Click on "Meal types" to enter foods and beverages. The next screen is broken down into Breakfast, Lunch, Snacks, and Dinner. Click on the applicable meal to enter the food and beverages you consumed.

3. Each category is broken down into the same 5 sections: Dairy & Eggs, Fruits & Vegetables, Fish & Meat, Cereals, and Seeds & Nuts (you may need to scroll down to see the last section on your screen). Click on the applicable section to search for foods or beverages in that category. For instance, Dairy &
Eggs contains milk, yogurt, cheese, eggs, etc. You switch between food groups by clicking on the top-left hand corner of the screen.

#

4. To enter food, click on the name of the food. For example, if you click "Milk", you will be taken to a screen pictured here. Enter the amount of milk you have consumed according to the units provided. In this case, the unit is liters and the consumed amount is 250 mL. You would enter this into the field labeled Units Consumed. If you observe more or less than one cup, enter this information accordingly. Or, if you cannot enter 1/2 or 1/4 cups, or 0.5 or half a cup, click "Save" to have this entry. You click "Reset" to change your information. Then, click on the button in the top-left hand corner to return to the previous screen.

#

5. Fill in all the foods and beverages you have consumed during your recording day. Please note that only foods that are a considerable source of vitamin D and/or calcium are included on the list. You do not need to enter other foods or beverages if you may have consumed throughout the day. For example, carrots are not a significant source of vitamin D or calcium, and they are not included here. Beverages such as water, pop, and tea are not included in the app for the same reason. If you have consumed tea or coffee containing milk, please include this in the milk category. Please make sure to review all of the meal type categories included in the app. In case you missed something, please note it in your notes. For example, you might not have known that peanut butter and almonds are sources of calcium, and you will see that these are included in the needs list. Please also make sure to read policy and package labels on the following foods. Go check whether they are fortified with vitamin D and/or calcium:

- Orange juice (100% orange juice, nut milk, etc.) fortified with vitamin D and/or calcium.
- Yogurt is high in calcium. The manufacturers are not required to use vitamin D fortified milk.
- Soy, almond, coconut, or rice milk. Certain brands are not fortified, while others have added vitamin D and/or calcium. Please check the label before entering these beverages into the app.

6. Return to the calculator by clicking the button in the top-left hand corner. Click on the button to select vitamin and mineral supplements you have consumed. Click on the My Multivitamin and enter the number of multivitamins you take, as well as the amount of vitamin D and calcium you take. You would enter this in the units of cup, mg, and in the vitamin D and calcium field. Alternately, you could enter in the number and enter the total amount of vitamin D you consumed; 100 IU is the default amount. For example, if you take a multivitamin containing 400 IU of vitamin D and 200 mg of calcium, enter 400 in the units field and 200 in the calcium field. Please remember to enter any multivitamins you did not consume and calcium or vitamin D supplement, as all fields must be filled in. Please check the bottle if you are not sure how much vitamin D or calcium is contained in your supplement, as this is important for your information and will affect your results.
7. Return to the Calculator tab and click on “Sun Exposure” to enter the amount of time you spent in sunlight during your recording day. The sun exposure tab will bring you to the first screen pictured here. Please select “yes” or “no” to indicate how much of your skin was exposed to the sun, whether you were wearing sunscreen, whether you were in direct sunlight and whether you were outside from 11am-4pm. Since vitamin D from the sun is only synthesized in the skin under certain conditions, you will only be taken to the next page if these conditions are fulfilled. If the conditions for vitamin D synthesis are fulfilled, you will be taken to the second screen shown here, where you can enter the number of minutes spent in sunlight. If you spent time outside in another location during your recording day, enter the postal code associated with that location. The postal code does not need to be an exact address, however it does need to be a valid postal code for the town or city you were in. Otherwise, enter your home postal code. This will ensure that the UV forecast associated with that region is used to estimate your UV exposure.

8. When you are finished entering your foods, beverages, vitamins and sun exposure, please review your entries to make sure they are accurate and you have not missed anything. Scrolling through the food categories might help to jog your memory. Please go through the following checklist in your mind:

✓ Did I remember to enter beverages consumed, such as milk, coffee latte, chai tea latte or vitamin D fortified orange juice?
✓ Did I enter milk added to cereal, tea, coffee or hot chocolate?
✓ Have I entered my multivitamins or supplements?
✓ Did I eat a meal containing tofu or soybeans?
✓ Did I remember to enter snacks, such as trail mix containing nuts and seeds?
✓ Did I enter my sun exposure?
✓ Did I check whether my yogurt, soy/almond/rice beverages, and orange juice were fortified with vitamin D, and enter this information appropriately?

9. Once you are certain that you have entered all of the relevant information, return to the Calculator tab and click on “Vitamin D Daily Total” or “Calcium Daily Total” to see your estimated intake of vitamin D or calcium for that day. Pictured to the right is an image of the Vitamin D Daily Total page. You will see a table outlining your intake of vitamin D from Dairy & Eggs, Fruits & Vegetables, Fish/Meat, Cereals, and a total for all food sources. The total amounts of vitamin D obtained from vitamins and the sun are also displayed.

IMPORTANT NOTE: please make sure to click “Submit” on the bottom of the calcium OR vitamin D total page before midnight (12:00am). This will ensure your data is saved and sent to the study database. If you do not do so, your data will be lost when the date changes on your device. You may modify or add to your intake of foods and beverages at any time during a recording day. However, once you click “Submit” on the daily total page for calcium or vitamin D, your data for that day will be finalized, and cannot be further modified.
This also means that if you forget to enter foods or beverages and remember the next day, you cannot add the previous day’s data since the data are stored on a daily or week basis. Please ensure you have entered all your foods and beverages before clicking “Submit” on the daily total page. Please also note that while you can enter your foods and beverages anytime, you must be connected to the Internet when you click “Submit” in order to send your data to the study database.

**Interpreting Your Results:** The Institute of Medicine (IOM) and Health Canada recommend that adults 19-30 years old consume 600 IU of vitamin D and 1,000 mg of calcium per day (see Table 1 on the last page of this document). On the Vitamin D Daily Total page you will see a coloured bar graph on the right side of the screen, indicating whether your estimated vitamin D consumption is below the IOM recommendation (<400 IU), approaching the recommended level (yellow: 400-600 IU) or meeting/exceeding the recommendation (>600 IU). The star indicates which category your intake falls in. For example, in the photo above, the star is in the orange (<400 IU) section, indicating that the user is not meeting recommendations.

Please note that while the IOM recommends 600 IU per day for adults aged 1-70 years, many health organizations recommend higher amounts. For instance, the Canadian Cancer Society recommends that adults take 1,000 IU per day and Osteoporosis Canada recommends that adults 18-50 years take 400-1,000 IU per day. Many vitamin D researchers recommend even higher amounts; check out the Vitamin D Society for the latest recommendations and research for vitamin D: http://www.vitaminsociety.org/index.php

10. To display a pie chart depicting your intake of vitamin D or calcium from various sources, click on the image of the pie chart on the bottom right of the Vitamin D or Calcium Daily total page (circled in the image here). In this case, the user obtained 14.8% of their vitamin D from dairy & eggs, 6.4% from vitamin D-fortified cereal, none from fruits & vegetables, fish & meat, or the sun, and 78.8% from vitamins. To return to the daily total page, click on the button in the top left corner.

11. Please repeat this procedure on your second and third recording days. Your scheduled recording days are listed on the last page of this document.
Important Notes:

We hope you enjoyed using this app. Please note that the "Get Social" tab of this app has links to Facebook, Twitter and YouTube pages related to vitamin D and the Vitamin D Calculator app. The app developer is not responsible for updating this information and is not necessarily representative of the opinions of the University of Guelph or the investigators of this study. Please feel free to visit these links; however, they are not part of this study.

The University of Guelph makes no warranty, express or implied, as to the vitamin D calculator app, including the results of the Vitamin D Calculator app or the particular purpose. The University of Guelph is not liable for any consequences associated with the use of this app. The webpages associated with the "Get Social" tab. Please see the following websites for more information about the Vitamin D Calculator app: http://www.vitcalc.com/about/

Please note that the information provided in these feedback pages is an estimate based on the information you have entered. The daily UV forecast in your area, the UV index and estimate forecasted by Environment Canada subjects to vary. The Vitamin D calculator app is intended for information purposes only. It should not be used to substitute for professional medical advice. You should consult your health care professional before making any health, medical or other decisions based on the results of the daily calculations. Vitamin D intake provided by this app. The information provided by this app is not medical diagnosis. This study is a non-experimental and exploratory nature and no particular results can be guaranteed.

If you would like to continue using this app, you can enter your name and subject ID number. Information entered will be used for study purposes: Information entered and your name will be sent to the main server associated with this application located in the United States. And we cannot ensure the confidentiality of this data.

RECORING DAYS

Your three recording days and visits will be scheduled with the research assistant.

Recording Day#1:____________________ Study Visit#1:____________________@______

Recording Day#2:____________________ Study Visit#2:____________________@______

Recording Day#3:____________________ Study Visit#3:____________________@______

If you need to reschedule any day, or if you have any questions regarding this study or how to use the vitamin D app, please email VitaminDapp@gmail.com.
Table 1: Dietary Reference Intakes for Calcium and Vitamin D

<table>
<thead>
<tr>
<th>Life Stage Group</th>
<th>Calcium</th>
<th>Vitamin D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimated</td>
<td>Estimated</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>Recommended</td>
</tr>
<tr>
<td></td>
<td>Requirement</td>
<td>Dietary</td>
</tr>
<tr>
<td></td>
<td>(mg/day)</td>
<td>Allowance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(IU/day)</td>
</tr>
<tr>
<td>infants 0 to 6 months</td>
<td>*</td>
<td>**</td>
</tr>
<tr>
<td>infants 6 to 12 months</td>
<td>*</td>
<td>**</td>
</tr>
<tr>
<td>1-3 years old</td>
<td>500</td>
<td>1000</td>
</tr>
<tr>
<td>4-8 years old</td>
<td>800</td>
<td>1500</td>
</tr>
<tr>
<td>9-13 years old</td>
<td>900</td>
<td>1900</td>
</tr>
<tr>
<td>14-18 years old</td>
<td>1100</td>
<td>2600</td>
</tr>
<tr>
<td>19-30 years old</td>
<td>800</td>
<td>1600</td>
</tr>
<tr>
<td>31-50 years old</td>
<td>800</td>
<td>1600</td>
</tr>
<tr>
<td>51-70 year old males</td>
<td>800</td>
<td>1600</td>
</tr>
<tr>
<td>51-70 year old females</td>
<td>1,000</td>
<td>2,000</td>
</tr>
<tr>
<td>&gt;70 years old</td>
<td>1,000</td>
<td>2,000</td>
</tr>
<tr>
<td>14-16 years old, pregnant/lactating</td>
<td>1100</td>
<td>2,000</td>
</tr>
<tr>
<td>19-50 years old, pregnant/lactating</td>
<td>800</td>
<td>2,000</td>
</tr>
</tbody>
</table>

*For infants, Adequate Intake is 240 mg/day for 0 to 6 months of age and 260 mg/day for 6 to 12 months of age.
**For infants, Adequate Intake is 400 IU/day for 0 to 6 months of age and 400 IU/day for 6 to 12 months of age.


References

1 Institute of Medicine (IOM). Food and Nutrition Board. Dietary Reference Intakes for Calcium and Vitamin D. Washington, DC.


3 Osteoporosis Canada. Vitamin D: an important nutrient that protects you against falls and fractures. Available at: http://www.osteoporosis.ca/osteoporosis-and-you/nutrition/vitamin-d/
## Appendix H: Validation Study 24-Hour Recall Template

Participant ID: __________
24-Hour Recall Visit #: _______
Date: ________________

<table>
<thead>
<tr>
<th>Time and Place</th>
<th>Foods, Beverage &amp; Supplements</th>
<th>Amount</th>
<th>Cooking/Preparation Method, Brand Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example: 8:00am; home</td>
<td>Bowl of cereal Milk (in cereal) Orange juice Multivitamin</td>
<td>1 cup ¼ cup ½ cup</td>
<td>Honey Nut Cheerios 1% milk Tropicana, fortified with vitamin D and calcium Centrum for Women</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix I: Validation Study Debriefing Letter Validation Study

FEEDBACK LETTER
Vitamin D intake among young Canadian adults: validation of a mobile vitamin D calculator ‘app’.

Thank you for your participation in the vitamin D calculator validation study. Your time and effort are greatly appreciated.

The purpose of this study was to establish the validity and reliability of the vitamin D calculator app as a measure of dietary vitamin D intake.

Participant data will be used to determine an average estimate of vitamin D intake among 18-25 year old adults living in Canada. The estimates from the vitamin D calculator will be compared with the 24-hour food recalls conducted by the research assistant during your three scheduled interviews.

If you would like to learn more about vitamin D, please visit the following websites:*

- Osteoporosis Canada: [http://www.osteoporosis.ca/osteoporosis-and-you/nutrition/vitamin-d/](http://www.osteoporosis.ca/osteoporosis-and-you/nutrition/vitamin-d/)
- Vitamin D Calculator website: [http://www.vitdcalculator.com](http://www.vitdcalculator.com)
- Vitamin D Society: [http://www.vitamindsociety.org](http://www.vitamindsociety.org)

*Please note that these websites are developed by external parties, and any information provided by these sites is not the responsibility of the researchers.

Study results will become available after publication. If you have any questions or concerns about the research, or would like a copy of the results of the research, please feel free to contact Dr. Barbara Morrongiello (519-824-4120 ext. 53086), Dr. Kelly Meckling (519-824-4120 ext. 53742) or Samantha Goodman (sgoodm01@uoguelph.ca).

Thank you again for your participation.

Sincerely,

Samantha Goodman, PhD Candidate, Department of Human Health & Nutritional Sciences, University of Guelph, Guelph, ON, N1G 2W1

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Intervention Study Materials

Appendix J: Intervention Study Demographic Questionnaire

1) What is your gender?
   7. Male
   8. Female
   9. Prefer not to say

2) What is your current age? _______ years

*If participant is above or below 18-25 years, online survey should not allow them to continue.

3) Which of these best describes your racial or ethnic background?
   27. White/Caucasian
   28. Japanese, Chinese, or Korean
   29. South East Asian
   30. South Asian
   31. African or Caribbean
   32. European
   33. Middle-Eastern/Arab
   34. Latin American (including Central America)
   35. Filipino
   36. Aboriginal
   37. Mixed ancestry
   38. Other: ____________________
   39. Prefer not to say

4) Are you currently a student?
   7. No
   8. Yes
   9. Prefer not to say

5) What is the highest level of formal education you have achieved?
   22. Some high school
   23. High school diploma
   24. Apprenticeship/professional certificate
   25. Some college
   26. College diploma
27. Some university
28. Undergraduate university degree
29. Some graduate school
30. Graduate degree
31. Other (please specify): ______________________________________
32. Prefer not to say

6) What is your employment status?
   9. Not employed
   10. Employed part-time
   11. Employed full-time
   12. Prefer not to say

7) Have you ever taken a nutrition course?
   7. Yes
   8. No
   9. Don’t know/prefer not to say

8) Which of the following best describes who makes decisions regarding food purchases in your household?
   1. I have complete responsibility
   2. I have primary responsibility, but someone else (or several others) also contribute
   3. I share responsibility equally with another person
   4. Someone else has primary responsibility, but I also contribute
   5. Someone else has complete responsibility
   6. Other (please specify) _________________

9) Is your current or past profession or program of study in a field related to health or nutrition? (e.g., Nutrition, Health, Wellness, Human Biology, Medicine)
   1. Yes
   2. No
   3. Don’t know/prefer not to say

10) Have you ever been diagnosed with osteoporosis, osteopenia, or low bone density?
    1. Yes
    2. No
    3. Don’t know/prefer not to say

11) Do you regularly wear a hijab or other type of veil that partially covers your face/head for cultural or religious reasons?
    1. Yes
    2. No
    3. Don’t know/prefer not to say

12) How many times a week, do you usually do 20 minutes of vigorous physical activity
that makes you sweat or puff and pant? (For example, jogging, heavy lifting, digging, aerobics, or fast bicycling)

1. >3 times/week
2. 1-2 times/week
3. None

13) How many times a week, do you usually do 30 minutes of moderate physical activity or walking that increases your heart rate or makes you breathe harder than normal? (For example, mowing the lawn, carrying light loads, bicycling at a regular pace, or playing doubles tennis)

1. >5 times/week
2. 3-4 times/week
3. 1-2 times/week
4. None

14) How often do you engage in weight-bearing physical activity (such as lifting free-weights or using weight machines?)

1. Never
2. Rarely
3. Sometimes
4. Frequently
5. Regularly

15) Are you currently pregnant?
1. Yes
2. No
3. Don’t know/prefer not to say

16) What is your height?
1. Height: _____ feet _____ inches OR _____ cm
2. Don’t know/prefer not to say

17) Please estimate your current weight:
1. Weight: _____ lbs OR _____ kg
2. Don’t know/prefer not to say
Appendix K: Vitamin D Survey

[Administered online]

1) Do you ever take vitamin D supplements, or a multivitamin containing vitamin D?
   1. No, never
   2. Yes, always
   3. Sometimes/when I remember
   4. I did in the past but I have stopped taking them
   5. Don’t know/prefer not to say

*Use automated skip logic (Q2-5 shown if they answered Yes or Sometimes to Q1):

2) You indicated that you take vitamin D supplements or a multivitamin containing vitamin D. How much vitamin D is in the supplement/multivitamin that you take most frequently? If you are unsure, please check the bottle.
   1. Less than 400 IU
   2. 400-599 IU
   3. 600-999 IU
   4. 1000 IU
   5. Over 1000 IU
   6. Don’t know/prefer not to say

3) You indicated that you take vitamin D supplements or a multivitamin containing vitamin D. How often do you take them?
   1. Once a week or less
   2. 2-3 times a week
   3. 4-6 times a week
   4. 1 per day
   5. 2 per day (e.g., two pills at 400 IU = 800 IU)
   6. 3 per more a day
   7. Don’t know/prefer not to say

4) You indicated that you take vitamin D supplements or a multivitamin containing vitamin D. In which season(s) do you take them?
   1. All year round
   2. In the fall and/or winter months only
   3. In the spring and/or summer months only
   4. Don’t know/prefer not to say

5) You indicated that you take vitamin D supplements or a multivitamin containing vitamin D. What motivated you to start taking vitamin D?
   1. A doctor, dietitian or health professional recommended it to me
   2. A friend, family member or colleague recommended it to me
   3. I read about vitamin D (e.g., newspaper, online, magazine, etc.)
   4. I learned about vitamin D in a course or textbook
   5. Someone else in my household takes vitamin D, so I do too
6. It just happens to be in the multivitamin I take
7. Don’t know/prefer not to say
8. Other (please specify): ____________

OR

*Use automated skip logic (Q6 shown if they answered No or I used to but stopped to Q1):

6) You indicated that you do not take vitamin D supplements or a multivitamin containing vitamin D. What is your primary reason for not taking vitamin D?
   1. No reason/I never thought about it
   2. I feel that I get enough vitamin D from my diet
   3. I feel that I get enough vitamin D from the sun
   4. I prefer not to take supplements/vitamins
   5. I do not see the point of doing so
   6. Don’t know/prefer not to say
   7. Other (please specify): ____________

7) If you are a parent, do you give your child(ren) vitamin D supplements (including drops, pills/tablets, or a multivitamin containing vitamin D)?
   1. No, never
   2. Yes, always
   3. Sometimes/when I remember
   4. I did in the past but I have stopped
   5. Don’t know/prefer not to say

*Use automated skip logic (Q8-9 shown if they answered Yes or Sometimes to Q7):

8) You indicated that you give your child(ren) vitamin D supplements or a multivitamin containing vitamin D. How much vitamin D is in the supplement/multivitamin that you give your child(ren) most frequently? If you are unsure, please check the bottle.
   1. Less than 400 IU
   2. 400-599 IU
   3. 600-999 IU
   4. 1000 IU
   5. Over 1000 IU
   6. Don’t know/prefer not to say

9) You indicated that you give your child(ren) vitamin D supplements or a multivitamin containing vitamin D. How often do you give your child vitamin D supplements (including drops, pills/tablets, or a multivitamin containing vitamin D)?
   1. Once a week or less
   2. 2-3 times a week
   3. 4-6 times a week
4. 1 per day
5. 2 per day (e.g., two 400 IU pills = 800 IU)
6. 3 or more per day
7. Unsure/prefer not to say

*Use automated skip logic (Q10 shown if they answered No or I used to to Q7):

10) You indicated that you do not give your child(ren) vitamin D supplements or a multivitamin containing vitamin D. What is your primary reason for not giving them vitamin D?
8. No reason/I never thought about it
9. I feel that they get enough vitamin D from they diet
10. I feel that they get enough vitamin D from the sun
11. I prefer not to give my child(ren) supplements/vitamins
12. I do not see the point of doing so
13. Don’t know/prefer not to say
14. Other (please specify): ____________

Please indicate how much you agree or disagree with the following statements.

11) From a health perspective, it is important for me to take vitamin D supplements in the spring/summer months in Canada.
   1. Strongly disagree
   2. Disagree somewhat
   3. Neither agree nor disagree
   4. Agree somewhat
   5. Strongly agree

12) From a health perspective, it is important for me to take vitamin D supplements in the fall/winter months in Canada.
   1. Strongly disagree
   2. Disagree somewhat
   3. Neither agree nor disagree
   4. Agree somewhat
   5. Strongly agree

13) From a health perspective, it is important for me to consume milk, dairy and/or fortified dairy alternatives (e.g. enriched soy/almond/coconut/goat’s milk) every day.
   1. Strongly disagree
   2. Disagree somewhat
   3. Neither agree nor disagree
   4. Agree somewhat
   5. Strongly agree
14) Consuming milk, dairy and/or fortified dairy alternatives (e.g. enriched soy/almond/coconut/goat’s milk) every day is a challenge for me.
   1. Strongly disagree
   2. Disagree somewhat
   3. Neither agree nor disagree
   4. Agree somewhat
   5. Strongly agree

15) From a health perspective, it is important for me to regularly take vitamin D supplements or multivitamins containing vitamin D.
   1. Strongly disagree
   2. Disagree somewhat
   3. Neither agree nor disagree
   4. Agree somewhat
   5. Strongly agree

16) From a health perspective, it is important for me to get some sun exposure every day.
   1. Strongly disagree
   2. Disagree somewhat
   3. Neither agree nor disagree
   4. Agree somewhat
   5. Strongly agree

Now we are going to ask you some general questions regarding your knowledge of vitamin D. Please answer to the best of your ability. We do not expect you to know all of the things we are asking about! If you do not know the answer to a question, please answer honestly and do not look it up before responding. Your responses will help us to understand what young adults do and do not know about vitamin D.

17) According to Health Canada, what is the recommended daily intake of vitamin D for adults of your age group? This is also known as the “Recommended Dietary Allowance” or RDA. Please enter a number in one of the boxes below. If you are unsure, please do your best to estimate.
   1. _______ International Units (IU) per day OR _______ micrograms (ug) per day
   2. Don’t know/prefer not to say

18) Which of the following nutrients does your body need in order to absorb calcium? (Please select only one response).
   1. Vitamin A
   2. Vitamin B₁₂
   3. Vitamin B₆
   4. Vitamin C
   5. Vitamin D
6. Vitamin E
7. Vitamin K
8. Thiamin
9. Iron
10. Magnesium
11. Phosphorus
12. Potassium
13. Zinc
14. Don’t know/prefer not to say

19) Which of the following are good dietary sources of vitamin D? Please check all that apply.
1. Fruits
2. Vegetables
3. Poultry (e.g. chicken, turkey)
4. Meat (e.g. beef, pork)
5. Liver
6. Oily fish (e.g. salmon, sardines, herring)
7. Fish oil (e.g. cod liver oil)
8. Egg yolks
9. Egg whites
10. Nuts, seeds
11. Bread, grain products
12. Cow’s milk
13. Butter
14. Margarine
15. Other dairy products (e.g. cheese, yogurt)
16. Fortified/enriched non-dairy products (e.g. enriched soy/almond/coconut/goat’s milk)
17. Unenriched non-dairy products (e.g. unenriched soy/almond/coconut/goat’s milk)
18. Fortified juices (e.g. fortified orange juice)
19. Other, please specify: ________

20) Do you know of any non-dietary sources of vitamin D? (Aside from foods, beverages or supplements?)
1. Yes; please specify:
2. Don’t know/prefer not to say

21) Vitamin D comes in more than one form. Do you know which form comes from the sun and is normally found in vitamin D supplements?
1. Vitamin D$_1$
2. Vitamin D$_2$
3. Vitamin D$_3$
4. I did not know there were different types of vitamin D
5. Don’t know/prefer not to say
22) According to Health Canada, what is the maximum amount of vitamin D that adults should consume per day from dietary sources (including foods, beverages and supplements)? This is also known as the “Tolerable Upper Limit” or UL. Please enter a number in one of the boxes below. If you are unsure, please do your best to estimate.
   1. _____ International Units (IU) OR _____ micrograms (ug) per day
   2. Don’t know/prefer not to say

Now we are going to ask you a few questions about your feelings towards sun exposure and tanning. Please answer honestly.

23) Which of the following best describes how you usually behave when you are spending time in the sun during the spring/summer:
   1. I don’t do anything special
   2. I usually wear a hat to keep the sun off my face/head
   3. I usually apply sunscreen
   4. I try to minimize my time in direct sunlight (select a partly/fully shady spot if I can)
   5. I usually cover up as much as I reasonably can (e.g., wear long sleeves)
   6. Other:

24) If you had the opportunity to spend a day sunbathing (i.e., sit out in the sun for the purpose of tanning), how long would you probably spend in the sun?
   ___ Minutes or ___ Hours

25) How often do you wear sunscreen?
   1. Never
   2. Rarely
   3. Only when I know I am going to be spending a long time in the sun (e.g. spending a day at the beach, working outside for the day)
   4. Sometimes
   5. Frequently
   6. Regularly

26) How often do you take measures to avoid the sun on hot days (e.g. wearing a hat or long sleeves, covering up, sitting in the shade, or staying indoors)?
   1. Never
   2. Rarely
   3. Sometimes
   4. Frequently
   5. Regularly

27) How often do you sunbathe to get a tan on a hot sunny day?
1. Never
2. Rarely
3. Sometimes
4. Frequently
5. Regularly

28) How often do you use tanning beds?
   1. Never
   2. Rarely
   3. Sometimes
   4. Frequently
   5. Regularly

29) When you consider sun exposure, how much do you think about each of the following?
   a. Damaging skin/ future skin health
   b. Getting a tan
   c. Getting a sun burn
   d. Developing skin cancer or melanoma
   e. Getting adequate sunlight for overall mood and well-being
   f. Getting adequate sunlight for vitamin D production

Response options:
   1. Not at all
   2. A little
   3. Somewhat
   4. A fair amount
   5. Very much

30) How much time in direct sunlight is needed in order for our bodies to make vitamin D in the skin? Please type a number in the box below to indicate a minimum number of minutes that you think is needed. If you don’t know, please do your best to estimate.
   1. Minimum # minutes: ___
   2. Don’t know/prefer not to say

31) Which of the following factors influence your body’s ability to make vitamin D from the sun?
   (Check all that apply)
   1. Age
   2. Sex
   3. Ethnicity
   4. Weight
   5. Cloud cover
   6. Clothing
   7. Sunscreen
   8. Amount of shade/sunlight
9. Skin type/pigmentation
10. UV index
11. Season
12. Geographic location (latitude)
13. Don’t know/prefer not to say
14. Other: ________

Now we are going to ask some questions about **how different nutrients affect your health**. Please answer to the best of your ability. Your responses will help us to understand what young adults know about this topic.

32) Which of the following nutrients affect your **bone health**?

(Check all that apply):

1. Vitamin A
2. Vitamin B\textsubscript{12}
3. Vitamin B\textsubscript{6}
4. Vitamin C
5. Vitamin D
6. Vitamin E
7. Vitamin K
8. Calcium
9. Iron
10. Magnesium
11. Phosphorus
12. Potassium
13. Zinc

33) There has been a lot of research regarding vitamin D. As far as you have heard, which of the following health conditions may result from **not consuming enough vitamin D**?

1. Alzheimer’s disease
2. Anemia
3. Blood clots
4. Bone fractures
5. Cancer
6. Celiac disease
7. Constipation
8. Crohn’s disease
9. Diabetes (type 1 or 2)
10. Diarrhea
11. Dizziness
12. Heart disease (cardiovascular disease)
13. Measles
14. Mumps
15. Multiple sclerosis
16. Osteoporosis, osteopenia
17. Rickets, osteomalacia
18. Rubella
19. Tooth decay
20. Weakened immune system (e.g. flu, bacterial or viral infections)
21. Other

Now we are going to ask a few questions regarding your attitudes towards a list of
behaviours. Please indicate your responses on the scale beside each question.

[Behavioural Expectations]
34) To what extent would you be likely to do each of the following behaviours, if the
opportunity arose?
   a. Take a vitamin D supplement every day
   b. Eat one to two servings of fish per week
   c. Drink at least two cups of cow’s milk (or enriched non-dairy alternative
      such as soy/almond/coconut/goat’s milk) per day
   d. Spend 15-30 minutes in the sun without sunscreen, with at least some skin
      exposed, twice per week

Response options:
   1. Not at all likely
   2. A little likely
   3. Somewhat likely
   4. Fairly likely
   5. Very likely

[Subjective norms]
35) How much do people who are important to you think you should do each of the
following over the next month?
   a. Take a vitamin D supplement every day
   b. Eat one to two servings of fish per week
   c. Drink at least two cups of cow’s milk (or enriched non-dairy alternative
      such as soy/almond/coconut/goat’s milk) per day
   d. Spend 15-30 minutes in the sun without sunscreen, with at least some skin
      exposed, twice per week

Response options:
   1. Not at all; they wouldn’t care if I did this
   2. A little
   3. Somewhat
   4. A fair amount
   5. A lot; they would want me to do this

[Descriptive norms]
36) a) What percentage of people your age do you think do each of the following? Please type a number between 0 and 100%.
   a. Take a vitamin D supplement every day  
   b. Eat one to two servings of fish per week  
   c. Drink at least two cups of cow’s milk (or enriched non-dairy alternative such as soy/almond/coconut/goat’s milk) per day  
   d. Spend 15-30 minutes in the sun without sunscreen, with at least some skin exposed, twice per week

36) b) What percentage of people your age that you know do you think do each of the following? Please type a number between 0 and 100%.
   a. Take a vitamin D supplement every day  
   b. Eat one to two servings of fish per week  
   c. Drink at least two cups of cow’s milk (or enriched non-dairy alternative such as soy/almond/coconut/goat’s milk) per day  
   d. Spend 15-30 minutes in the sun without sunscreen, with at least some skin exposed, twice per week

[Perceived behavioural control]

37) How easy would it be for you to do each of the following over the next month?
   a. Take a vitamin D supplement every day  
   b. Eat one to two servings of fish per week  
   c. Drink at least two cups of cow’s milk (or enriched non-dairy alternative such as soy/almond/coconut/goat’s milk) per day  
   d. Spend 15-30 minutes in the sun without sunscreen, with at least some skin exposed, twice per week

Response options:
   1. Not at all easy  
   2. A little easy  
   3. Somewhat easy  
   4. Fairly easy  
   5. Very easy to do if I wanted to

[Behavioural Intentions]

38) On a scale of 1 to 100, where 0=I do not intend to do this at all and 100=I definitely intend to do this…  
How much do you intend to do each of the following over the next month? Please type a number between 0 and 100%.
   a. Take a vitamin D supplement every day  
   b. Eat one to two servings of fish per week  
   c. Drink at least two cups of cow’s milk (or enriched non-dairy alternative such as soy/almond/coconut/goat’s milk) per day

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d. Spend 15-30 minutes in the sun without sunscreen, with at least some skin exposed, twice per week

Response Scale:
0=Do not intend to do this at all
100=Definitely intend to do this

[Past behaviour]

39) **How often have you done each of the following over the last month?**
   a. Taken a vitamin D supplement every day
   b. Eaten one to two servings of fish per week
   c. Drank at least two cups of cow’s milk (or enriched non-dairy alternative such as soy/almond/coconut/goat’s milk) per day
   d. Spent 15-30 minutes in the sun without sunscreen, with at least some skin exposed, twice per week

Responses:
1. Never
2. Rarely
3. Sometimes
4. Frequently
5. Every day/each time

The following questions concern your images of people. For example, we all have ideas about what typical movie stars are like or what the typical grandmother is like. We might think of the typical movie star as being pretty or rich, and the typical grandmother as sweet and frail. We are not saying that all movie stars or all grandmothers are exactly alike, but rather that many of them share certain characteristics.

[Prototype evaluation]
This one is broken up into 4 questions labelled 40a-d because otherwise there was no way to have them select all that apply.
40) Think about the **type of person** who does each of the following behaviours. Pick from the following words to describe **YOUR impression of this type person**, including any negative or positive thoughts that go through your mind as you think about this type of person.
   a. Takes a vitamin D supplement every day
   b. Eats one to two servings of fish per week
   c. Drinks at least two cups of cow’s milk per day (or non-dairy alternative such as fortified soy/almond/coconut/goat’s milk)
   d. Spends 15-30 minutes in the sun without sunscreen, with at least face, arms, leg or back exposed, twice per week

Response options:
Select all that apply:

Smart
Foolish
Worrier
Control freak
Conscientious
Healthy
Wasting their time and/or money
Fit
Health conscious
Diet-obsessed

[Prototype similarity]
41) In general, how similar are you to the type of person your age who does the following? (Please think for a moment about the type of person that does each behaviour before indicating your response).
   a. Takes a vitamin D supplement every day
   b. Eats one to two servings of fish per week
   c. Drinks at least two cups of cow’s milk per day (or non-dairy alternative such as soy/almond/coconut/goat’s milk fortified with vitamin D)
   d. Spends 15-30 minutes in the sun without sunscreen, with at least face, arms, leg or back exposed, twice per week

Responses:
   1. Not at all similar to me
   2. A little similar to me
   3. Somewhat similar to me
   4. Fairly similar to me
   5. Very similar to me
Goal Setting
[Included in Survey 2 for Intervention Participants Only]

As we learned earlier, the Recommended Dietary Allowance (RDA) for adults is 600 IU per day, and many experts recommend 1,000 IU per day. Consider your current intake. Please take a few moments now to set one goal related to your vitamin D intake. Effective goals are SMART. That is: Specific, Measurable, Achievable, Realistic, and Time-related.

For example, if I wanted to consume more vitamin D than I do now, a SMART goal might be: "I will take one 1,000 IU vitamin D supplement every morning when I drink my orange juice with breakfast." In contrast, a poor goal might be, "I will increase my vitamin D consumption", because it is too vague. The SMART goal in this example is:
- **Specific** - states how I will get my vitamin D (through a supplement)
- **Measurable** - states how much I will increase my intake (1,000 IU per day)
- **Achievable** - I know I can achieve this goal, since it involves a simple action rather than a huge lifestyle change (taking one vitamin supplement per day is simple enough to remember)
- **Realistic** - the likelihood of me meeting my goal is increased because I have tied it to a habit I have already formed (drinking orange juice with breakfast)
- **Time-related** - I have stated when and how often I will take the supplement (every morning when I have breakfast).

Your goal can be related to taking a vitamin D supplement (as in the example above), but it doesn't have to. Some other ways you might plan to increase your intake are: Eating one or two servings of fish per week. Think about: What kind of fish do you like? How will you incorporate it into your current dietary habits? (E.g. Will you replace a meat meal with fish once per week? Will you switch your usual lunch with a tuna or salmon salad sandwich twice a week?) Drinking one extra glass of milk (or vitamin D-fortified milk alternative) per day.

Make sure you specify how and when in the day you will do this! (E.g. Will you drink a glass of milk with dinner? Will you start ordering a latte every morning instead of your regular coffee? Will you make a smoothie with milk at breakfast?) Taking a daily multivitamin that contains vitamin D. When will you take your multivitamin? (E.g. Will you take it every morning or every evening?)

How will you remember to take it? TIP: tying your goal behaviour to a related, existing habit will help you remember it. Think about what habits you already have. For instance, if you drink a certain beverage (e.g. coffee, juice) or eat a certain food (e.g. cereal) every morning, you could plan to take your multivitamin or vitamin D supplement at that time. Personally, I find that pouring my orange juice now reminds me to take my vitamin D, since I have formed the habit of using it to swallow my vitamins every morning. Another idea: you could choose to keep your vitamins on your bedside table or beside your
toothbrush, so that you remember to take them when you wake up, or when you brush your teeth. Your own idea - be creative and choose something that will work for YOU!

Now it's time to set one SMART goal that would work for you. Please type your goal in the box below. If you feel that you already consume enough vitamin D, please set a SMART goal outlining how you will continue to maintain your current intake.

**Goal Setting Check-in Email (Week 9)**

We wanted to touch base regarding the goal you set as part of the second online survey. If you remember, we asked you to set a SMART goal to help increase your vitamin D intake. Now that you’ve been using the Vitamin D Calculator app, we are wondering two things. Please respond to the following quick questions by responding to this email.

1. Did seeing your vitamin D results in the feedback page of the app lead you to increase your commitment to your goal? (Yes/No)

2. Did seeing your vitamin D results lead you to modify or change your goal? (Yes/No)
   - If yes, how so?
   - What is your new goal?

We appreciate you taking the time to answer these questions and to continue to complete your recordings! If you have any questions, don’t hesitate to ask by replying to this email.

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**Fitzpatrick Skin Type Questionnaire**  
(Fitzpatrick, 1988)

*(Administered as part of online survey once only)*

1) Which best describes your eye colour?
   0. Light blue, light gray or light green
   1. Blue, gray or green
   2. Hazel or light brown
   3. Brown
   4. Black

2) What is your natural hair colour?
   0. Red or light blonde
   1. Blonde
   2. Dark blonde or light brown
   3. Dark brown
   4. Black
3) Which best describes your skin colour (in unexposed areas)?
   0. Ivory white
   1. Fair or pale
   2. Fair to beige, with golden undertone
   3. Olive or light brown
   4. Dark brown or black

4) How many freckles do you have in unexposed areas?
   0. Many
   1. Several
   2. Few
   3. Very few
   4. None

5) What happens if you stay in the sun too long?
   0. Always burns, blisters and peels
   1. Often burns, blisters and peels
   2. Burns moderately
   3. Burns rarely, if at all
   4. Never burns

6) Does your skin tan?
   0. Never
   1. Seldom
   2. Sometimes
   3. Often
   4. Always

7) How deeply do you tan?
   0. Not at all or very little
   1. Lightly
   2. Moderately
   3. Deeply
   4. My skin is naturally dark

8) Is your face sensitive to the sun?
   0. Very sensitive
   1. Sensitive
   2. Normal/ Sometimes sensitive
   3. Resistant
   4. Very resistant/ Never have a problem

9) How often do you tan (e.g. in the sun or in a tanning bed)?
   0. Never
   1. Seldom
2. Sometimes
3. Often
4. Always

10) When did you last expose your body to the sun or a tanning bed?
   0. +3 months ago
   1. 2−3 months ago
   2. 1−2 months ago
   3. Weeks ago
   4. Days ago
Appendix L: Blood Spot Test Instructions

Healthy Living Study
Blood Spot Testing Instructions

*NOTE: To ensure your blood test is done correctly, please READ instructions through from start to finish before starting your blood spot test!

1. Getting ready to test
   - Lay out your kit in order of use: alcohol pad, 2 lancets, gauze, blood spot card, and bandage.
   - Wash hands under HOT water (to better allow blood to flow).
   - Use alcohol pad to wipe fingertip to be used. Allow fingertip to dry. (It is best to use the inside edge of your fingertip on your non-dominant hand).

2. Drawing the blood
   - Twist blue cap off one lancet. Position small white tip against inside edge of fingertip. Press the lancet until it clicks. IMPORTANT: wipe off the first drop of blood with the sterile gauze pad one or more times. This helps the blood flow.

3. Collecting the sample
   - Position pricked finger over card and gently squeeze until one big drop of blood forms. Drop into the centre of each circle.
   - Make sure drops are at least ¼ inch wide, completely fill the circles and soak through the filter paper. If you are having trouble getting enough blood, quickly wipe the finger again with the gauze pad.
   - If necessary, use the second lancet to draw more blood (otherwise, this lancet can be discarded). Please completely fill both circles. Large drops are acceptable as long as they do not overlap.
-Allow blood spots to dry for 30 minutes.-

4. Sending it in
   - Once the spots are dry, close the flap on the card. Print your participant ID (if it is not already filled out), date of birth and date of collection on the card. Place the card in the enclosed envelope, write your return address in the top left corner, and put in the mail. Or, drop it off at ANNU (Animal Science & Nutrition) room 317.

5. Contact information
   - If you have any questions or concerns, please email the researcher, Samantha Goodman at guelph.healthy.living@gmail.com
Appendix M: How to use the App Instructions (Intervention Study)

HOW TO DOWNLOAD THE VITAMIN D CALCULATOR APP

In order to download the free app (called “Vitamin D Calculator”), please follow these steps:

- Ensure your device is running iOS 7.0 or higher.
- Click on the “App Store” icon on your iPhone.
- Click the “Search” icon. Type “Vitamin D Calculator” in the search bar, and click “Search”.
- The Vitamin D Calculator app should be one of the first results in your search results. If you are using an iPad, and you don’t see the app in your results, change the setting at the top of the screen to “iPhone only” and the app should show up. The icon associated with this app should look like the square image with a sun, shown here.
- Install the app.

GETTING STARTED WITH THE VITAMIN D CALCULATOR APP

1. Under the “Profile” tab, please fill in your unique ID number under the field that says “Name”. DO NOT ENTER YOUR NAME. This is VERY important as it ensures that your data are kept confidential. If you enter your name, your information will not be saved in the study database.

   Your ID number is: __________________________

2. Please fill in your age, height, weight, and the first 3 digits of your postal code.

3. Under “Skin Type”, please enter Skin Type #__________.

4. Press “Save” to save your profile. You should get a pop-up message that says, “Profile successfully saved”. Or, press “Reset” to edit your profile if you made an error. *Note: you must be connected to the Internet when you save your profile.

USING THE VITAMIN D CALCULATOR APP

1. Once you have saved your profile, the app will remember your information each time you log in. You do
not need to fill out your profile each time. However, if you made an error, you can change this information by clicking on the “Profile” tab, pressing “Reset” and changing the applicable information. Press “Save” to save your changes.

2. On your first recording day, click on the “Calculator” tab to enter the foods and beverages you have consumed that day. You will see a screen that looks like the one pictured here. Click on “Meal types” to enter foods and beverages. The next screen is broken down into Breakfast, Lunch, Snacks, and Dinner. Click on the applicable meal to enter the food and beverages you consumed.

3. Each category is broken down into the same 5 sections: Dairy & Eggs, Fruits & Vegetables, Fish & Meat, Cereals, and Seeds & Nuts (you may need to scroll down to see the last section on your screen). Click on the applicable section to search for foods or beverages in that category. For instance, Dairy & Eggs contains milk, yogurt, cheese, eggs, etc. To switch between food groups or screens, click on the tab on the top left hand corner of the screen.

4. To enter a food, click on the name of the food. For example, if you click “Milk”, you will be taken to the screen pictured here. Enter the amount of milk you have consumed, according to the units provided. In this case, the unit is 1 cup, and if you consumed 1 cup (250mL), you would enter 1 into the field labelled “Units Consumed”. If you drank more or less than one cup, enter this information accordingly. For instance, you can enter 2 for 2 cups, or 0.5 for half a cup. Click “Save” to save this entry, or click “Reset” to change or clear this information. Then, click on the button in the top left hand corner to return to the previous screen.

5. Fill in all the foods and beverages you consumed during your recording day. Please note that only foods that are a considerable source of vitamin D and/or calcium are included in the list. You do not need to enter other foods or beverages you may have consumed throughout the day. For example, carrots are not a significant source of vitamin D or calcium, so they are not included here. Beverages such as water, pop, and tea are not included in the app for the same reason. If you have consumed tea or coffee containing milk, please include this in the milk category. Please make sure to review all of the meal type categories included in the app, in case you missed something. For example, you might not have known that peanut butter and almonds are sources of calcium, and you will see that these are included in the Seeds & Nuts category. Please also make sure to read package labels on the following foods, to check whether they are fortified with vitamin D and/or calcium:
✓ **Orange juice** → some orange juice, but not all, is fortified with vitamin D and calcium. If your juice is fortified, it should say so on the front of the package.

✓ **Yogurt** → in Canada, yogurt manufacturers are not required to use vitamin D fortified milk. However, certain brands now contain vitamin D fortified milk, so please check the labels!

✓ **Soy, almond, coconut, or rice milk** → certain brands are not enriched, while others have added vitamin D and calcium. Please check the label before entering these beverages into the app.

6. Return to the Calculator tab using the button in the top left hand corner. Click on “Vitamins” to enter any vitamins or supplements you have consumed. Click “My Multivitamin” and enter the number of multivitamins/supplements you took, as well as the amount of vitamin D and calcium in each.

For instance, if you took 2 vitamin D tablets that each contained 400 IU, you would enter 2 in the Units field, 400 in the vitamin D field, and 0 in the calcium field. (Alternately, you could enter 1 unit and enter the total amount of vitamin D you consumed; 800 IU in this case). As another example, if you took a multivitamin containing 400 IU vitamin D and 200 mg calcium, enter 1 for units, 400 in the vitamin D field, and 200 in the calcium field. Please remember to enter 0 if you did not consume a calcium or vitamin D supplement, as all fields must be filled in.

Please check the bottle if you are not sure how much vitamin D or calcium is contained in your supplement, as this is important information that will affect your results.

7. Return to the Calculator tab and click on “Sun Exposure” to enter the amount of time you spent in sunlight during your recording day. The sun exposure tab will bring you to the first screen pictured here. Please select “yes” or “no” to indicate how much of your skin was exposed to the sun, whether you were wearing sunscreen, whether you were in direct sunlight and whether you were outside from 11am-4pm. Since vitamin D from the sun is only synthesized in the skin under certain conditions, you will only be taken to the next page if these conditions are fulfilled. If the conditions for vitamin D synthesis are fulfilled, you will be taken to the
second screen shown here, where you can enter the number of minutes spent in sunlight. If you spent time outside in another location during your recording day, enter the postal code associated with that location. The postal code does not need to be an exact address, however it does need to be a valid postal code for the town or city you were in. Otherwise, enter your home postal code. This will ensure that the UV forecast associated with that region is used to estimate your UV exposure.

8. When you are finished entering your foods, beverages, vitamins and sun exposure, please review your entries to make sure they are accurate and you have not missed anything. Scrolling through the food categories might help to jog your memory. Please go through the following checklist in your mind:

- Did I remember to enter beverages consumed, such as milk, coffee latte, chai tea latte or vitamin D fortified orange juice?
- Did I enter milk added to cereal, tea, coffee or hot chocolate?
- Have I entered my multivitamins or supplements?
- Did I eat a meal containing tofu or soybeans?
- Did I remember to enter snacks, such as trail mix containing nuts and seeds?
- Did I enter my sun exposure?
- Did I check whether my yogurt, soy/almond/rice beverages, and orange juice were fortified with vitamin D, and enter this information appropriately?

9. Once you are certain that you have entered all of the relevant information, return to the Calculator tab and click on “Vitamin D Daily Total” or “Calcium Daily Total” to see your estimated intake of vitamin D or calcium for that day. Pictured to the right is an image of the Vitamin D Daily Total page. You will see a table outlining your intake of vitamin D from Dairy & Eggs, Fruits & Vegetables, Fish/Meat, Cereals, and a total for all food sources. The total amounts of vitamin D obtained from vitamins and the sun are also displayed.

IMPORTANT NOTE: please make sure to click “Submit” on the bottom of the calcium OR vitamin D total page before midnight (12:00am). This will ensure your data is saved and sent to the study database. If you do not do so, your data will be lost when the date changes on your device. You may modify or add to your intake of foods and beverages at any time during a recording day. However, once you click “Submit” on the
daily total page for calcium or vitamin D, your data for that day will be finalized, and cannot be further modified. This also means that if you forget to enter a food or beverage and remember the next day, you cannot add to the previous day’s data since the data are stored on a day-to-day basis. Please ensure you have entered all your foods and beverages before clicking “Submit” on the daily total page. If you forget to press “Submit” before midnight, you will need to re-enter all of the data you have entered and then press “Submit”, since it will have cleared at midnight.

Please also note that while you can enter your foods and beverages anytime, you must be connected to the Internet when you click “Submit” in order to send your data to the study database.

Interpreting your results: The Institute of Medicine (IOM) and Health Canada recommend that adults 19-30 years old consume 600 IU of vitamin D and 1,000 mg of calcium per day¹ (see Table on the last page of this document). On the Vitamin D Daily Total page you will see a coloured bar graph on the right side of the screen, indicating whether your estimated vitamin D consumption is below the IOM recommendation (<400 IU), approaching the recommended level (yellow; 400-600 IU) or meeting/exceeding the recommendation (>600 IU). The star indicates which category your intake falls in. For example, in the photo above, the star is in the orange (<400 IU) section, indicating that the user is not meeting recommendations.

Please note that while the IOM recommends 600 IU per day for adults aged 1-70 years, many health organizations recommend higher amounts. For instance, the Canadian Cancer Society recommends that adults take 1,000 IU per day² and Osteoporosis Canada recommends that adults 18-50 years take 400-1,000 IU per day.³ Many vitamin D researchers recommend even higher amounts; check out the Vitamin D Society for the latest research and recommendations for vitamin D: http://www.vitamindsociety.org/index.php

10. To display a pie chart depicting your intake of vitamin D or calcium from various sources, click on the image of the pie chart on the bottom right of the Vitamin D or Calcium Daily total
11. **Please repeat this procedure on your second and third recording days, for the next 12 weeks.** If you miss a recording day, please complete your recording the next day or as soon as you remember. Then, go back to recording on your usual recording days.

**Important Notes:**

- We hope you enjoyed using this app. Please note that the “Get Social” tab of this app has links to Facebook, Twitter and YouTube pages related to vitamin D and the Vitamin D Calculator app. The app developer is responsible for updating this information and it is not necessarily representative of the viewpoints or opinions of the University of Guelph or the investigators of this study. Please feel free to visit these links; however they are not a part of this research study.

- The University of Guelph makes no warranty, express or implied, as to the vitamin D calculator app, including the results or fitness of the Vitamin D Calculator app for a particular purpose. The University of Guelph is not liable for any consequences associated with the use of this app or the webpages associated with the “Get Social” tab. Please see the following website for more information about the Vitamin D Calculator app: [http://www.vitdcalculator.com/about/](http://www.vitdcalculator.com/about/)

- Please note that the information provided in these feedback pages is an estimate based on the information you have entered, and the daily UV forecast in your area. The UV index is an estimate forecasted by Environment Canada and is subject to vary. The vitamin D calculator app is intended for information purposes only. It should not be used as a substitute for professional medical advice. You should consult your health care professional before making any health, medical or other decisions based on the results of the daily calculations of vitamin D intake provided by this app. The information provided by this app is not a medical diagnosis. This study is of an experimental and exploratory nature and no particular results can be guaranteed.

- If you would like to continue using this app for personal use after completion of the study, please feel free to do so by entering your name in the “Name” field of the app, rather than your subject ID number. Information entered under your subject ID
number will send your data to a secure server at the University of Guelph and will be used for study purposes. Information entered under your name will be sent to the main server associated with this application located in the United States, and we cannot ensure the confidentiality of this data.

If you need to change your recording days, or if you have any questions regarding the study or how to use the vitamin D app, please email guelph.healthy.living@gmail.com.
### Table: Dietary Reference Intakes for Calcium and Vitamin D

<table>
<thead>
<tr>
<th>Life Stage Group</th>
<th>Est. Average Requirement (mg/day)</th>
<th>Recommended Dietary Allowance (mg/day)</th>
<th>Upper Level Intake (mg/day)</th>
<th>Est. Average Requirement (IU/day)</th>
<th>Recommended Dietary Allowance (IU/day)</th>
<th>Upper Level Intake (IU/day)</th>
</tr>
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<tbody>
<tr>
<td>Infants 0 to 6 months</td>
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<td>*</td>
<td>1,000</td>
<td>*</td>
<td>*</td>
<td>1,000</td>
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<tr>
<td>Infants 6 to 12 months</td>
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<td>1,500</td>
<td>*</td>
<td>*</td>
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<td>1-3 years old</td>
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<td>700</td>
<td>2,500</td>
<td>400</td>
<td>600</td>
<td>2,500</td>
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<td>4-8 years old</td>
<td>800</td>
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<td>2,500</td>
<td>400</td>
<td>600</td>
<td>3,000</td>
</tr>
<tr>
<td>9-13 years old</td>
<td>1,100</td>
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<td>3,000</td>
<td>400</td>
<td>600</td>
<td>4,000</td>
</tr>
<tr>
<td>14-18 years old</td>
<td>1,100</td>
<td>1,300</td>
<td>3,000</td>
<td>400</td>
<td>600</td>
<td>4,000</td>
</tr>
<tr>
<td>19-30 years old</td>
<td>800</td>
<td>1,000</td>
<td>2,500</td>
<td>400</td>
<td>600</td>
<td>4,000</td>
</tr>
<tr>
<td>31-50 years old</td>
<td>800</td>
<td>1,000</td>
<td>2,500</td>
<td>400</td>
<td>600</td>
<td>4,000</td>
</tr>
<tr>
<td>51-70 year old males</td>
<td>800</td>
<td>1,000</td>
<td>2,000</td>
<td>400</td>
<td>600</td>
<td>4,000</td>
</tr>
<tr>
<td>51-70 year old females</td>
<td>1,000</td>
<td>1,200</td>
<td>2,000</td>
<td>400</td>
<td>600</td>
<td>4,000</td>
</tr>
<tr>
<td>&gt;70 years old</td>
<td>1,000</td>
<td>1,200</td>
<td>2,000</td>
<td>400</td>
<td>800</td>
<td>4,000</td>
</tr>
<tr>
<td>14-18 years old, pregnant/lactating</td>
<td>1,100</td>
<td>1,300</td>
<td>3,000</td>
<td>400</td>
<td>600</td>
<td>4,000</td>
</tr>
<tr>
<td>19-50 years old, pregnant/lactating</td>
<td>800</td>
<td>1,000</td>
<td>2,500</td>
<td>400</td>
<td>600</td>
<td>4,000</td>
</tr>
</tbody>
</table>

*For infants, Adequate Intake is 200 mg/day for 0 to 6 months of age and 260 mg/day for 6 to 12 months of age.
**For infants, Adequate Intake is 400 IU/day for 0 to 6 months of age and 400 IU/day for 6 to 12 months of age.


References


3. Osteoporosis Canada. Vitamin D: an important nutrient that protects you against falls and fractures. Available at: [http://www.osteoporosis.ca/osteoporosis-and-you/nutrition/vitamin-d/](http://www.osteoporosis.ca/osteoporosis-and-you/nutrition/vitamin-d/)
Appendix N: Goal Setting and Feedback Survey for Intervention Participants

Goal Setting Questions

1) When you completed the previous online survey, you created a SMART goal to help you increase your intake of vitamin D. Do you remember what your original goal was?
   1. Yes, my original goal was: [Open-ended]
   2. I do not remember my goal
   3. I did not set a goal

2) After receiving feedback regarding your vitamin D intake from the app, you may have made changes to your goal, or made a new goal. Did you make changes to your original goal at any point during the study?
   1. Yes
   2. No

3) You indicated that you made changes to your original goal. What was your most recent goal? [Open-ended]

4) Sometimes things happen that make it hard for us to reach our goals, despite our best intentions. How well did you do at meeting your goal? If you made changes to your original vitamin D goal, please answer in relation to your most recent goal.
   1. Not at all – I did not meet any aspects of my goal
   2. A little
   3. Somewhat
   4. Fairly well
   5. Very well – I met my goal completely

Feedback Questions

Finally, we’d like some feedback on this study, including the video, the newsletters we sent you, and your experiences using the Vitamin D Calculator app. Please answer honestly based on your own opinions and experiences.

During the second online survey, you watched a short video about vitamin D by registered dietitian Leslie Beck.

1) How much would you say watching the video influenced you to make changes to your dietary intake of foods containing vitamin D?
   1. Did not influence me at all
   2. Did not influence me very much
   3. Influenced me somewhat
4. Influenced me very much  
5. I do not remember

2) How much would you say watching the video influenced you to make changes to your dietary intake of foods containing calcium?  
1. Did not influence me at all  
2. Did not influence me very much  
3. Influenced me somewhat  
4. Influenced me very much  
5. I do not remember

3) How much would you say watching the video influenced you to take a supplement or multivitamin containing vitamin D?  
1. Did not influence me at all  
2. Did not influence me very much  
3. Influenced me somewhat  
4. Influenced me very much  
5. I do not remember

4) How much would you say watching the video influenced to spend more time in the sun?  
1. Did not influence me at all  
2. Did not influence me very much  
3. Influenced me somewhat  
4. Influenced me very much  
5. I do not remember

After watching the video, we provided you with some information about vitamin D. This information was presented as a series of screens with some facts about vitamin D. This was included as part of the second online survey.  

5) How much would you say reading this information influenced you to make changes to your dietary intake of foods containing vitamin D?  
1. Did not influence me at all  
2. Did not influence me very much  
3. Influenced me somewhat  
4. Influenced me very much  
5. I do not remember

6) How much would you say using reading this information influenced you to make changes to your dietary intake of foods containing calcium?  
1. Did not influence me at all  
2. Did not influence me very much  
3. Influenced me somewhat  
4. Influenced me very much
5. I do not remember

7) How much would you say reading this information influenced you to take a supplement or multivitamin containing vitamin D?
   1. Did not influence me at all
   2. Did not influence me very much
   3. Influenced me somewhat
   4. Influenced me very much
   5. I do not remember

8) How much would you say reading this information influenced you to spend more time in the sun?
   1. Did not influence me at all
   2. Did not influence me very much
   3. Influenced me somewhat
   4. Influenced me very much
   5. I do not remember

9) Did you read the "Vitamin D tricks and tips" newsletters that we sent you by email attachment?
   1. Yes, I read all 3 newsletters
   2. I read one or two of the 3 newsletters
   3. No, I did no read the newsletters

10) How much would you say receiving the “Vitamin D Tips & Tricks” newsletters influenced you to make changes to your dietary intake of foods containing vitamin D?
    1. Did not influence me at all
    2. Did not influence me very much
    3. Influenced me somewhat
    4. Influenced me very much
    5. N/A – I did not read the newsletters

11) How much would you say receiving the “Vitamin D Tips & Tricks” newsletters influenced you to make changes to your dietary intake of foods containing calcium?
    1. Did not influence me at all
    2. Did not influence me very much
    3. Influenced me somewhat
    4. Influenced me very much
    5. N/A – I did not read the newsletters
12) How much would you say receiving the “Vitamin D Tips & Tricks” newsletters influenced you to take a supplement or multivitamin containing vitamin D?
   1. Did not influence me at all
   2. Did not influence me very much
   3. Influenced me somewhat
   4. Influenced me very much
   5. N/A – I did not read the newsletters

13) How much would you say receiving the “Vitamin D Tips & Tricks” newsletters influenced you to spend more time in the sun?
   1. Did not influence me at all
   2. Did not influence me very much
   3. Influenced me somewhat
   4. Influenced me very much
   5. N/A – I did not read the newsletters

Now we'll ask you a few questions regarding the Vitamin D Calculator app. How much did you like using the app?

14) How much did you like using the app?
   1. Did not like using it at all
   2. Did not like using it very much
   3. Liked using it somewhat
   4. Liked using it very much
   5. N/A – I did not use the app

15) How easy was it to use the app?
   1. Very difficult
   2. Somewhat difficult
   3. Somewhat easy
   4. Very easy
   5. N/A – I did not use the app

16) How much would you say using the app influenced you to make changes to your dietary intake of foods containing vitamin D?
   1. Did not influence me at all
   2. Did not influence me very much
   3. Influenced me somewhat
   4. Influenced me very much
   5. N/A – I did not use the app

17) How much would you say using the app influenced you to make changes to your dietary intake of foods containing calcium?
   1. Did not influence me at all
   2. Did not influence me very much
   3. Influenced me somewhat
18) How much would you say the app influenced you to take a supplement or multivitamin containing vitamin D?
   1. Did not influence me at all
   2. Did not influence me very much
   3. Influenced me somewhat
   4. Influenced me very much
   5. N/A – I did not use the app

19) How much would you say the app influenced you to spend more time in the sun?
   1. Did not influence me at all
   2. Did not influence me very much
   3. Influenced me somewhat
   4. Influenced me very much
   5. N/A – I did not use the app

20) What is one thing you liked about using the vitamin D calculator app? [Open-ended]

21) What is one thing we could do to improve the vitamin D calculator app? [Open-ended]

22) Do you have any other comments or feedback regarding your experience using the Vitamin D Calculator app? [Open-ended]
Appendix O: Food Frequency Questionnaire

**UNIVERSITY OF SASKATCHEWAN**  
**COLLEGE OF PHARMACY AND NUTRITION**

**FOOD FREQUENCY QUESTIONNAIRE V2**

Please use HB Pencil making sure response bubble is filled in completely. Please list nutritional supplements used in past month, using as much detail as you can remember.

<table>
<thead>
<tr>
<th>BRAND NAME OF SUPPLEMENT OR TYPE</th>
<th>AMOUNT TAKEN</th>
</tr>
</thead>
<tbody>
<tr>
<td>(e.g. Exact calcium 500 mg &amp; vitamin D 400 IU)</td>
<td>(e.g. 1 tablet every other day)</td>
</tr>
</tbody>
</table>

1. We want to know how often you eat or drink certain foods **each month**.
2. Think about a **typical month** not just what you ate this week which might be different.
3. **Medium** portion sizes are given to help you determine the usual size of the food or drink, and to compare to small and large.
4. If you drink or eat much less (approximately half) than the medium portion size described, then check small. If you drink a large glass of milk every day (approximately 1.5 times the size of medium), then check large.
5. Fill out the form similar to this example:
   - If you drink a carton of chocolate milk (500 mL) Monday through Friday, then choose M (medium) and show it as 5 - 6 times per week.

<table>
<thead>
<tr>
<th>TYPE of FOOD or DRINK</th>
<th>Never or less than 1 per month</th>
<th>1 per month</th>
<th>2-3 per month</th>
<th>1 per week</th>
<th>2 per week</th>
<th>3-4 per week</th>
<th>5+ per week</th>
<th>1 per day</th>
<th>2+ per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chocolate</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>1 cup (8 oz or 240 mL)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix P: Intervention Study Vitamin D ‘Tips & Tricks’ Newsletters

Tips & Tricks Newsletter #1
(2 pages)

Meet your vitamin D needs in ONE SIMPLE STEP!

Taking a daily supplement is the easiest way to get your recommended intake of vitamin D during the fall and winter months. Vitamin D is available in tablet, capsule or drop form. The recommended intake for adults under age 70 is 600 IU, but many health professionals recommend upwards of 1000 IU per day.

**VITAMIN D AND THE SUN**

Although the sun is the easiest way to get vitamin D, the UV is not strong enough during the fall and winter months in Canada for our bodies to make vitamin D in the skin.

**KEY POINTS IN THIS ISSUE:**

- The easiest way to meet your vitamin D needs in the fall and winter is through a supplement.
- In Canada, milk and margarine are fortified with vitamin D by law.
- Other foods that may be fortified with vitamin D include certain brands of orange juice, yogurt and select breakfast cereals.

**TIP:** Keep vitamin D supplements somewhere that you’ll remember to take them at the same time every day (e.g. beside your breakfast cereal, on your bedside table, or beside your toothbrush).

**Orange Juice**
Fortified orange juice is an easy way to add vitamin D to your diet. These Canadian orange juice brands contain added vitamin D:
- Tropicana Essentials with added Calcium + Vitamin D
- President’s Choice Blue Menu 100% Florida Orange Juice with added Calcium & Vitamin D
- Minute Maid “Home Squeezed Style” or “Pure Squeezed, No Pulp” Orange Juice with Calcium & Vitamin D

**Breakfast Cereal**
Some Canadian breakfast cereals now contain a small amount of added vitamin D. Check the Nutrition Facts table on your cereal box to see if your cereal is fortified!

**Kellogg’s cereals that may contain added vitamin D:**
- Crispix Krispies
- FrootLoops
- Mini Wheats (Little Bites only)
- Rice Krispies (including brown rice and gluten free varieties)
- Special K (not including granola)
- Vector

**Yogurt**
Canadian manufacturers are just starting to use vitamin D-fortified milk when making yogurt, so some brands now contain vitamin D (typically a small amount; about 10-25% of the DV).

(Continued on p. 2)
**Does my yogurt contain vitamin D?**

As mentioned on page 1, some manufacturers now use vitamin D fortified milk to make their yogurt, but this is not required by law. If you're wondering whether your yogurt contains vitamin D, it's best to check product labels—especially since manufacturers frequently make changes to their recipes and come out with new brands. However, we did some of the work for you...

### Vitamin D in Canadian yogurt brands*

<table>
<thead>
<tr>
<th>Brand</th>
<th>Contains Vitamin D</th>
<th>Does not contain Vitamin D</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Astro</strong></td>
<td>Astro Biobest Probiotic</td>
<td>Astro Balkan style</td>
</tr>
<tr>
<td></td>
<td>Astro Kik (drinkable)</td>
<td>Astro Original Greek</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Astro Smooth n' Fruity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Astro Zero%</td>
</tr>
<tr>
<td><strong>Danone</strong></td>
<td>Activia</td>
<td>Activia Greek</td>
</tr>
<tr>
<td></td>
<td>DanActive</td>
<td>Silhouette Greek</td>
</tr>
<tr>
<td></td>
<td>Danino</td>
<td>Oikos Greek</td>
</tr>
<tr>
<td></td>
<td>Danino Greek</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Danino Drinkable</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Silhouette</td>
<td></td>
</tr>
<tr>
<td><strong>İęgo</strong></td>
<td><em>All varieties:</em></td>
<td><em>None</em></td>
</tr>
<tr>
<td></td>
<td>İęgo Original</td>
<td></td>
</tr>
<tr>
<td></td>
<td>İęgo 0%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>İęgoProbiotic(probiotic)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>İęgoGreko(Greek)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>İęgoNano, Nomad, and Zip (drinkable)</td>
<td></td>
</tr>
<tr>
<td><strong>President’s Choice</strong></td>
<td>PC Blue Menu Finessse 0%</td>
<td>PC Blue Menu Finessse Greek</td>
</tr>
<tr>
<td></td>
<td>PC Creamy 1.5%</td>
<td>PC 0% or 2% Greek</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PC Probiotic Greek</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PC Organics</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PC 1% or 3% Plain</td>
</tr>
<tr>
<td><strong>Liberté</strong></td>
<td>None</td>
<td>All varieties</td>
</tr>
<tr>
<td><strong>Yoplait</strong></td>
<td>Yoptimal Probiotic (lactose-free)</td>
<td>Source</td>
</tr>
<tr>
<td></td>
<td>Yoplait Minigo</td>
<td>Source Greek</td>
</tr>
<tr>
<td></td>
<td>Yoplait Yop (drinkable)</td>
<td>Yopal (Greek)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yoplait Creamy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yoplait Tubes</td>
</tr>
</tbody>
</table>

*As of May 30, 2014*
Tips & Tricks Newsletter #2
(1 page)

How to get vitamin D, naturally

Fish is one of the only NATURAL dietary sources of vitamin D.

Here are some easy ways to include more fish in your diet:

- Instead of the classic lunchmeat or peanut butter sandwich, try a canned tuna or salmon salad sandwich (tip: canned light tuna has more vitamin D than albacore tuna).
- Bagels and lox, anyone? Try smoked salmon on crackers or a bagel.
- Try a tuna melt: http://www.eatingwell.com/recipes/tuna_melt.html
- Have fish for dinner at least once a week. Remember that white fish like tilapia do not contain much vitamin D, so try oily/fatty fish such as salmon, trout, or mackerel.

If you like it, go for it...

- Add anchovies or sardines to your pizza!
- Try chopped liver on crackers (beef liver is high in both vitamins A and D).

Don't eat fish?

Here are some more ways to get vitamin D:

- Cook with vitamin D-enriched tofu! You can add tofu to just about any meal, including stir-fry, quinoa salad, pasta, etc.

Get vitamin D the old fashioned way!

Spring/summer: get out in the sun! If you're stuck inside, go outside for your lunch break. 15-30 minutes is often enough!

Fall/winter (a not-so-old-fashioned solution): invest in a vitamin D lamp or bulb (look up "vitamin D light therapy" for more information). Talk to your physician if you think you have Seasonal Affective Disorder (S.A.D.)

Oily fish is the primary natural dietary source of vitamin D.

Replace a meat meal with fish 1-2 times per week.
Try some of our easy recipes!

Vitamin D enriched tofu is a good vegetarian alternative.

Popular salmon recipes: http://www.canadianliving.com/food/recipes/our_most_popular_salmon_recipes.php
Tasty trout recipes: http://www.canadianliving.com/food/recipes/tasty_trout_recipes.php
Easy mackerel recipes: http://www.bbcgoodfood.com/search/node?search_api_fulltext=mackerel&[f0]=type%3Areceipe
Dairy (and non-dairy) goodness

Milk is a good source of vitamin D and calcium because it is fortified by law in Canada.

If you don't drink cow's milk, check the package label on your favourite non-dairy alternative. Certain brands of almond milk, soymilk, coconut milk, goat milk and rice milk are enriched with vitamin D. When following the recipes below, simply substitute cow’s milk with your favourite non-dairy milk alternative.

Smoothies & shakes are a great way to include more milk in your diet. Try these delicious recipes:

- Smoothies or milk shakes with milk. There are hundreds of recipes on the internet, or you can make up your own. Here are a few to start:
  4. Easy coconut milk smoothie: put 1 cup coconut milk, 1 banana and 2 cups of raw spinach in a blender, blend and serve! Or try this recipe: [http://www.drinksilk.ca/recipes/berry-breakfast-smoothie](http://www.drinksilk.ca/recipes/berry-breakfast-smoothie)

Coffee drinker?

- Instead of ordering a regular coffee, choose a café latte, cappuccino or chai tea latte. Or make your latte at home with this recipe: [http://angelaharris.hubpages.com/hub/Homemade-Latte-Recipe-Like-Starbucks](http://angelaharris.hubpages.com/hub/Homemade-Latte-Recipe-Like-Starbucks)

- Make a frozen iced coffee drink with low-fat milk. To make your own iced cappuccino: combine 2 spoonfuls of instant coffee or instant espresso, and 1 tsp sugar or sweetener (if desired) and 3 tbsp hot water in a glass, and stir until coffee granules have dissolved. Pour in a blender and add a cup of milk, a few ice cubes (about 4), and blend. Pour in a glass over ice.

- Order like a kid again! When you go out to eat, order chocolate or white milk instead of other sugar-sweetened beverages such as pop or iced tea.

Warm up in the winter:

- Make hot chocolate with milk instead of water (if using hot chocolate mix, just heat your milk in the microwave or on the stove before adding the mix)

- Prepare canned soups with milk instead of water, or use half milk and half water for a creamier consistency. This is especially good with canned tomato soup.

(Continued on p.2)
Milk, margarine & eggs, oh my!

Some more ways to include milk in your diet:

**Soup's on!**
Make homemade soups or sauces with milk instead of cream:

- "Real" tomato soup: [http://www.hcgoodfood.com/recipes/4671/real-tomato-soup](http://www.hcgoodfood.com/recipes/4671/real-tomato-soup)

**Comfort Food**
Make homemade macaroni and cheese with milk, and use vitamin D fortified margarine instead of butter. Here are two recipes with good reviews:


**Sweet tooth?** Make rice pudding for dessert:


**Did you know?**
Egg yolks are a source of vitamin D! Two egg yolks have about 10% of your recommended daily value.

Like eggs? Try an omelet, frittata or quiche!
Here are some easy recipes to try:


**Combine your sources!**
Make scrambled eggs or French toast with milk and eggs, and use margarine to grease the pan (eggs, milk and margarine all contain vitamin D!)

- Basic scrambled eggs: [http://www.egg.ca/recipes/basic-stovetop-scrambled-eggs](http://www.egg.ca/recipes/basic-stovetop-scrambled-eggs)

**Still looking for ideas?**
Here are some more vitamin D-containing recipes: [http://www.eatingwell.com/recipes_menu/recipe_slideshows/recipes_to_get_more_vitamin_d?slide=1#view_toggles](http://www.eatingwell.com/recipes_menu/recipe_slideshows/recipes_to_get_more_vitamin_d?slide=1#view_toggles)
### Table Q.1: Vitamin D Intake Behaviours among Intervention Study Participants at Baseline (n=90)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Frequency % (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Do you ever take vitamin D supplements, or a multivitamin containing vitamin D?</strong></td>
<td></td>
</tr>
<tr>
<td>Yes, always</td>
<td>13.3% (12)</td>
</tr>
<tr>
<td>Sometimes/when I remember</td>
<td>20.0% (18)</td>
</tr>
<tr>
<td>I did in the past but have stopped taking them</td>
<td>20.0% (18)</td>
</tr>
<tr>
<td>No, never</td>
<td>45.6% (41)</td>
</tr>
<tr>
<td>Don’t know/prefer not to say</td>
<td>1.1% (1)</td>
</tr>
<tr>
<td><strong>How much vitamin D is in the supplement that you take most frequently?</strong></td>
<td></td>
</tr>
<tr>
<td>400-599 IU</td>
<td>3.3% (3)</td>
</tr>
<tr>
<td>600-999 IU</td>
<td>7.8% (7)</td>
</tr>
<tr>
<td>1000 IU</td>
<td>10.0% (9)</td>
</tr>
<tr>
<td>≥1000 IU</td>
<td>1.1% (1)</td>
</tr>
<tr>
<td>Don’t know/prefer not to say</td>
<td>6.7% (6)</td>
</tr>
<tr>
<td>Not applicable (do not take vitamin D supplements)</td>
<td>66.7% (60)</td>
</tr>
<tr>
<td><strong>How often do you take them?</strong></td>
<td></td>
</tr>
<tr>
<td>Once a week or less</td>
<td>6.7% (6)</td>
</tr>
<tr>
<td>2-3 times per week</td>
<td>12.2% (11)</td>
</tr>
<tr>
<td>4-6 times per week</td>
<td>2.2% (2)</td>
</tr>
<tr>
<td>Once per day</td>
<td>11.1% (10)</td>
</tr>
<tr>
<td>Twice per day</td>
<td>1.1% (1)</td>
</tr>
<tr>
<td>Not applicable (do not take vitamin D supplements)</td>
<td>66.7% (60)</td>
</tr>
<tr>
<td><strong>In which seasons do you take them?</strong></td>
<td></td>
</tr>
<tr>
<td>All year round</td>
<td>25.6% (23)</td>
</tr>
<tr>
<td>In the fall/winter only</td>
<td>5.6% (5)</td>
</tr>
<tr>
<td>In the spring/summer only</td>
<td>1.1% (1)</td>
</tr>
<tr>
<td>Don’t know/prefer not to say</td>
<td>1.1% (1)</td>
</tr>
<tr>
<td>Not applicable (do not take vitamin D supplements)</td>
<td>66.7% (60)</td>
</tr>
<tr>
<td><strong>What primarily motivated you to start taking vitamin D?</strong></td>
<td></td>
</tr>
<tr>
<td>A doctor, dietitian or health professional recommended it to me</td>
<td>4.4% (4)</td>
</tr>
<tr>
<td>A friend, family member or colleague recommended it to me</td>
<td>10.0% (9)</td>
</tr>
<tr>
<td>I read about vitamin D (e.g. newspaper, online, magazine)</td>
<td>3.3% (3)</td>
</tr>
<tr>
<td>I learned about vitamin D in a course or textbook</td>
<td>3.3% (3)</td>
</tr>
<tr>
<td>Someone else in my household takes vitamin D, so I do too</td>
<td>2.2% (2)</td>
</tr>
<tr>
<td>It just happens to be in the multivitamin I take</td>
<td>7.8% (7)</td>
</tr>
<tr>
<td>Other</td>
<td>2.2% (2)</td>
</tr>
<tr>
<td>Not applicable (do not take vitamin D supplements)</td>
<td>66.7% (60)</td>
</tr>
<tr>
<td><strong>What is your primary reason for not taking vitamin D?</strong></td>
<td></td>
</tr>
<tr>
<td>No reason/never thought about it</td>
<td>32.2% (29)</td>
</tr>
<tr>
<td>I feel that I get enough vitamin D from my diet</td>
<td>5.6% (5)</td>
</tr>
<tr>
<td>I feel that I get enough vitamin D from the sun</td>
<td>6.7% (6)</td>
</tr>
<tr>
<td>I prefer not to take supplements/ vitamins</td>
<td>11.1% (10)</td>
</tr>
</tbody>
</table>
I do not see the point of doing so 3.3% (3)  
Don’t know/prefer not to say 1.1% (1)  
Other 5.6% (5)  
Not applicable (takes vitamin D supplements) 34.4% (31)

**If you are a parent, do you give your child(ren) vitamin D supplements (including drops, pills/tablets, or a multivitamin containing vitamin D)?**  
Yes, always 2.2% (2)  
Sometimes/ when I remember 2.2% (2)  
No, never 4.4% (4)  
Don’t know/prefer not to say 1.1% (1)  
I do not have children 90.0% (81)

**Table Q.2: Perceptions towards vitamin D among Intervention Study Participants at Baseline (n=90)**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% (n)</td>
</tr>
<tr>
<td>From a health perspective, it is important for me to take vitamin D supplements in the spring/summer months in Canada</td>
<td></td>
</tr>
<tr>
<td>Strongly disagree</td>
<td>13.3% (12)</td>
</tr>
<tr>
<td>Disagree somewhat</td>
<td>32.2% (29)</td>
</tr>
<tr>
<td>Neither agree or disagree</td>
<td>32.2% (29)</td>
</tr>
<tr>
<td>Agree somewhat</td>
<td>16.7% (15)</td>
</tr>
<tr>
<td>Strongly agree</td>
<td>5.6% (5)</td>
</tr>
<tr>
<td>From a health perspective, it is important for me to take vitamin D supplements in the fall/winter months in Canada</td>
<td></td>
</tr>
<tr>
<td>Strongly disagree</td>
<td>3.3% (3)</td>
</tr>
<tr>
<td>Disagree somewhat</td>
<td>5.6% (5)</td>
</tr>
<tr>
<td>Neither agree or disagree</td>
<td>22.2% (20)</td>
</tr>
<tr>
<td>Agree somewhat</td>
<td>40.0% (36)</td>
</tr>
<tr>
<td>Strongly agree</td>
<td>28.9% (26)</td>
</tr>
<tr>
<td>From a health perspective, it is important for me to consume milk, dairy, and/or fortified non-dairy alternatives every day</td>
<td></td>
</tr>
<tr>
<td>Strongly disagree</td>
<td>5.6% (5)</td>
</tr>
<tr>
<td>Disagree somewhat</td>
<td>8.9% (8)</td>
</tr>
<tr>
<td>Neither agree or disagree</td>
<td>7.8% (7)</td>
</tr>
<tr>
<td>Agree somewhat</td>
<td>32.2% (29)</td>
</tr>
<tr>
<td>Strongly agree</td>
<td>45.6% (41)</td>
</tr>
<tr>
<td>Consuming milk, dairy, and/or fortified non-dairy alternatives every day is a challenge for me</td>
<td></td>
</tr>
<tr>
<td>Strongly disagree</td>
<td>35.6% (32)</td>
</tr>
<tr>
<td>Disagree somewhat</td>
<td>26.7% (24)</td>
</tr>
<tr>
<td>Neither agree or disagree</td>
<td>5.6% (5)</td>
</tr>
<tr>
<td>Agree somewhat</td>
<td>20.0% (18)</td>
</tr>
</tbody>
</table>
Table Q.3: Sun-Related Habits and Perceptions of Intervention Study Participants at Baseline (n=90)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Which of the following best describes how you usually behave when spending time in the sun during the spring/summer?</strong></td>
<td></td>
</tr>
<tr>
<td>I don’t do anything special</td>
<td>33.3% (30)</td>
</tr>
<tr>
<td>I usually wear a hat to keep the sun off my face/head</td>
<td>3.3% (3)</td>
</tr>
<tr>
<td>I usually apply sunscreen</td>
<td>40.0% (36)</td>
</tr>
<tr>
<td>I try to minimize my time in direct sunlight (select a partly/shady spot if I can)</td>
<td>15.6% (14)</td>
</tr>
<tr>
<td>I usually cover up as much as I reasonably can (e.g. wear long sleeves)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>4.4% (4)</td>
</tr>
<tr>
<td><strong>How often do you wear sunscreen?</strong></td>
<td></td>
</tr>
<tr>
<td>Never or Rarely</td>
<td>24.5% (22)</td>
</tr>
<tr>
<td>Only when I know I am going to be spending a long time in the sun (i.e., spending a day at the beach, or working outside)</td>
<td>46.7% (42)</td>
</tr>
<tr>
<td>Sometimes</td>
<td>3.3% (3)</td>
</tr>
<tr>
<td>Frequently or Regularly</td>
<td>25.6% (23)</td>
</tr>
<tr>
<td><strong>How often do you do each of the following?</strong></td>
<td></td>
</tr>
<tr>
<td>Take measures to avoid the sun on hot days</td>
<td></td>
</tr>
<tr>
<td>Never or Rarely</td>
<td>38.9% (35)</td>
</tr>
<tr>
<td>Sometimes</td>
<td>27.8% (25)</td>
</tr>
<tr>
<td>Frequently or Regularly</td>
<td>33.4% (30)</td>
</tr>
<tr>
<td>Sunbathe to get a tan on a hot sunny day</td>
<td></td>
</tr>
<tr>
<td>Never or Rarely</td>
<td>63.4% (57)</td>
</tr>
<tr>
<td>Sometimes</td>
<td>22.2% (20)</td>
</tr>
<tr>
<td>Frequently or Regularly</td>
<td>14.4% (13)</td>
</tr>
</tbody>
</table>

From a health perspective, it is important for me to regularly take vitamin D supplements or multivitamins containing vitamin D

| Strongly disagree | 15.6% (14) |
| Disagree somewhat | 10.0% (9)  |
| Neither agree or disagree | 35.6% (32) |
| Agree somewhat    | 30.0% (27) |
| Strongly agree    | 8.9% (8)   |

From a health perspective, it is important for me to get some sun exposure every day

| Strongly disagree | 3.3% (3)  |
| Disagree somewhat | 5.6% (5)  |
| Neither agree or disagree | 6.7% (6)  |
| Agree somewhat    | 46.7% (42) |
| Strongly agree    | 37.8% (34) |
**Use tanning beds**
- Never or Rarely: 94.5% (85)
- Sometimes: 3.3% (3.3)
- Frequently or Regularly: 2.2% (2)

**When you consider sun exposure, how much do you think about each of the following?**

**Damaging skin/future skin health**
- Not at all, or A little: 28.8% (26)
- Somewhat: 12.2% (11)
- A fair amount, or Very much: 58.9% (53)

**Getting a tan**
- Not at all, or A little: 32.3% (29)
- Somewhat: 27.8% (25)
- A fair amount, or Very much: 40.0% (36)

**Getting a sun burn**
- Not at all, or A little: 19.1% (17)
- Somewhat: 18.0% (16)
- A fair amount, or Very much: 63.0% (56)

**Developing skin cancer or melanoma**
- Not at all, or A little: 36.6% (33)
- Somewhat: 17.8% (16)
- A fair amount, or Very much: 45.5% (41)

**Getting adequate sunlight for overall mood and well-being**
- Not at all, or A little: 24.4% (22)
- Somewhat: 28.9% (26)
- A fair amount, or Very much: 46.7% (42)

**Getting adequate sunlight for vitamin D production**
- Not at all, or A little: 42.2% (38)
- Somewhat: 33.3% (30)
- A fair amount, or Very much: 24.4% (22)
Table Q.4: Perceived Importance of Vitamin D-Related Behaviours among Intervention Study Participants Over Time (n=90)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Intervention (n=41) M(SD)</th>
<th>Control (n=49) M(SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>From a health perspective, it is important for me to regularly take supplements or multivitamins containing vitamin D.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time 1 (Baseline)</td>
<td>3.17 (1.09)</td>
<td>2.98 (1.25)</td>
</tr>
<tr>
<td>Time 2</td>
<td>3.56 (1.14)</td>
<td>2.98 (1.23)</td>
</tr>
<tr>
<td>Time 3 (Follow-up)</td>
<td>3.71 (1.12)</td>
<td></td>
</tr>
<tr>
<td>From a health perspective, it is important for me to take vitamin D supplements in the spring/summer months in Canada</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time 1 (Baseline)</td>
<td>2.88 (1.05)</td>
<td>2.53 (1.08)</td>
</tr>
<tr>
<td>Time 2</td>
<td>2.98 (1.17)</td>
<td>2.67 (1.09)</td>
</tr>
<tr>
<td>Time 3 (Follow-up)</td>
<td>2.95 (1.07)</td>
<td>2.82 (1.32)</td>
</tr>
<tr>
<td>From a health perspective, it is important for me to take vitamin D supplements in the fall/winter months in Canada.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time 1 (Baseline)</td>
<td>4.07 (0.88)</td>
<td>3.67 (1.09)</td>
</tr>
<tr>
<td>Time 2</td>
<td>4.27 (0.95)</td>
<td>3.73 (1.10)</td>
</tr>
<tr>
<td>Time 3 (Follow-up)</td>
<td>4.12 (1.01)</td>
<td>3.78 (1.25)</td>
</tr>
<tr>
<td>From a health perspective, it is important for me to consume milk, dairy and/or fortified non-dairy alternatives every day.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time 3 (Follow-up)</td>
<td>4.17 (1.14)</td>
<td>3.92 (1.22)</td>
</tr>
<tr>
<td>Time 1 (Baseline)</td>
<td>4.12 (0.93)</td>
<td>4.12 (0.95)</td>
</tr>
<tr>
<td>Time 2</td>
<td>4.12 (0.98)</td>
<td>4.29 (0.84)</td>
</tr>
<tr>
<td>Time 3 (Follow-up)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consuming milk, dairy, and/or fortified non-dairy alternatives is a challenge for me.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time 1 (Baseline)</td>
<td>2.44 (1.48)</td>
<td>2.49 (1.45)</td>
</tr>
<tr>
<td>Time 2</td>
<td>3.17 (1.47)</td>
<td>2.33 (1.18)</td>
</tr>
<tr>
<td>Time 3 (Follow-up)</td>
<td>3.22 (1.26)</td>
<td>2.94 (1.38)</td>
</tr>
<tr>
<td>From a health perspective, it is important for me to get some sun exposure every day.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time 1 (Baseline)</td>
<td>4.05 (1.05)</td>
<td>4.14 (0.94)</td>
</tr>
<tr>
<td>Time 2</td>
<td>4.07 (0.99)</td>
<td>4.12 (0.86)</td>
</tr>
<tr>
<td>Time 3 (Follow-up)</td>
<td>3.95 (1.12)</td>
<td>4.43 (0.76)</td>
</tr>
<tr>
<td>Variable</td>
<td>Frequency</td>
<td>% (n)</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>-----------</td>
<td>-------</td>
</tr>
<tr>
<td><strong>How much would you say watching the video influenced you to make changes to your dietary intake of foods containing vitamin D?</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Did not influence me at all</td>
<td>17.1%</td>
<td>(7)</td>
</tr>
<tr>
<td>Did not influence me very much</td>
<td>31.7%</td>
<td>(13)</td>
</tr>
<tr>
<td>Influenced me somewhat</td>
<td>36.6%</td>
<td>(15)</td>
</tr>
<tr>
<td>Influenced me very much</td>
<td>12.2%</td>
<td>(5)</td>
</tr>
<tr>
<td>I do not remember</td>
<td>2.4%</td>
<td>(2)</td>
</tr>
<tr>
<td><strong>How much would you say watching the video influenced you to make changes to your dietary intake of foods containing calcium?</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Did not influence me at all</td>
<td>19.5%</td>
<td>(8)</td>
</tr>
<tr>
<td>Did not influence me very much</td>
<td>29.3%</td>
<td>(12)</td>
</tr>
<tr>
<td>Influenced me somewhat</td>
<td>41.5%</td>
<td>(17)</td>
</tr>
<tr>
<td>Influenced me very much</td>
<td>7.3%</td>
<td>(3)</td>
</tr>
<tr>
<td>I do not remember</td>
<td>2.4%</td>
<td>(1)</td>
</tr>
<tr>
<td><strong>How much would you say watching the video influenced you to take a supplement or multivitamin containing vitamin D?</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Did not influence me at all</td>
<td>31.7%</td>
<td>(13)</td>
</tr>
<tr>
<td>Did not influence me very much</td>
<td>24.4%</td>
<td>(10)</td>
</tr>
<tr>
<td>Influenced me somewhat</td>
<td>29.3%</td>
<td>(12)</td>
</tr>
<tr>
<td>Influenced me very much</td>
<td>12.2%</td>
<td>(5)</td>
</tr>
<tr>
<td>I do not remember</td>
<td>2.4%</td>
<td>(1)</td>
</tr>
<tr>
<td><strong>How much would you say watching the video influenced to spend more time in the sun?</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Did not influence me at all</td>
<td>22.0%</td>
<td>(9)</td>
</tr>
<tr>
<td>Did not influence me very much</td>
<td>26.8%</td>
<td>(11)</td>
</tr>
<tr>
<td>Influenced me somewhat</td>
<td>34.1%</td>
<td>(14)</td>
</tr>
<tr>
<td>Influenced me very much</td>
<td>14.6%</td>
<td>(6)</td>
</tr>
<tr>
<td>I do not remember</td>
<td>2.4%</td>
<td>(1)</td>
</tr>
</tbody>
</table>

After watching the video, we provided you with some information about vitamin D.

**How much would you say reading this information influenced you to make changes to your dietary intake of foods containing vitamin D?**

<table>
<thead>
<tr>
<th>Frequency</th>
<th>% (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did not influence me at all</td>
<td>14.6%</td>
</tr>
<tr>
<td>Did not influence me very much</td>
<td>24.4%</td>
</tr>
<tr>
<td>Influenced me somewhat</td>
<td>29.3%</td>
</tr>
<tr>
<td>Influenced me very much</td>
<td>24.4%</td>
</tr>
<tr>
<td>I do not remember</td>
<td>7.3%</td>
</tr>
</tbody>
</table>

**How much would you say using reading this information influenced you to make changes to your dietary intake of foods containing calcium?**

<table>
<thead>
<tr>
<th>Frequency</th>
<th>% (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did not influence me at all</td>
<td>12.2%</td>
</tr>
<tr>
<td>Response</td>
<td>Percentage (Count)</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>--------------------</td>
</tr>
<tr>
<td>Did not influence me very much</td>
<td>34.1% (14)</td>
</tr>
<tr>
<td>Influenced me somewhat</td>
<td>31.7% (13)</td>
</tr>
<tr>
<td>Influenced me very much</td>
<td>14.6% (6)</td>
</tr>
<tr>
<td>I do not remember</td>
<td>7.3% (3)</td>
</tr>
</tbody>
</table>

**How much would you say reading this information influenced you to take a supplement or multivitamin containing vitamin D?**

<table>
<thead>
<tr>
<th>Response</th>
<th>Percentage (Count)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did not influence me at all</td>
<td>24.4% (10)</td>
</tr>
<tr>
<td>Did not influence me very much</td>
<td>24.4% (10)</td>
</tr>
<tr>
<td>Influenced me somewhat</td>
<td>26.8% (11)</td>
</tr>
<tr>
<td>Influenced me very much</td>
<td>17.1% (7)</td>
</tr>
<tr>
<td>I do not remember</td>
<td>7.3% (3)</td>
</tr>
</tbody>
</table>

**How much would you say reading this information influenced you to spend more time in the sun?**

<table>
<thead>
<tr>
<th>Response</th>
<th>Percentage (Count)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did not influence me at all</td>
<td>19.5% (8)</td>
</tr>
<tr>
<td>Did not influence me very much</td>
<td>24.4% (10)</td>
</tr>
<tr>
<td>Influenced me somewhat</td>
<td>34.1% (14)</td>
</tr>
<tr>
<td>Influenced me very much</td>
<td>14.6% (6)</td>
</tr>
<tr>
<td>I do not remember</td>
<td>7.3% (3)</td>
</tr>
</tbody>
</table>

**How much would you say receiving the “Vitamin D Tips & Tricks” newsletters influenced you to make changes to your dietary intake of foods containing vitamin D?**

<table>
<thead>
<tr>
<th>Response</th>
<th>Percentage (Count)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did not influence me at all</td>
<td>2.4% (1)</td>
</tr>
<tr>
<td>Did not influence me very much</td>
<td>29.3% (12)</td>
</tr>
<tr>
<td>Influenced me somewhat</td>
<td>19.5% (8)</td>
</tr>
<tr>
<td>Influenced me very much</td>
<td>19.5% (8)</td>
</tr>
<tr>
<td>N/A – I did not read the newsletters</td>
<td>22.0% (9)</td>
</tr>
<tr>
<td>I do not remember</td>
<td>7.3% (3)</td>
</tr>
</tbody>
</table>

**How much would you say receiving the “Vitamin D Tips & Tricks” newsletters influenced you to make changes to your dietary intake of foods containing calcium?**

<table>
<thead>
<tr>
<th>Response</th>
<th>Percentage (Count)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did not influence me at all</td>
<td>4.9% (2)</td>
</tr>
<tr>
<td>Did not influence me very much</td>
<td>26.8% (11)</td>
</tr>
<tr>
<td>Influenced me somewhat</td>
<td>29.3% (12)</td>
</tr>
<tr>
<td>Influenced me very much</td>
<td>9.8% (4)</td>
</tr>
<tr>
<td>N/A – I did not read the newsletters</td>
<td>22.0% (9)</td>
</tr>
<tr>
<td>I do not remember</td>
<td>7.3% (3)</td>
</tr>
</tbody>
</table>

**How much would you say receiving the “Vitamin D Tips & Tricks” newsletters influenced you to take a supplement or multivitamin containing vitamin D?**

<table>
<thead>
<tr>
<th>Response</th>
<th>Percentage (Count)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did not influence me at all</td>
<td>12.2% (5)</td>
</tr>
<tr>
<td>Did not influence me very much</td>
<td>19.5% (8)</td>
</tr>
<tr>
<td>Influenced me somewhat</td>
<td>22.0% (9)</td>
</tr>
</tbody>
</table>
Influenced me very much 17.1% (7)
N/A – I did not read the newsletters 22.0% (9)
I do not remember 7.3% (3)

How much would you say receiving the “Vitamin D Tips & Tricks” newsletters influenced you to spend more time in the sun?
Did not influence me at all 14.6% (6)
Did not influence me very much 17.1% (7)
Influenced me somewhat 24.4% (10)
Influenced me very much 19.5% (8)
N/A – I did not read the newsletters 22.0% (9)
I do not remember 7.3% (3)

How much would you say using the app influenced you to make changes to your dietary intake of foods containing vitamin D?
Did not influence me at all 24.4% (10)
Did not influence me very much 14.6% (6)
Influenced me somewhat 26.8% (11)
Influenced me very much 24.4% (10)
N/A – I did not use the app 9.8% (4)

How much would you say using the app influenced you to make changes to your dietary intake of foods containing calcium?
Did not influence me at all 29.3% (12)
Did not influence me very much 17.1% (7)
Influenced me somewhat 24.4% (10)
Influenced me very much 19.5% (8)
N/A – I did not use the app 9.8% (4)

How much would you say the app influenced you to take a supplement or multivitamin containing vitamin D?
Did not influence me at all 43.9% (18)
Did not influence me very much 12.2% (5)
Influenced me somewhat 17.1% (7)
Influenced me very much 17.1% (7)
N/A – I did not use the app 9.8% (4)

How much would you say the app influenced you to spend more time in the sun?
Did not influence me at all 43.9% (18)
Did not influence me very much 14.6% (6)
Influenced me somewhat 24.4% (10)
Influenced me very much 7.3% (3)
N/A – I did not use the app 9.8% (4)

How much did you like using the app?
Did not like using it at all 19.5% (8)
Did not like using it very much 19.5% (8)
| Liked using it somewhat | 39.0% (16) |
| Liked using it very much | 7.3% (3) |
| N/A – I did not use the app | 14.6% (6) |

**How easy was it to use the app?**

<table>
<thead>
<tr>
<th>Difficulty</th>
<th>Percentage (Count)</th>
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<tr>
<td>Very difficult</td>
<td>9.8% (4)</td>
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<tr>
<td>Somewhat difficult</td>
<td>26.8% (11)</td>
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<tr>
<td>Somewhat easy</td>
<td>22.0% (9)</td>
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<td>Very easy</td>
<td>31.7% (13)</td>
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<td>N/A – I did not use the app</td>
<td>9.8% (4)</td>
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Table Q.6: Bivariate Correlations Between Independent and Dependent Variables and Socio-Demographic Factors, For Each of Four Health-Protective Behaviours (n=109).

### A) Take a vitamin D supplement every day

<table>
<thead>
<tr>
<th></th>
<th>Serum D₃ (nmol/L) (n=63)</th>
<th>Mean Vitamin D Intake (IU) (log)</th>
<th>Sex</th>
<th>Age</th>
<th>Race</th>
<th>Education Level</th>
<th>BMI</th>
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<td>Perceived Behavioural Control</td>
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<td>0.74</td>
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### B) Eat 1 or 2 servings of fish per week

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<th></th>
<th>Serum D₃ (nmol/L) (n=63)</th>
<th>Mean Vitamin D Intake (IU) (log)</th>
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<td>0.25* (61)</td>
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<td>0.97 (107)</td>
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</table>

C) Drink at least 2 cups of cow’s milk per day
(or enriched non-dairy alternative such as soy/almond/coconut/goat’s milk)

<table>
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<th>Serum D₃ (nmol/L) (n=63)</th>
<th>Mean Vitamin D Intake (IU) (log)</th>
<th>Sex</th>
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<td>0.001</td>
<td>-0.10 (107)</td>
<td>0.32</td>
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</table>
D) Spend 15-30 minutes in the sun without sunscreen, with at least some skin exposed, twice per week

<table>
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<tr>
<th></th>
<th>Serum D₃ (nmol/L) (n=63)</th>
<th>Mean Vitamin D Intake (IU) (log)</th>
<th>Sex</th>
<th>Age</th>
<th>Race</th>
<th>Education Level</th>
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<td>-0.15 (107)</td>
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<td>-0.13 (107)</td>
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<td>Descriptive norms (A)</td>
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<td>0.13 (107)</td>
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<td>-0.19* (107)</td>
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<tr>
<td>Descriptive norms (B)</td>
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<td>-0.07 (107)</td>
<td>0.48</td>
<td>0.04 (107)</td>
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<td>-0.10 (107)</td>
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<td>Perceived Behavioural Control</td>
<td>-0.24 (107)</td>
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<td>0.49</td>
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<td>0.84</td>
<td>-0.04 (107)</td>
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*p≤0.05; **p<0.01, 2-tailed
Appendix R: Supplementary Data: Young Adults’ Knowledge & Perceptions of Vitamin D

Study Objective

The objective of this study was to examine knowledge, perceptions and attitudes related to vitamin D among a sample of young adults living in Canada. This data was collected in order to inform an intervention related to vitamin D knowledge and intake in young adults.

METHODS

This (unpublished) data was collected in the focus group study described in chapter 3, with the same sample of young adults aged 18-25 (N=50). Please refer to chapter 3 for detailed descriptions of participants and recruitment, procedures and sample characteristics.

Measures

Participants completed the short demographic survey described above. Knowledge and attitudes towards vitamin D and sun-seeking behaviours were examined through focus group discussions. Questions were open-ended and related to bone health, vitamin D (including sources and health outcomes), recommended daily intake, the perceived importance of taking supplements, drinking milk, and attitudes towards sun exposure and tanning (see Appendix B: Focus Group Questions).

Data Analysis

Audio files were transcribed verbatim using ExpressScribe (ExpressScribe Software, NCH Software, Boston, MA, 2002). Responses regarding knowledge and attitudes towards vitamin D were examined using content analysis (Neuendorf, 2002) in order to summarize and describe common responses to each question.

RESULTS
Knowledge & Attitudes Towards Vitamin D. When asked, “what do you know about bone health?” few respondents mentioned calcium or vitamin D. The male focus groups were specifically asked whether they were aware of the association between calcium and vitamin D, and the majority were not. Similarly, only one woman mentioned that vitamin D helps the body absorb calcium. When asked about conditions associated with a low intake of calcium and/or vitamin D, osteoporosis was the most common response; both sexes also mentioned arthritis, rickets and brittle or breaking bones. When asked whether there are any specific foods or nutrients that affect your bones, milk was the most common response, followed by calcium; participants also mentioned dairy, cheese, vitamin D, salmon, fortified orange juice, leafy greens and soy. Six participants (3 men, 3 women) stated that they did not know when peak bone density was reached; the remaining respondents had a general idea that it is reached in early adulthood. Females had a slightly more accurate understanding, with the most common response being the 20s. In the male focus groups, five participants guessed; responses were fairly accurate, ranging from age 20-30. Only one woman mentioned that bone density decreases after menopause.

Given the research cited above suggesting that vitamin D may play a role in the prevention of certain cancers, participants were asked, “What have you heard about nutrients or foods that can help prevent cancer?” The most common responses among women were antioxidants, fruits, vegetables and green tea. Women also mentioned the following foods at least once: whole foods, ‘super foods/fruits’ (defined by the women as foods that contain a lot of antioxidants or phytochemicals, such as Goji berries or blueberries), spices, wine, resveratrol, dark chocolate, fish oil, fiber, Aspirin, leafy greens, chia and flax
seeds. The most common responses among men were blueberries and broccoli, followed by antioxidants and grapes. The men also named the following foods/nutrients at least once: vegetables, carrots, lycopene (in tomatoes), avocados, fish, chicken, red wine, and pomegranates. When asked, “Did you know that vitamin D has been linked to preventing certain cancers and other chronic diseases?” the entirety of five focus groups (2 female, 3 male; n=30) stated that they were unaware of this research. In the discussion surrounding this question, some women mentioned that vitamin D has been linked with depression, osteoporosis and cardiovascular disease, and can be used to treat multiple sclerosis. In contrast, the men did not know of any other conditions associated with vitamin D.

Sources of Vitamin D. When asked where we get vitamin D from, responses were mixed. A few groups who had not previously discussed the sun named it here. Most participants had heard the nickname “the sunshine vitamin”. When asked if they knew any food sources of vitamin D, the most common response among both men and women was milk (n=6 participants). The facilitator asked one female group whether margarine, cheese or yogurt contained vitamin D, and no one knew. Yogurt and cheese were mentioned once each among the men; the facilitator explained that some yogurts in Canada contain vitamin D, but they are more often made with unfortified milk. When asked if they knew the other food that is mandatorily fortified with vitamin D in Canada, none of the men were able to identify margarine as the correct response. Both males and females mentioned soymilk (which is not mandatorily fortified in Canada); the women also noted that orange juice and calcium supplements sometimes contain added vitamin D. Although fish is the primary natural dietary source of vitamin D, this was not widely known by participants. Animal or
meat products were mentioned once among women and twice among men. The facilitator clarified that the liver is the only notable source of vitamin D in animal products, and that red meat and poultry are not good sources of vitamin D. Participants had several other misconceptions regarding the food sources of vitamin D. Two women named dark green vegetables, while others mentioned seaweed and breakfast cereals (leafy greens are a source of calcium but not vitamin D, and breakfast cereals are not commonly fortified with vitamin D in Canada). The men produced several additional incorrect responses, including: broccoli, bananas, carrots, tomatoes, bread, soy, plants, nuts, Kraft Dinner, and Vitamin Water.

Use and Perceived Importance of Supplements. Less than a quarter of participants (24%; 7 women and 5 men) reported taking vitamin D supplements. Further, regular supplement use was uncommon in this sample; out of the 12 participants who reported taking supplements, one man and one woman indicated that they take them irregularly; three stated that they often forget to take them, and two men indicated that they took them in the past but no longer do. Reasons cited for not taking supplements included eating healthily and preferring to get vitamin D from dietary sources or the sun (4 men, 3 women). When asked what dosage they take, three men reported 1000 IU and one was unsure; one woman reported taking 5000-6000 IU per week in the wintertime. Three women and six men reported taking a multivitamin that contains vitamin D; two women also reported that used to but no longer take multivitamins. When asked, “Do you think it is important to take vitamin D supplements?” only one man and one woman clearly responded “yes”. The woman reasoned that it would be especially important if you were vegan, while the man
thought it was important to take supplements unless you were willing to drink six cups of milk per day to meet the RDA. Two men were unsure how they felt, while five said that they might start taking vitamin D in the winter; either because they do not consume dairy products or because of the lower intensity UVB rays.

**Recommendations for Vitamin D.** When asked if they knew the recommended daily amount of vitamin D recommended by Health Canada, it became clear that participants were not aware of the RDA for their age group (600 IU per day; IOM, 2010). The closest estimate was “600-800 IU”; other guesses included 1000 IU, 1200 IU, and 4000-5000 IU. The vast majority of participants indicated that they did not know the recommendation.

**Perceived Importance and Consumption of Dairy Products.** When asked whether they consume milk every day, the majority of men responded “yes”; only one man did not consume dairy products at all. When women were asked, “Do you consume milk or dairy products?” responses were mixed. More women reported consuming almond milk or soymilk than cow’s milk; women also mentioned chocolate milk, rice milk, hemp milk, smoothies, cheese and yogurt. Four men indicated that they drank soy or almond milks. When asked, “Do you think it’s important to drink milk every day?” agreement was much higher among men. While the general consensus among women was that it is not very important to consume milk/dairy every day, only three men felt this way. Finally, when asked if they knew how much vitamin D is in one cup of milk, there was no consensus; the facilitator revealed the correct response to each group (about 100 IU).
Perceived Importance of Sun Exposure. When asked, “Do you think it is important to get sun exposure every day?” female responses were mixed. One woman felt that the sun is the most efficient way to get vitamin D, and one indicated that she prefers it to a supplement. On the other hand, one woman mentioned that the sun is an unreliable way to get vitamin D in Canada, and others were more hesitant, mentioning that the sun causes skin cancer. In contrast, several men responded “yes”, either because they feel it makes them feel happier/prevents Seasonal Affective Disorder (SAD) or because they enjoy being in the sun. Two men responded that they do not consciously think about it, two said they make a point to go outside but not for vitamin D specifically, and two did not feel that it was important. When asked if they knew how long one must spend in the sun in order to synthesize vitamin D, responses varied. Among women, responses were fairly accurate, ranging from 10-30 minutes. Estimates among men ranged from 5-10 minutes to 2 hours. The facilitator clarified that recent estimates from the US National Institutes of Health estimate that we need about 5-30 minutes outside between the hours of 10am-3pm, at least twice a week, with your face, arms, legs or back exposed (NIH, 2011). Several participants were also surprised at how little time we must spend in the sun in order to initiate vitamin D synthesis.

Attitudes towards Tanning and Sunscreen. When asked, “How do you feel about tanning?” responses between men and women differed. In the female focus groups, the general consensus was that some women go tanning and some do not; it appeared to be a fairly even split. A few women mentioned that they tan easily due to their darker skin pigmentation and therefore do not worry about burning. A couple of women indicated that
they tanned purposely when they were younger but no longer do; others stated that they avoid tanning to prevent burning or skin cancer. In contrast, men generally reported not tanning purposely; this was generally regarded as a female activity.

When asked, “Do you regularly wear sunscreen?” results were mixed for both sexes. Several participants indicated that they do not regularly use sunscreen; reasons included not spending much time outside or not burning easily. Several others specified that they only wear sunscreen if they are purposely going to be spending a lot of time in the sun (e.g. going to the beach) or that they wear it only at the beginning of the summer and then discontinue use once they develop a “base tan”. On the other hand, several men and women reported wearing sunscreen regularly because they burn easily. Overall, attitudes and frequency of use seemed to depend on skin tone and whether or not participants felt they were likely to burn.

Costs and Benefits of Sun Exposure. When the men were asked, “When you think about sun exposure, do you think about getting adequate vitamin D – is that something that ever crosses your mind? Or are you more worried about skin health?” responses were varied. None of the men specifically indicated that they purposely spend time in the sun in order to synthesize vitamin D; among the women, only one participant indicated that she tries to get some sunlight every day. The principle of moderation was discussed by both sexes; an example suggested by one woman was that you should wear sunscreen if you are going to sit in the sun all day, but not if you are going out for a 5-minute walk. Several men indicated that they do not consciously think about getting vitamin D from the sun, and
others felt that they did not need to intentionally make an effort because they were probably getting enough vitamin D from their diet or from being outside for short periods of time. Finally, a few men and women were worried about burning or the risk of skin cancer. Virtually no one was aware that wearing sunscreen could block vitamin D synthesis. Overall, spending time in the sun in order to synthesize vitamin D did not seem to be an issue that participants perceived as being very important or ‘top of mind’.

**Relative Importance of Vitamin D-Related Health Issues.** Participants were asked, “Overall, which issues relating to vitamin D would be most relevant to you?” Overall, findings indicated that mental health/avoiding SAD was one of the two issues most frequently mentioned by both sexes, which is interesting given the weak evidence linking vitamin D to SAD (Howland, 2011). Bone health and preventing cancer were the other issues most frequently mentioned by women and men, respectively. Calcium absorption was the second most frequent concern mentioned by both sexes. Preventing cancer and bone health were the third most frequently mentioned issues for women and men, respectively; followed by preventing other chronic diseases, which was mentioned the fewest times by both sexes.

**DISCUSSION**

Overall, knowledge of vitamin D was fairly low among the young adults examined in this study. Not all participants were aware that the body can synthesize vitamin D from UVB, and participants were split when it came to attitudes towards sun exposure, sunscreen and tanning. In general, spending time in the sun in order to attain vitamin D was not a priority for most participants. The majority of participants did not report taking vitamin D.
supplements, and several individuals expressed their preference for attaining nutrients from natural sources. The perceived importance of regular milk consumption was quite low, especially among women. On the whole, it seems that this population could benefit from further education on vitamin D, including its relation to bone health, preventing cancer and other chronic diseases, daily recommendations, sources and information regarding supplements.

This study also has potential public health implications. Firstly, knowledge surrounding vitamin D among this population was fairly low. Secondly, attitudes towards sun exposure and tanning were mixed, and many participants were concerned about the risk of skin cancer. Thus, attaining vitamin D from the sun was not a priority for most participants. These findings highlight the need for increased awareness regarding the importance of vitamin D among young adults. A public health campaign targeted specifically at this age group might help to increase knowledge of vitamin D in this population. Given that many young adults are concerned about the risk of skin cancer, such a campaign must aim to increase the consumption of supplements or natural vitamin D sources (such as fatty fish or milk), rather than focusing on sun exposure.