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Knowledge and attitudes of vitamin D and sun exposure
practices amongst New Zealand mothers with children aged
five years old and under.

A thesis presented in partial fulfilment of the requirements for the degree of

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Abstract

Background: Currently, there is no research in New Zealand that assesses the knowledge and attitudes of mothers in New Zealand regarding vitamin D. It is unknown whether public health messages are sufficient and if mothers are receiving the correct advice and support to ensure both themselves and their young children reach and maintain adequate vitamin D status.

Aim: The primary aim was to assess the overall knowledge of vitamin D and common practices involving sun exposure amongst New Zealand women with children under five years of age.

Methods: This cross-sectional online questionnaire was administered in 2009 and received responses from 9,220 mothers from around New Zealand. From this, 8,032 responses were analysed. The questionnaire items were based on expert advice, literature and guidelines available in 2009. Mothers were only included if their youngest child was 5 years old or under.

The online questionnaire was developed and reviewed by a panel of experts and then piloted before it was advertised to participants. To measure knowledge, mothers were expected to answer true/false questions or choose the answers to questions they thought were most accurate. Answers were determined accurate if they aligned with the literature and guidelines available in 2009. When measuring sun exposure practices mothers were asked to either agree, disagree or choose an answer most suitable to their practices. Statistical analysis included descriptive statistics using SPSS.

Results: Knowledge of vitamin D was generally poor amongst this sample of mothers. There was a deficit in knowledge relating to vitamin D sources, 88.9% correctly identified sunlight as the single most important source of vitamin D. However, 63.2% thought breast milk was a good source and less than a quarter thought toddler or infant formula were good sources of vitamin D. There was a knowledge deficit for risk factors for deficiency, including poor awareness for dark skin and exclusive breast feeding being high risk factors. Knowledge of barriers to vitamin D synthesis were poor, mothers were unaware of the impact of skin covering on vitamin D status and 67.2% of mothers thought it was true or were unsure when asked if sun through a window is just as effective at synthesising vitamin D. Participants followed vigilant sun exposure practices for their children and themselves, especially during summer months, 55.9% and 73.2% reported always/usually keeping their child in the shade or dressing their child in protective clothing. Of those mothers surveyed, 86.5% would always/usually put a hat on their child and 78% would always/usually apply sunblock to their child's skin. There were strong concerns of sun exposure leading to skin damage and skin cancer, 80.9% agreed that they worry sun will damage their child's skin. Only 15.8% of mothers chose health professionals as their main source of information regarding vitamin D. A very small proportion of mothers received advice from health professionals regarding vitamin D supplementation (3.1%) and safe sun exposure for adequate vitamin D for their infant (30.5%). Half of mothers agreed they did not know what to do when it came to sun exposure and vitamin D and a further 72.4% agreed skin cancer prevention messages make it difficult to understand vitamin D messages.

Conclusion: In 2009, knowledge of vitamin D amongst mothers and sun exposure practices amongst this group was unknown. This research provides the first insight into both knowledge and sun exposure practices amongst New Zealand mothers. However, considering the development of vitamin D guidelines over the past 10 years, findings from this study must be interpreted with caution, especially when applying them to current times. More up to date research is required to determine current knowledge and attitudes on vitamin D.

Key words: vitamin D, knowledge, attitudes, mothers, pregnancy, infancy.

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Abbreviations

UV-Ultraviolet

UV α -Ultraviolet alpha

UV β -Ultraviolet beta

VDR-Vitamin D receptor

GDM-Gestational Diabetes Mellitus

PTH-Parathyroid hormone

SGA-Small for Gestational Age

IUGR-Intrauterine growth restriction

DBP-Vitamin D Binding Protein

25(OH)D₃-25-hydroxyvitamin D₃

Nmol-Nanomoles

BMI-Body Mass Index

Kg-Kilogram

IU-International Units

AI-Adequate intake

μ g-Micrograms

RTI-Respiratory Tract Infection

TB-Tuberculosis

NZ-New Zealand

UK-United Kingdom

L-Litre

MoH-Ministry of Health

%-Percentage

N-Sample size

Chapter 1. Introduction

1.1 Background

Vitamin D is an important nutrient required for optimal health and plays a vital role throughout the life cycle (Barrett & McElduff, 2010; Chapuy, Arlot, Duboeuf, Brun, Crouzet, Arnaud, Delmas, & Meunier, 1992). Unique amongst vitamins, the main source of vitamin D is sunlight, more specifically ultraviolet β (UV β) radiation (290-315nm) (Chen, Chimeh, Lu, Mathieu, Person, Zhang, Kohn, Martinello, Berkowitz, & Holick, 2007). Natural dietary sources of vitamin D only provide a small portion of daily requirements (Chen, Chimeh, Lu, Mathieu, Person, Zhang, Kohn, Martinello, Berkowitz, & Holick, 2007). In New Zealand, it would be almost impossible to meet daily vitamin D requirements through diet alone (Ministry of Health, 2017). Currently, vitamin D fortification of food is not mandatory in New Zealand.

The association between vitamin D and bone health has been well established (Holick, 1996). Vitamin D deficiency during pregnancy, infancy and early childhood can have detrimental impacts on bone development and growth. Vitamin D is required for the intestinal absorption of calcium and phosphorous, inadequate levels of these nutrients within the body may lead to poor bone mineralisation (Holick, 2007; Wheeler, Dickson, Houghton, Ward, & Taylor, 2015). A severe vitamin D deficiency may result in rickets, a childhood disease characterised by weakened bones, bowed legs, skeletal deformities and growth impairment (Holick, 2007). Vitamin D status of an infant is associated with maternal status (Barrett & McElduff, 2010), those infants with vitamin D deficient mothers are at higher risk of deficiency themselves (Dijkstra, Van Beek, Janssen, De Vleeschouwer, Huysman, & Van den Akker, 2007).

Recently, non-classical roles of vitamin D in pregnancy, infancy and early childhood have been investigated. Vitamin D may likely influence additional health systems throughout the entire body. Many tissues have been found to express the vitamin D receptor (VDR) and can synthesise 1,25(OH)₂D₃, for example, the placenta and immune system (Cantorna, Zhu, Froicu, & Wittke, 2004; Holick, 2008). Additionally, vitamin D has a significant role in gene expression. The activation of VDR by 1,25(OH)₂D₃ initiates transcription factors for gene expression, resulting in control of cellular proliferation, differentiation and apoptosis (Holick, 2008; Pike & Meyer, 2012).

Emerging evidence highlights the profound impact vitamin D deficiency can have on both mother and fetus. During pregnancy, poor vitamin D status has been associated with increased risk for pre-eclampsia (Akbari, Khodadadi, Ahmadi, Abbaszadeh, & Shahsavar, 2018). Although the exact mechanisms have not been identified, it is proposed that vitamin D may influence genetic factors related to placental implantation (Bodnar, Catov, Simhan, Holick, Powers, & Roberts, 2007). Complications related to pre-eclampsia can prove fatal for both mother and child (Bhattacharya & Campbell, 2005).

A further potential complication of vitamin D deficiency during pregnancy is gestational diabetes mellitus (GDM). Poor vitamin D status may be associated with increased risk for GDM (Wilson, Leviton, Leemaqz, Anderson, Grieger, Grzeskowiak, Verburg, McCowan, Dekker, & Bianco-Miotto, 2018). The exact mechanism related to vitamin D deficiency and GDM has not

yet been determined. Fetal complications of GDM include macrosomia, injuries during birth i.e. bone fractures and hypoglycaemia (Crowther, Hiller, Moss, McPhee, Jeffries, & Robinson, 2005). Maternal long-term complications include an increased risk for maternal diabetes. Infants may experience long term complications such as an increased risk for obesity later in life, impaired glucose tolerance and hypertension (Bianco & Josefson, 2019; Crowther, Hiller, Moss, McPhee, Jeffries, & Robinson, 2005).

Preterm birth and small for gestational age (SGA) infants are an additional complication during pregnancy associated with poor vitamin D status (Zhou, Tao, Huang, Zhu, & Tao, 2017). Preterm birth is one of the top causes of fetal death in New Zealand (Ministry of Health, 2018). Preterm birth is defined as <37 weeks' gestation (Ministry of Health, 2018). The cause of preterm birth varies and depending on the severity of prematurity there can be major implications for the neonate, mother, and family (World Health Organisation, 2012). It is suspected the immunomodulatory role of vitamin D influences the risk for preterm birth (Hewison, Freeman, Hughes, Evans, Bland, Eliopoulos, Kilby, Moss, & Chakraverty, 2003). Additionally, poor vitamin D status during pregnancy may contribute to low birth weight due to intrauterine growth restriction (IUGR) (Chen, Fu, Hao, Yu, Zhu, Wang, Xu, Zhang, Tao, & Xu, 2015). However, the exact mechanism is yet to be identified (Chen, Fu, Hao, Yu, Zhu, Wang, Xu, Zhang, Tao, & Xu, 2015).

Bone development is greatly impacted by vitamin D status and vitamin D deficiency is a major cause of rickets in children and osteomalacia in adults (Charoenngam, Shirvani, & Holick, 2019). However, extending beyond this role, vitamin D has been found to influence childhood immune function, respiratory diseases such as asthma (Jensen, Murphy, Gibson, Mattes, & Camargo Jr, 2019; Li, Qin, Gao, Jiang, Chai, Guan, Ge, & Chen, 2019; Shi, Wang, Meng, Chen, Mu, & Chen, 2019) and body composition (Golzarand, Hollis, Mirmiran, Wagner, & Shab-Bidar, 2018).

Currently, in New Zealand, there is no information regarding the level of knowledge of vitamin D or sun exposure practices amongst mothers. Additionally, there is very little information regarding vitamin D knowledge from the general public. However, international studies have provided some insight into the knowledge and sun exposure practices of overseas populations. There were clear knowledge gaps amongst the general population and mothers, in vitamin D sources, benefits and requirements (Harrison, Nikles, & Nowak, 2013; Janda, Youl, Merollini, Niland, & Kimlin, 2010; Toher, Lindsay, McKenna, Kilbane, Curran, Harrington, Uduma, & McAuliffe, 2014).

Understanding sun exposure practices is essential when trying to understand risks for individuals who may be vitamin D deficient. In New Zealand, there is considerable emphasis placed on safe sun exposure for skin cancer prevention. Our skin cancer rates are amongst some of the highest in the world (Pondicherry, Martin, Meredith, Rolfe, Emanuel, & Elwood, 2018), and subsequently, we have very strong public health messages regarding sun safety. A New Zealand study of athletes found there was a significantly higher concern for sun safety compared to concern for vitamin D status (Walker, Love, Baker, Healey, Haszard, Edwards, & Black, 2014). This supports the idea that public health messages regarding sun exposure are heavily directed towards safe sun practices. There is much less emphasis on achieving optimal vitamin D status. This may suggest a knowledge deficit related to vitamin D amongst the New

Zealand population due to poor awareness. A study by Brown et al. suggested one of the main reasons for the re-emergence of rickets may be due to poor knowledge of vitamin D amongst mothers (Brown, Nunez, Russell, & Spurney, 2009). At the time this survey was administered (2009), there were minimal guidelines available to the general public and health professionals regarding vitamin D. However since then, the Consensus Statement on Vitamin D and Sun Exposure in New Zealand and the Companion Statement on vitamin D and Sun Exposure in Pregnancy and Infancy in New Zealand (Ministry of Health, 2012a) was released. It is unknown whether the release of this statement has improved vitamin D knowledge or altered sun exposure practices.

1.2 Purpose of this study

Identifying the knowledge gaps amongst mothers regarding vitamin D and sun exposure practices will be useful in determining whether the level of public health messaging in 2009 was appropriate for vitamin D awareness and safe sun exposure for adequate vitamin D. Improved knowledge of vitamin D may influence behaviour change, especially in a highly motivated population such as pregnant women (Bandura, 2004). If mothers are not aware of vitamin D and the recommendations for themselves and their children, they are less likely to follow guidelines (Lee, Newton, Radcliffe, & Belski, 2018). An increase in knowledge regarding vitamin D and sun exposure practices may increase awareness for sources, risk factors and guidelines. Mothers must be provided with the appropriate resources to help ensure their children and themselves are reaching their optimal vitamin D status.

1.3 Aim

The present study aims to assess the overall knowledge for vitamin D and common practices involving sun exposure amongst New Zealand women with children under five years of age.

1.4 Objectives

1. To investigate mother's knowledge about vitamin D including sources, benefits, risk factors and barriers to synthesis.
2. To assess sources of advice and knowledge regarding vitamin D.
3. To identify both sun exposure practices and knowledge and attitudes regarding sun safety for both mothers and their infants.

1.5 Thesis structure

This thesis consists of four chapters. The first chapter introduces the study and identifies the purpose of the study. Chapter two is a narrative literature review of the history and metabolism of vitamin D, it identifies the current status of New Zealanders, followed by the impacts of poor vitamin D status in pregnancy and infancy. Finally, risk factors for deficiency are identified and the current level of knowledge regarding vitamin D both locally and internationally is discussed. The third chapter is presented in the form a manuscript for publication; this chapter provides a complete presentation of the study. The final chapter is

the conclusion and recommendation chapter, it will also highlight the study's strengths and limitations and addresses recommendations for future research and practice.

1.6 Researchers' contributions

Table 1.1: Researcher's contributions to the research project

Researcher	Contributions
Mia Franklin Student	Main researcher. Cleaned and handled data, completed statistical analysis, interpreted and discussed results. Author of thesis.
Associate Professor Pamela Von Hurst Main supervisor	Academic supervisor. Obtained ethics, designed survey and collected data. Provided academic support and feedback for thesis.
Cathryn Conlon Co-supervisor	Academic supervisor. Obtained ethics, designed survey and collected data. Provided academic support and feedback for thesis.

Chapter 2 Literature review

2.1 The history of the sunshine vitamin

It was the late 1700s in Northern Europe and business, industry and manufacturing were booming, the industrial revolution had begun. An increase in the use of coal caused thick smog to pollute the skies and exposure to UV light was greatly reduced (Holick, 2004). Hoards migrated from small rural communities to large cities. The living conditions were poor and space was limited (Holick, 2004). Sickness became rife and new diseases began to emerge. Children began to suffer from weak and bowed legs caused by skeletal deformities (Holick, 1995; Wheeler, Dickson, Houghton, Ward, & Taylor, 2015). This disease, known today as rickets, continued to increase in prevalence during the industrial revolution and into the 20th century (Holick, 1995).

The first time that sunlight exposure was suggested to be curative for rickets was in 1822 by Sniadecki, a Polish physician (Holick, 2009; MozoÅowski, 1939). Sniadecki observed a high prevalence of rickets in children living in the city of Warsaw, he also noted that this condition was practically non-existent amongst those living in nearby rural areas (MozoÅowski, 1939). Sniadecki concluded that the most effective cure and prevention for this disease was to expose children to direct sunlight (Holick, 1995; MozoÅowski, 1939). Unfortunately, the idea of sunlight playing a role in the treatment and prevention of rickets was dismissed by the medical and scientific community at this time, resulting in at least another 100 years of unnecessary suffering by children living in industrialised cities (Holick, 1995).

It was not until 1919, nearly 100 years after Sniadecki's revelation that sun exposure began to be widely accepted as a cure for rickets. Huldschinsky, a German paediatrician, investigated the impact of exposure to artificial UV radiation on four children with rickets. It was discovered through x-ray analysis that after four months of the artificial UV radiation the rickets were cured (Holick, 1995; Huldschinsky, 1919). Huldschinsky also found that the therapy was not only effective at the local site but also extended to other parts of the body (Huldschinsky, 1919). Similar findings were replicated a few years later, seven children were exposed to regular direct sun light and it was found through x-ray analysis that each child's rickets had significantly improved (Hess & Unger, 1921; Holick, 1995). Sun light was not the only treatment for rickets to be identified. Experiments on beagle dogs identified cod liver oil as a successful treatment for rickets (McCollum, Simmonds, Becker, & Shipley, 1922). The beagles were fed diets similar to those who lived in areas with a high prevalence of rickets and were not exposed to sun light. Eventually the dogs developed rickets and through supplementation of cod liver oil the rickets were cured (McCollum, Simmonds, Becker, & Shipley, 1922).

After having confirmed the discovery of the role of sunshine in bone health, researchers changed their focus to the impact of UV radiation on food (Hess & Weinstock, 1924; Steenbock, 1924). It was concluded that irradiated foods had antirachitic affects (Hess & Weinstock, 1924; Steenbock, 1924). This breakthrough greatly reduced the prevalence of rickets in a number of countries. The irradiation process ceased once the structure of vitamin D was identified and was able to be added directly to milk as vitamin D₂ (Yeh, Barbano, &

Drake, 2017). However, vitamin D fortification of milk was discontinued after increased rates of hypercalcemia occurred during the 1950s in the United Kingdom (UK) (Samuel, 1964).

2.2 Vitamin D metabolism

Vitamin D is particularly unique due to the way in which it is obtained. Despite its name, vitamin D may be more appropriately referred to as a hormone due to the major source of vitamin D being through cutaneous synthesis from direct exposure to UV β sunlight (Christakos, Dhawan, Verstuyf, Verlinden, & Carmeliet, 2015).

The form of vitamin D produced within the skin is known as vitamin D₃ or cholecalciferol, this form is biologically inert and must be converted to its active form to modulate physiological responses within the body (Christakos, Dhawan, Verstuyf, Verlinden, & Carmeliet, 2015). The chemical precursor for vitamin D₃ is 7-dehydrocholesterol and is found within the skin (Christakos, Dhawan, Verstuyf, Verlinden, & Carmeliet, 2015). Exposure to UV β radiation causes the rearrangement in chemical structure of 7-dehydrocholesterol within the skin resulting in the formation of vitamin D₃ (Christakos, Dhawan, Verstuyf, Verlinden, & Carmeliet, 2015). This process is dependent on radiation intensity, therefore environmental factors such as latitude and seasons can have a significant impact on serum vitamin D levels (Christakos, Dhawan, Verstuyf, Verlinden, & Carmeliet, 2015).

Vitamin D₃ must be transported in the blood to the liver via vitamin D binding protein (DBP) (Christakos, Dhawan, Verstuyf, Verlinden, & Carmeliet, 2015). The liver is the site of conversion for vitamin D₃ to 25-hydroxyvitamin D₃ (25(OH)D₃) via hydroxylation of C-25 enzyme with vitamin-D-25-hydroxylase (CYP27A1) (Christakos, Dhawan, Verstuyf, Verlinden, & Carmeliet, 2015). The 25(OH)D₃ is the circulating form of vitamin D and is used to measure vitamin D status, the biologically active form of vitamin D is 1,25(OH)₂D₃.

It was once believed the circulating form of vitamin D was only transported to the kidney to be converted to its active form (1,25(OH)₂D₃). The active form of vitamin D was then thought to be released from the kidney into the blood stream and traveled to target cells. However, it has now been identified that this process can occur within a variety of tissues throughout the body and not the kidney alone. Consequently, vitamin D has been implicated within numerous body systems. Vitamin D acts on the nuclei of target cells through the activation of the vitamin D receptor (VDR). This causes the hetero-dimerization between the VDR and the nucleic receptor, retinoic X receptor (Christakos, Dhawan, Liu, Peng, & Porta, 2003). This process results in VDR mediated gene transcription (Christakos, Dhawan, Liu, Peng, & Porta, 2003).

A feedback loop acts as a control for the amount of 1,25(OH)₂D₃ produced. When calcium levels are low, parathyroid hormone (PTH) synthesis and secretion is increased, this promotes the hydroxylation of 25(OH)D₃ to 1,25(OH)₂D₃. Conversely, when calcium levels are high this pathway is inhibited (Clemens & Holick, 1983; Salle, Delvin, Lapillonne, Bishop, & Glorieux, 2000).

2.3 Intestinal absorption of vitamin D

The small intestine is the main site for absorption of vitamin D₂ and D₃, it is packaged into chylomicrons and transported to the hepatic portal circulation via the lymphatic system (Holick, 2007). Plant sources are known as ergocalciferol or vitamin D₂ (Stocklin & Eggersdorfer, 2013). Additionally, vitamin D₂ is produced via UVβ irradiation of the ergosterol in fungi and plants (Bikle, 2014). The chemical structure of vitamin D₂ differs to that of vitamin D₃.

Animal sources of vitamin D are referred to as cholecalciferol or vitamin D₃. Unfortunately, foods with naturally high levels of vitamin D are scarce and fortified foods are limited in New Zealand. Dietary sources that have small amount of naturally occurring vitamin D₃ include oily fish such as salmon and tuna, milk and milk products, liver and eggs (Holick, 2007). Alternatively, foods can be for fortified with vitamin D, for example margarine, dairy products and plant-based dairy substitutes (Holick, 2007). In New Zealand the form of vitamin D used in fortification is vitamin D₃, this is also true for the form of vitamin D in supplements.

Table 2.1: Vitamin D content of New Zealand foods

Food type	Vitamin D content (µg/100g)
New Zealand King Salmon, raw	20.1
Margarine*	16.7
Greek style yoghurt*	7.3
Light cottage cheese*	4.0
Whole egg, raw	1.5
Milk, high calcium, 0.1%,	0.66

*Assumed to be fortified.

Values sourced from (Thomson & Cressey, 2011).

This vitamin has well-established roles in bone metabolism and the homeostasis of minerals through both the kidney and gastrointestinal tract. However, non-classical roles of vitamin D continue to be investigated. Research has found this vitamin to have profound importance in human health, providing good reason for further investigations and research.

2.4 Current situation in New Zealand

The most recent assessment of vitamin D status of New Zealanders was the 2008/09 New Zealand Adult Nutrition survey. It appeared that 68.1% of New Zealand adults had sufficient levels of serum 25(OH)D (>50 nmol/L) (Ministry of Health, 2012b). A further 27% had serum 25(OH)D levels below recommended but were not deficient (25.0-49.9 nmol/L) (Ministry of Health, 2012b) and 4.9% had vitamin D deficiency (12.5-24.9 nmol/L) (Ministry of Health, 2012b) with 1.9 percent of this group having a severe deficiency (<12.5 nmol/L) (Ministry of Health, 2012b).

The 2008/09 Adult Nutrition survey identified mean serum 25(OH)D was 56.6 nmol/L for those adults living in the most deprived areas of New Zealand (NZDep2006 quintile 5) (Ministry of Health, 2012b), whereas those living in the least deprived areas (quintile 1) had

a mean serum 25(OH)D of 69.9 nmol/L (Ministry of Health, 2012b). Those living in the most deprived areas were 3.2 times more likely to be vitamin D deficient compared to those living in the least deprived areas (Ministry of Health, 2012b).

Vitamin D status was related to body size. Adults within the obese category (defined as a body mass index (BMI) of $>30\text{kg/m}^2$) were identified as having a significantly lower mean annual level of serum 25(OH)D compared to those within the normal (BMI of $18.5\text{-}24.9\text{ kg/m}^2$) and underweight (BMI of $<18.5\text{ kg/m}^2$) category, after adjusting for sex, age, and ethnicity (Ministry of Health, 2012b).

The New Zealand Ministry of Health currently recommends annual mean serum 25(OH)D to be $>50\text{nmol/L}$ (Ministry of Health, 2012b). This value is based on the statements made by the Institute of Medicine (Institute of Medicine, 2011). Adequate, inadequate and deficient serum 25(OH)D has been determined by the Ministry of Health as $>50\text{nmol/L}$, $25\text{-}50\text{nmol/L}$ and $<25\text{nmol/L}$, respectively.

Genetic variations in vitamin D pathways have been identified (Sinotte, Diorio, Berube, Pollak, & Brisson, 2008). Polymorphisms in genes related to vitamin D metabolism and transport have been found to have impacts on health outcomes (Abbas, Linseisen, Slinger, Kropp, Mutschelknauss, Flesch-Janys, & Chang-Claude, 2008; Janssens, Bouillon, Claes, Carremans, Lehouck, Buyschaert, Coolen, Mathieu, Decramer, & Lambrechts, 2010; Kurylowicz, Ramos-Lopez, Bednarczyk, & Badenhop, 2006). Considering these factors, suggested guidelines should only be used as guides, as individual requirements are likely to vary. There is currently a lack of standardisation in measuring serum 25(OH)D. Research has identified variation in results when using different assays (Nowak, Harrison, Buettner, Kimlin, Porter, Kennedy, & Speare, 2011), suggesting the possibility of misdiagnosing adequate or inadequate serum 25(OH)D. This must be taken into consideration when comparing vitamin D status of New Zealanders with the rest of the world.

2.4.1 Vitamin D status of New Zealand women and their children

Maternal vitamin D status has a significant impact on fetal status. Vitamin D deficiency in mothers is a risk factor for deficiency in infants. Furthermore, low vitamin D status is associated with increased risk for poor maternal and fetal health outcomes. It was identified in the 2008/09 New Zealand Adult Nutrition survey that 28.5% of women had serum vitamin D below the recommended range (Ministry of Health, 2011).

More specifically, one study investigating predictors of vitamin D status of pregnant women in South Auckland, New Zealand found that of the 259 women included, 42% were identified to be deficient in vitamin D (Ekeroma, Camargo Jr, Scragg, Wall, Stewart, Mitchell, Crane, & Grant, 2015). Different ethnic groups have been highlighted as particularly at risk for vitamin D deficiency (Ekeroma, Camargo Jr, Scragg, Wall, Stewart, Mitchell, Crane, & Grant, 2015; Mazahery, Stonehouse, & Von Hurst, 2015; Nessvi, Johansson, Jopson, Stewart, Reeder, McKenzie, & Scragg, 2011). Those ethnic groups with the highest incidence of vitamin D deficiency in New Zealand were Pacific, Māori, Middle Eastern and South Asian women (Ekeroma, Camargo Jr, Scragg, Wall, Stewart, Mitchell, Crane, & Grant, 2015; Mazahery, Stonehouse, & Von Hurst, 2015; von Hurst, Stonehouse, & Coad, 2010). Research

investigating vitamin D status of the general population living in Auckland and Dunedin further supported this; Asian, Māori and Pacific groups were more likely to have lower serum 25(OH)D than their New Zealand European counterparts (Nessvi, Johansson, Jopson, Stewart, Reeder, McKenzie, & Scragg, 2011). Additional studies also identified that ethnicity is associated with differences in serum 25(OH)D (Delshad, Beck, Conlon, Mugridge, Kruger, Jensen, Ma, & von Hurst, 2019; Ekeroma, Camargo Jr, Scragg, Wall, Stewart, Mitchell, Crane, & Grant, 2015; Nessvi, Johansson, Jopson, Stewart, Reeder, McKenzie, & Scragg, 2011).

It is apparent that some women of child bearing age are at risk for deficiency and poor vitamin D status. It has been investigated whether these same trends are apparent in New Zealand children. Earlier research identified that of 929 newborn babies born between 1997 and 2007 in either Wellington or Christchurch, 57% had serum 25(OH)D <50nmol/L (Camargo, Ingham, Wickens, Thadhani, Silvers, Epton, Town, Espinola, Crane, New Zealand Asthma, & Allergy Cohort Study Group, 2010). Additionally, Pacific and other non-European children were more likely to have poor vitamin D status compared to New Zealand European children (Cairncross, Stonehouse, Conlon, Grant, McDonald, Houghton, Eyles, Camargo Jr, Coad, & von Hurst, 2017; Rockell, Green, Skeaff, Whiting, Taylor, Williams, Parnell, Scragg, Wilson, & Schaaf, 2005).

2.4.2 Current recommendations in New Zealand

The current recommendations in New Zealand for vitamin D are guided by the 2012 Consensus Statement (Ministry of Health, 2012a) on Vitamin D and Sun Exposure in New Zealand and the Companion Statement on vitamin D and Sun Exposure in Pregnancy and Infancy in New Zealand (Ministry of Health, 2013). These statements suggest that those who are most at risk for deficiency may require some form of supplementation. However, it is concluded within the statement that for the majority of the population, especially those without medical issues related to vitamin D deficiency or do not have the listed risk factors, that vitamin D supplementation is not necessary nor recommended. For the general population in New Zealand, the Consensus Statement recommends exposure to sunlight to promote vitamin D synthesis. However, it cautions unprotected exposure to UV β light, as it is a known cause of skin cancer. Furthermore, it is recommended that individuals protect themselves from direct sunlight from the hours 10am-4pm, especially in the months September through to April (Ministry of Health, 2012a).

The requirement for vitamin D supplementation is often based on risk factors (refer to section 2.7) rather than blood tests. In New Zealand, the cost of a blood test is significantly higher than the cost of a supplement. The PHARMAC-subsidised vitamin D supplement is a 1.25mg (50,000 IU) tablet of cholecalciferol once per month. Currently, it is unclear whether vitamin D supplementation at this level for those pregnant mothers who are not at risk for vitamin D deficiency is safe for their unborn child (Palacios, Kostiuk, & Peña-Rosas, 2019). The Consensus Statement recommends that lower daily doses rather than large monthly doses may be more appropriate if vitamin D supplementation becomes mandatory for pregnant women in New Zealand (Ministry of Health, 2012a).

Previously, the vitamin D supplement for infants listed on the PHARMAC schedule was an oral liquid supplement, Vitadol-C. From August 2019 a new supplement, Puria, has been listed and

replaced Vitadol-C. Puria contains 7,500 IU/ml and 400 IU/drop (recommended daily dose) of vitamin D. It can be prescribed to a child with proven vitamin D deficiency. A recent systematic review and meta-analysis concluded that 400 IU/day was effective in achieving satisfactory 25(OH)D in infants (Zittermann, Pilz, & Berthold, 2019).

The 2019 Cochrane review of vitamin D supplementation in pregnant women found that supplementation of vitamin D alone during pregnancy likely reduces the risk for pre-eclampsia, low birth weight, and gestational diabetes when compared to those pregnant women who received a placebo or no intervention (Palacios, Kostiuik, & Peña-Rosas, 2019). However, it is suggested that further research be conducted to determine the most effective and safe dosages of vitamin D supplements and the impacts of vitamin D supplementation in conjunction with other supplements. Additionally, more research is required investigating whether outcomes of vitamin D supplementation is altered in a variety of different populations i.e. different skin pigmentations, vitamin D status and body mass index. This research is required to best guide policy making regarding supplementation for pregnant women (Palacios, Kostiuik, & Peña-Rosas, 2019).

Currently, there has been no research in New Zealand investigating health professionals' knowledge on vitamin D supplementation. However, a study of Australian dietitians found a lack of knowledge regarding supplementation doses for treatment and prevention of vitamin D deficiency (Dix, Robinson, Bauer, & Wright, 2017). It would be valuable to assess health professional's knowledge of vitamin D supplementation; if knowledge of supplementation is lacking amongst this group it would indicate the need for the development of additional supplementation guidelines.

2.5 Vitamin D in pregnancy

Maternal vitamin D status during pregnancy has been shown to influence health outcomes in both mother and fetus. Maternal vitamin D status has a significant impact on fetal stores at birth (Wheeler, Taylor, de Lange, Harper, Jones, Mekhail, & Houghton, 2018). Fetal bone mineral accrual occurs largely in the third trimester (Wheeler, Taylor, de Lange, Harper, Jones, Mekhail, & Houghton, 2018). It is reliant on maternal vitamin D and calcium, making them important nutrients for positive fetal outcomes. The exchange of 25(OH)D from mother to fetus is via the placenta, therefore maternal serum 25(OH)D and fetal cord blood 25(OH)D are positively correlated (Dijkstra, Van Beek, Janssen, De Vleeschouwer, Huysman, & Van den Akker, 2007). Evidence suggests mothers who are deficient in vitamin D may have higher risk for pre-eclampsia, preterm pregnancy, gestational diabetes and poor fetal growth (Bodnar, Catov, Simhan, Holick, Powers, & Roberts, 2007; Chen, Fu, Hao, Yu, Zhu, Wang, Xu, Zhang, Tao, & Xu, 2015; Mathieu, van Etten, Decallonne, Guilietti, Gysemans, Bouillon, & Overbergh, 2004; Parlea, Bromberg, Feig, Vieth, Merman, & Lipscombe, 2012). A New Zealand study found vitamin D inadequacy and deficiency was common during pregnancy, with 87% of women found to have serum 25(OH)D <50 nmol/L (Eagleton & Judkins, 2006). However, this study did not consider seasonal variation, this may have influenced serum 25(OH)D of mothers in this study.

2.5.1 Preeclampsia

Preeclampsia is a severe complication that can occur during pregnancy, it can have detrimental health impacts and can be fatal for both mother and fetus (Redman & Sargent, 2005). Preeclampsia can present during later stages of pregnancy and is characterised by proteinuria and hypertension (George & Granger, 2010; Redman & Sargent, 2005). The exact cause of preeclampsia is not well understood but it has been suggested maternal vitamin D deficiency may play a role (Bodnar, Catov, Simhan, Holick, Powers, & Roberts, 2007; Mirzakhani, Litonjua, McElrath, O'Connor, Lee-Parritz, Iverson, Macones, Strunk, Bacharier, & Zeiger, 2016).

Vitamin D deficiency at <22 weeks' gestation was found to be a strong, independent risk factor for preeclampsia (Bodnar, Catov, Simhan, Holick, Powers, & Roberts, 2007). Mirzakhani et. al found that although vitamin D supplementation at 10-18 weeks' gestation did not reduce risk for preeclampsia, those mothers with serum 25(OH)D >75 nmol/L at the beginning of the trial and late in pregnancy were at lower risk for preeclampsia (Mirzakhani, Litonjua, McElrath, O'Connor, Lee-Parritz, Iverson, Macones, Strunk, Bacharier, & Zeiger, 2016). Additionally, a 2018 meta-analysis of the association of vitamin D levels and risk for preeclampsia concluded that women with serum vitamin D <50nmol/L were at increased risk for preeclampsia (Akbari, Khodadadi, Ahmadi, Abbaszadeh, & Shahsavari, 2018).

Placental hypoxia, often due to abnormal implantation, is a characteristic of preeclampsia (Bodnar, Catov, Simhan, Holick, Powers, & Roberts, 2007; George & Granger, 2010). Animal studies have shown the active form of vitamin D, 1,25(OH)₂D₃, plays a role in placental implantation (Halhali, Acker, & Garabedian, 1991). This may suggest a deficiency in vitamin D during early pregnancy impairs placental implantation, subsequently increasing risk for preeclampsia. However, the exact mechanisms have not yet been determined in human pregnancy.

2.5.2 Preterm birth

In 2017, 4,500 babies were born preterm in New Zealand (Figure.nz, 2017). Māori, Pacific and Indian mothers were found to have the highest rates of preterm birth (Figure.nz, 2017). Preterm birth is defined as delivery prior to 37 weeks' gestation and can have many severe complications, including increased risk for fetal mortality (Zhou, Tao, Huang, Zhu, & Tao, 2017). Further complications of preterm birth include impaired cognitive function, poor vision and hearing, chronic lung disease and cerebral palsy (Howson, Kinney, McDougall, & Lawn, 2013).

Vitamin D deficiency in pregnant women was found to increase the risk for preterm birth (Zhou, Tao, Huang, Zhu, & Tao, 2017). Furthermore, vitamin D supplementation during pregnancy may reduce the risk for preterm birth (Zhou, Tao, Huang, Zhu, & Tao, 2017). Although the exact mechanism has not yet been determined, vitamin D may reduce risk for preterm birth via what is thought to be an immunomodulatory function (Mathieu, van Etten, Decallonne, Guilietti, Gysemans, Bouillon, & Overbergh, 2004). There is a need for further research to better determine the impact and effect of serum vitamin D and vitamin D supplementation during pregnancy on preterm birth.

2.5.3 Vitamin D and gestational diabetes mellitus (GDM)

GDM is a common complication in pregnancy. In New Zealand, 6.6% of pregnant women will experience GDM (Ministry of Health, 2014). Those mothers who develop GDM are at increased risk for caesarean section delivery, pre-eclampsia, birthing complications due to macrosomia, neonatal asphyxia and the development of maternal metabolic syndrome and type 2 diabetes later in life (Poel, Hummel, Lips, Stam, Van Der Ploeg, & Simsek, 2012).

Currently, there is conflicting research regarding the association between serum vitamin D levels and glucose metabolism. However, some results have identified low serum vitamin D has been associated with increased risk for GDM (Parlea, Bromberg, Feig, Vieth, Merman, & Lipscombe, 2012; Wilson, Leviton, Leemaqz, Anderson, Grieger, Grzeskowiak, Verburg, McCowan, Dekker, & Bianco-Miotto, 2018; Zhang, Qiu, Hu, David, Van Dam, Bralley, & Williams, 2008). The exact mechanism in which vitamin D is thought to influence glucose metabolism has not yet been determined. However, research of animal and in vitro studies have found vitamin D to have a significant role in insulin metabolism, secretion and sensitivity (Alvarez & Ashraf, 2010; Cade & Norma, 1986).

The causal relationship between vitamin D status and GDM has not yet been proven. Considering that maternal age, BMI, and ethnicity are all risk factors for both vitamin D deficiency and GDM, it is difficult to rule these out as potential confounders. The previously mentioned research controlled for these factors and still found that risk for developing GDM was significantly higher amongst those who were vitamin D deficient (Parlea, Bromberg, Feig, Vieth, Merman, & Lipscombe, 2012; Wilson, Leviton, Leemaqz, Anderson, Grieger, Grzeskowiak, Verburg, McCowan, Dekker, & Bianco-Miotto, 2018; Zhang, Qiu, Hu, David, Van Dam, Bralley, & Williams, 2008). However, there is research available that have not made adjustments for these confounding factors and therefore the reliability of these results must be questioned.

Despite claims that inadequate vitamin D increases risk for GDM, there is evidence suggesting glucose metabolism was not improved after supplementation with 5,000 IU of vitamin D per day in those pregnant women who were deficient in vitamin D (Yap, Cheung, Gunton, Athayde, Munns, Duke, & McLean, 2014). However, a 2019 systematic review and meta-analysis of randomised controlled trials found that vitamin D supplementation in women with GDM did have the potential to improve glycaemic control (Ojo, Weldon, Thompson, & Vargo, 2019). These findings were based on a small amount of trials (n=10) and therefore the results should be interpreted with caution and further research is required to fully determine the link between vitamin D supplementation and glycaemic control (Ojo, Weldon, Thompson, & Vargo, 2019).

Although research is still emerging for the association between vitamin D and GDM, achieving adequate vitamin D in pregnant women and their infants is still imperative given the possible and proven benefits adequate vitamin D status provides.

2.6 Vitamin D in infancy

2.6.1 Bone health

It has been well established that vitamin D plays a crucial role in forming and maintaining proper bone health. One of vitamin D's essential roles is calcium homeostasis via control of calcium absorption in the gastrointestinal tract and renal absorption together with PTH (Goltzman, 2018).

Adequate calcium is essential for healthy bone mineralisation. Vitamin D acts to promote transcellular calcium absorption by increasing calcium channels on the apical membrane of duodenal cells (Goltzman, 2018). Vitamin D influences calcium absorption via paracellular pathways through the regulation of proteins associated with tight junctions (Goltzman, 2018). In the transcellular pathway, vitamin D regulates the calcium binding protein, calbindin, allowing the movement of calcium through the cytosolic component of the cell (Goltzman, 2018). Finally, vitamin D facilitates calcium transport across the basolateral membrane and into the blood stream (Goltzman, 2018). Adequate serum calcium must be maintained to prevent the release of calcium from bone by PTH (Cashman, 2007).

During pregnancy it is vital mothers have adequate vitamin D and calcium to ensure the healthy development of their fetus' skeleton, as well as maintaining their own bone density. Long term vitamin D deficiency in infancy and childhood can lead to the development of rickets. Although once considered a disease of the past, rickets is still present in New Zealand. One longitudinal study investigating 25(OH)D and PTH status of mothers and their infants living in the South Island of New Zealand found that three of the infants (n=66) had biochemical results consistent with vitamin D deficiency rickets (Wheeler, Taylor, de Lange, Harper, Jones, Mekhail, & Houghton, 2018). Additional research highlights the annual incidence of rickets in New Zealand to be 2.2/100,000 for all children aged under 15 years and 10.6/100,000 of children aged under three years (Wheeler, Dickson, Houghton, Ward, & Taylor, 2015). The area of New Zealand with the highest incidence of rickets was those children living in the highest latitude of the South Island (Wheeler, Dickson, Houghton, Ward, & Taylor, 2015).

2.6.2 Vitamin D and breast milk

Breast milk is not a good source of vitamin D for infants (Chang & Lee, 2019). Levels of vitamin D in breast milk are estimated to be between 15-60 IU/L in mothers with optimal vitamin D status (Balasubramanian & Ganesh, 2008; Misra, Pacaud, Petryk, Collett-Solberg, & Kappy, 2008). The Australia and New Zealand Nutrient reference values state infants aged 0-6 months require 5µg/day (200 IU) for adequate intake (AI) of vitamin D per day (Ministry of Health, 2017). Therefore, it is unlikely an exclusively breastfed infant, even from a mother with adequate vitamin D levels, will meet their daily vitamin D requirements.

During pregnancy, stores of vitamin D from mother are transferred in utero and provide at least eight weeks of vitamin D stores to her newborn child if mother is vitamin D replete (Misra, Pacaud, Petryk, Collett-Solberg, & Kappy, 2008). Beyond this eight-week timeframe, vitamin D supplementation may be beneficial to ensure adequate vitamin D levels in infants.

Those who are breastfed by vitamin D deficient mothers are at increased risk for vitamin D deficiency (Misra, Pacaud, Petryk, Collett-Solberg, & Kappy, 2008). Exclusively breastfed babies are unlikely to develop rickets as they often are exposed to incidental sun light (Ministry of Health, 2013), and exclusive breastfeeding is strongly encouraged in New Zealand.

In New Zealand, vitamin D supplementation amongst exclusively breastfed infants is not mandatory or commonly recommended by health professionals (Lovell, Wall, & Grant, 2016). The lack of routine supplementation amongst exclusively breastfed infants may be reflected in poor serum vitamin D levels as demonstrated by Lovell et al. In a sample of exclusively breast fed infants living in Auckland, New Zealand, 44% were found to have serum vitamin D <50 nmol/L (Lovell, Wall, & Grant, 2016). The serum 25(OH)D of infants was found to be independent of other factors such as maternal dietary factors and maternal sunlight exposure and practices (Lovell, Wall, & Grant, 2016). Risk for deficiency amongst infants increased during winter and for those of non-European ethnicity (Lovell, Wall, & Grant, 2016). The Consensus Statement does not currently recommend supplementation for exclusively breast fed infants or lactating mothers (Ministry of Health, 2012a). However, maternal supplementation of vitamin D has positive impacts on vitamin D content of breast milk. This was found to improve serum 25(OH)D of infants. Therefore, supplementation of vitamin D for mothers may be an effective way to increase serum 25(OH)D in both mother and child (World Health Organisation, 1998). Currently, the UK recommends daily vitamin D supplementation in all exclusively breast fed infants aged up to 12 months (Scientific Advisory Committee on Nutrition, 2018).

2.6.3 Vitamin D and childhood immunity

The biggest contributor of childhood morbidity and mortality is infection according to the World Health Organisation (Bryce, Boschi-Pinto, Shibuya, Black, & WHO Child Health Epidemiology Reference Group, 2005). This demonstrates that healthy immune function is imperative for childhood survival. Although the exact mechanisms are not completely understood, research suggests that vitamin D plays a significant role in immune development (Rueter, Jones, Siafarikas, Lim, Bear, Noakes, Prescott, & Palmer, 2019).

2.6.4 Vitamin D and respiratory illness

Vitamin D has been found to play a role in the susceptibility to respiratory tract infections (RTIs) in children. Tuberculosis (TB) was one of the first infectious respiratory diseases to be implicated with vitamin D deficiency. Rates of TB in New Zealand are higher than other developed countries such as Australia, United States and Canada. Those ethnicities with the highest prevalence of TB in New Zealand include Asian, Middle Eastern, Latin American, African and Pacific (The Institute of Environmental Science and Research Ltd, 2018). Those children with either active or latent TB are more likely to have poor vitamin D status (Venturini, Facchini, Martinez-Alier, Novelli, Galli, de Martino, & Chiappini, 2014; Wilkinson, Llewelyn, Toossi, Patel, Pasvol, Lalvani, Wright, Latif, & Davidson, 2000; Williams, Williams, & Anderson, 2008). Studies have suggested vitamin D supplementation to have a therapeutic role as a supplementary treatment for TB. One study (n=259) found those vitamin D deficient patients with pulmonary TB had improved clinical and radiographical outcomes at 12 weeks

after having two doses of 600,000 IU of intramuscular vitamin D₃ (Salahuddin, Ali, Hasan, Rao, Aqeel, & Mahmood, 2013). Conversely, another study found that administration of 100,000 IU, three times over eight months did not alter clinical outcomes in comparison to the placebo group (Wejse, Gomes, Rabna, Gustafson, Aaby, Lisse, Andersen, Glerup, & Sodemann, 2009). The exact mechanism that implicates vitamin D in the susceptibility to and treatment of TB is not yet well understood, further studies are required to establish these mechanisms and associations.

Asthma is a respiratory disease that impacts many New Zealanders' lives. In 2016, one in seven children were reported to have been taking medication for asthma, one of the highest rates globally. Hospital admissions due to asthma have been increasing over recent years and it is one of the most common causes for hospital admission amongst children. Recent research found those infants born with lower cord 25(OH)D were more likely to have recurrent wheeze/asthma by the time they were three years old (Mirzakhani, Carey, Zeiger, Bacharier, O'Connor, Schatz, Laranjo, Weiss, & Litonjua, 2019). Whereas children with sufficient cord 25(OH)D levels at birth were 34% less likely to develop a recurrent wheeze/asthma by the age of three compared to those who had poor vitamin D status (<12 nmol/L) at birth, independent of maternal asthma status (Mirzakhani, Carey, Zeiger, Bacharier, O'Connor, Schatz, Laranjo, Weiss, & Litonjua, 2019). Moreover, risk was reduced up to 50% if maternal vitamin D status was adequately maintained throughout pregnancy (Mirzakhani, Carey, Zeiger, Bacharier, O'Connor, Schatz, Laranjo, Weiss, & Litonjua, 2019). Likely related to vitamin D's immunoregulatory function, the complete role of vitamin D and asthma is not fully understood.

2.6.5 Vitamin D and body composition

The 2017/18 New Zealand Health survey found one in eight children were obese in New Zealand (Ministry of Health, 2019). It is widely accepted that poor dietary choices and low physical activity are the main contributors to obesity. However, research has suggested vitamin D status may also contribute to body composition.

Those children with higher 25(OH)D throughout their first three years of life were more likely to have higher lean body mass and lower BMI at three and six years compared to their more vitamin D deficient peers (Hazell, Gallo, Vanstone, Agellon, Rodd, & Weiler, 2017; Trilok-Kumar, Kaur, Rehman, Arora, Rajput, Chugh, Kurpad, Sachdev, & Filteau, 2015). However, there were no further long term effects seen on body composition for those supplemented with vitamin D early in life (Trilok-Kumar, Kaur, Rehman, Arora, Rajput, Chugh, Kurpad, Sachdev, & Filteau, 2015). One study with a cohort of nearly 5,000 mothers and their children found that those mothers who were severely vitamin D deficient were more likely to have children with higher adiposity and lower lean mass compared to those mothers with normal vitamin D status (Miliku, Felix, Voortman, Tiemeier, Eyles, Burne, McGrath, & Jaddoe, 2019).

2.7 Risk factors for vitamin D deficiency in pregnant women and children

Considering vitamin D has such a significant role during pregnancy, early infancy and childhood, it is imperative that those who are at high risk of deficiency are identified. Risk factors for vitamin D deficiency can be both intrinsic and environmental.

2.7.1 Skin colour

The variance in skin colour amongst humans is largely determined by the epidermal melanin pigment (Fajuyigbe & Young, 2016). Those with darker skin will have higher levels of melanin compared to those with lighter skin (Khalid, Moore, Hall, Olabopo, Rozario, Holick, Greenspan, & Rajakumar, 2017). Melanin acts as a barrier to the photoproduction of vitamin D within the epidermis, it acts as a filter for UV β light (Khalid, Moore, Hall, Olabopo, Rozario, Holick, Greenspan, & Rajakumar, 2017; Rockell, Skeaff, Williams, & Green, 2008). This is an issue as UV β light is required by 7-dehydrocholesterol within the epidermis to form previtamin D₃. Due to the high melanin content of those with dark skin, there is an increased risk for vitamin D deficiency amongst this population (Khalid, Moore, Hall, Olabopo, Rozario, Holick, Greenspan, & Rajakumar, 2017). It is estimated those with dark skin are required to spend five to ten times longer in the sun compared to those with lighter skin types to synthesise the equivalent vitamin D (Camargo, Ingham, Wickens, Thadhani, Silvers, Epton, Town, Espinola, Crane, New Zealand Asthma, & Allergy Cohort Study Group, 2010).

A 2019 Sydney based study found that amongst healthy adult office workers, those with darker pigmented skin were much more likely to be vitamin D deficient at the end of winter compared to their lighter skinned counterparts (Fayet-Moore, Brock, Wright, Ridges, Small, Seibel, Conigrave, & Mason, 2019). A New Zealand based study found a significant difference between mean serum 25(OH)D of European and Pacific adults, using forearm skin colour as a measure of skin colour type (Rockell, Skeaff, Williams, & Green, 2008). Europeans typically had lighter skin types and were found to have higher mean serum 25(OH)D (Rockell, Skeaff, Williams, & Green, 2008).

Considering the increased risk for vitamin D deficiency amongst those with darker pigmented skin, recommended routine supplementation may be beneficial to help this population achieve adequate vitamin D status year-round.

2.7.2 Ethnicity

New Zealand is an ethnically diverse country. Although there are around 200 different ethnic groups living within New Zealand, the majority of New Zealanders identify as European (74%), followed by Māori (15%), Asian (12%) and then Pacific (7%) (Statistics New Zealand, 2013). Within New Zealand, ethnicity has been identified as a predictor of low vitamin D status in newborns, children and adults.

A study of Wellington and Christchurch based newborns identified those of Pacific ethnicity and those who identified as “other” (i.e. non-European, non-Māori and non-Pacific) had the lowest median serum 25(OH)D concentrations (Camargo, Ingham, Wickens, Thadhani, Silvers, Epton, Town, Espinola, Crane, New Zealand Asthma, & Allergy Cohort Study Group, 2010). Those newborns of European ethnicity were most likely to have higher vitamin D status

(Camargo, Ingham, Wickens, Thadhani, Silvers, Epton, Town, Espinola, Crane, New Zealand Asthma, & Allergy Cohort Study Group, 2010). Similarly, in a recent New Zealand study, European children were found to have higher serum 25(OH)D compared to Maori, Pacific and South Asian children (Delshad, Beck, Conlon, Mugridge, Kruger, Jensen, Ma, & von Hurst, 2019).

After having adjusted for age it was apparent from the 2008/09 Adult Nutrition survey that Pacific adults were 2.3 times more likely to have vitamin D deficiency compared to non-Pacific adults (Ministry of Health, 2012b). After adjustment, there were no significant differences in vitamin D deficiency prevalence in Māori men and women compared to non-Māori men and women (Ministry of Health, 2012b). Unfortunately, there was a lack of data from the survey for those of Asian ethnicity, therefore a reliable estimate of vitamin D status could not be concluded (Ministry of Health, 2012b). However, one study investigating vitamin D status of South Asian women living in Auckland, New Zealand highlighted vitamin D deficiency was prevalent amongst this population with only 16% of participants (n=235) achieving adequate serum 25(OH)D (von Hurst, Stonehouse, & Coad, 2010). Although not a true representation of the South Asian population within New Zealand, this study does shed some light on the possibility that vitamin D deficiency may be more likely in South Asian adults compared to non-Asian. Further research is needed to more accurately identify the prevalence of vitamin D deficiency within this ethnic group in New Zealand.

Research in pregnant women and the impact of ethnicity on vitamin D status further supports the idea that those individuals who identify with darker skinned ethnicities are most likely to have poor vitamin D status (Clifton-Bligh, McElduff, & McElduff, 2008). Serum 25(OH)D was lower in those women who identified as Middle Eastern or Indian (Clifton-Bligh, McElduff, & McElduff, 2008).

Due to high rates of inter-ethnic marriage in New Zealand, ethnicity may not be a good determinant of skin colour (Callister, Galtry, & Didham, 2011). Ethnicity is also a culturally constructed concept and those who identify with certain ethnicities may not do so based on physical characteristics such as skin colour but rather through cultural identity (Callister, Galtry, & Didham, 2011). Although targeting specific ethnic groups is convenient and a common channel when delivering public health messages, it may be more effective to target specific skin types rather than ethnic groups when delivering public health messages regarding vitamin D (Callister, Galtry, & Didham, 2011). However, this does not come without barriers, Callister et al. suggests individuals may not have an accurate perception of their own skin colour, for example an individual who identified as Māori may perceive their skin colour as darker than it really is and may unnecessarily expose themselves to additional sunlight, increasing their risk for skin cancer.

Targeting individuals based on their skin colour may promote negative discrimination (Callister, Galtry, & Didham, 2011). Therefore, any public health messages or policy targeting individuals based on skin colour must be done so carefully and with consideration for the aforementioned factors.

2.7.3 Latitude

Cutaneous vitamin D production is dependent on exposure to UV β radiation. Latitude is an important factor for this as the amount of UV β radiation at a given location is dependent on the distance the sun's rays have to travel through the atmosphere (van der Mei, Ponsonby, Engelsen, Pasco, McGrath, Eyles, Blizzard, Dwyer, Lucas, & Jones, 2007). During some months of the year those living at latitudes $>51^\circ$ will not be exposed to sufficient UV β radiation to synthesise cutaneous vitamin D (Engelsen, Brustad, Aksnes, & Lund, 2005). Those latitudes with the greatest distance from the equator were more likely to synthesise the least vitamin D, particularly during the winter months (Nowson, McGrath, Ebeling, Haikerwal, Daly, Sanders, Seibel, & Mason, 2012).

There have been conflicting results regarding the impact of latitude on vitamin D status in New Zealand. The Adult Nutrition survey identified that those living in the central and southern regions of New Zealand were likely to have significantly lower mean serum 25(OH)D than those living in northern regions (Ministry of Health, 2012b). However, there were no significant differences in vitamin D deficiency between the three regions (Ministry of Health, 2012b). It was during the winter months that those living in the Southern region were more likely to be vitamin D deficient (Ministry of Health, 2012b). However, in the national survey of 5 to 14 year olds it was identified that there was no difference in serum 25(OH)D between those living in the North Island (35-40°S) and the South Island (40-47°S) (Rockell, Green, Skeaff, Whiting, Taylor, Williams, Parnell, Scragg, Wilson, & Schaaf, 2005). It was seasonality rather than latitude that was found to have a greater impact in this study. A more recent study of pre-school aged children in New Zealand also found that latitude did not impact winter serum vitamin D (Cairncross, Stonehouse, Conlon, Grant, McDonald, Houghton, Eyles, Camargo Jr, Coad, & von Hurst, 2017).

An Australian study also identified those adults living in the Southern regions of Australia ($>35^\circ$ S) were more likely to have lower serum 25(OH)D compared to those living in Northern regions ($<30^\circ$ S) (Daly, Gagnon, Lu, Magliano, Dunstan, Sikaris, Zimmet, Ebeling, & Shaw, 2012). However, another Australian study found minimal differences in serum 25(OH)D between different latitudes ranging from 27°S and 43°S. Their results found latitude to account for only 3.9% in the differences in serum 25(OH)D (van der Mei, Ponsonby, Engelsen, Pasco, McGrath, Eyles, Blizzard, Dwyer, Lucas, & Jones, 2007).

Based on these findings, recommendations for vitamin D supplementation for New Zealanders living at latitudes near 51° may not be necessary and should rather be based on other, more significant risk factors such as skin colour or sun exposure practices. Due to the lack of association between latitude and serum vitamin D, public health messages and policies regarding vitamin D should be delivered nationwide.

2.7.4 Seasonality

Seasons have a profound impact on the amount of UV β light that reaches the earth's surface (Godar, 2005). During summer months, doses of UV light can be four to six times higher than during winter months (Godar, 2005).

Seasonality appears to influence vitamin D status in New Zealand. Research conducted in Auckland, New Zealand found female participants had significant changes in serum 25(OH)D due to a change in season (Lucas, Bolland, Grey, Ames, Mason, Horne, Gamble, & Reid, 2005). The prevalence of deficiency increased during winter months and decreased during summer months (Lucas, Bolland, Grey, Ames, Mason, Horne, Gamble, & Reid, 2005). Additionally, season was a major influencer of vitamin D status amongst 5 to 14-year-old children living in New Zealand. During winter months, children were 27% more likely to have vitamin D insufficiency compared to the summer months (Rockell, Green, Skeaff, Whiting, Taylor, Williams, Parnell, Scragg, Wilson, & Schaaf, 2005). Finally, further research investigating vitamin D status of 12 to 22-month-old children living in New Zealand also found significant differences in vitamin D status depending on the season. During winter months nearly 80% of the children had vitamin D insufficiency, whereas during summer months the majority of children had vitamin D sufficiency (Houghton, Szymlek-Gay, Gray, Ferguson, Deng, & Heath, 2010).

During the summer months, the southern hemisphere is closest to the sun (Godar, 2005). This increased proximity increases the intensity of UV β exposure (Godar, 2005), thus increasing cutaneous synthesis of vitamin D. However, it is apparent that although UV β exposure is likely adequate for the majority of the population during summer, it is not enough to maintain year-round vitamin D sufficiency. During winter there is decreased sunlight hours and intensity, less time spent outside and increased clothing cover for warmth and protection against the elements. All of these factors increase risk for poor exposure to the UV β light required for adequate vitamin D synthesis. Current recommendations are for individuals to expose themselves to sunlight during the winter through outdoor activities such as a daily walk, ideally with the face, arms and legs exposed (Ministry of Health, 2012a). However, this may not always be practical in the cooler months. Further research into sun exposure practices of New Zealanders during the winter months and the recommendations given by health professionals for ideal sun exposure for adequate vitamin D throughout the year should be conducted.

2.7.5 Sunscreen and sun exposure practices

Skin cancer is the most common cause of cancer in New Zealand (Gage, Barr, Stanley, Reeder, Mackay, Smith, Chambers, Leung, & Signal, 2018). Unfortunately, New Zealand has one of the highest rates of sun-related skin cancers worldwide (Pondicherry, Martin, Meredith, Rolfe, Emanuel, & Elwood, 2018) and UV radiation has been identified as the primary cause for skin cancer (Gilchrest, 2008). Compared to North American locations of similar latitude, New Zealand has 40% higher peak UV radiation (McKenzie, 2017). The combination of close proximity of the Southern Hemisphere to the sun during summer, low air pollution, a depleted ozone layer and a high percentage of fair skinned individuals within the population all contribute to the high skin cancer incidence in New Zealand (Pondicherry, Martin, Meredith, Rolfe, Emanuel, & Elwood, 2018).

New Zealanders have been encouraged to be sun smart when spending time outside, especially during the months September through to April (Health Promotion Agency, 2019). The Sun Smart campaign encourages New Zealanders to protect skin with clothing, shade, sunscreen, hats and sun glasses for eye protection especially during summer months and

times from 10am-4pm (Health Promotion Agency, 2019). These sun protection practices likely influence vitamin D status as they decrease skin to direct sun exposure (Robinson, 2005).

Vitamin D synthesis is dependent on exposure of skin to the sun. Research from countries where cultural and religious practices mean a large percentage of skin is covered with clothing have shown a link between skin covering clothes and vitamin D status. Turkish women wearing a full veil (niqab) had mean serum 25(OH)D of 9nmol/L. Those Turkish women who wore Western clothing had a much higher mean serum 25(OH)D of 56nmol/L (Alagöl, Shihadeh, Boztepe, Tanakol, Yarman, Azizlerli, & Sandalci, 2000). In New Zealand, covering skin with clothing is usually for protection from the elements. However, considering New Zealand diverse ethnic population covering by clothing may be due to religious or cultural reasons. Covering skin with clothing will likely have negative impacts on cutaneous vitamin D synthesis, therefore increasing risk for suboptimal vitamin D status.

Sunscreen is strongly encouraged as a preventative measure for sun-related skin cancer. Sunscreen protects skin through reducing exposure to UV α and UV β radiation (Paxton, Teale, Nowson, Mason, McGrath, Thompson, Sifarikas, Rodda, & Munns, 2013). The implication of sunscreen use may be a reduction in vitamin D synthesis. Cutaneous vitamin D synthesis can be reduced up to 99% when sun protection factor (SPF) 30 sunscreen is applied following the recommendation of 2mg/cm² skin (Grigalavicius, Iani, & Juzeniene, 2016; Matsuoka, Ide, Wortsman, Maclaughlin, & Holick, 1987). A qualitative study of early childhood centers in New Zealand found there was a high emphasis on hat and sunscreen use (Duignan, Signal, & Thomson, 2014). This finding was similar to an Australian study; early childhood centers were more likely to apply sunscreen and enforce hat use than dress children in protective clothing during the summer (Ettridge, Bowden, Rayner, & Wilson, 2010). There is conflicting evidence regarding the impact of sunscreen use on vitamin D status. Research of Australian adults found sunscreen use did not impact serum 25(OH)D (Jayaratne, Russell, & van der Pols, 2012; Marks, Foley, Jolley, Knight, Harrison, & Thompson, 1995). Conversely, a study of Italian children found those who applied sunscreen regularly were seven times more likely to be vitamin D deficient compared to those who did not (Vierucci, Del Pistoia, Fanos, Gori, Carlone, Erba, Massimetti, Federico, & Saggese, 2013).

The way in which sunblock is applied might influence these results (Delshad, Beck, Conlon, Mugridge, Kruger, Jensen, Ma, & von Hurst, 2019). In a population of New Zealand athletes, sunblock use was relatively low, with only 9% reporting they always apply sunblock before going in the sun and no athletes reported reapplying sunscreen hourly. The thickness and timing in which sunblock is applied will likely influence differences in reported results (Walker, Love, Baker, Healey, Haszard, Edwards, & Black, 2014). Therefore, the impact of sunblock on vitamin D synthesis has not been fully determined and sunblock use should continue, especially throughout the summer months as recommended by the New Zealand Cancer Society.

Exposing infants to sunlight for a short amount of time is perceived to be beneficial for jaundice, nappy rash and vitamin D sufficiency (Harrison & Buettner, 1999; Harrison, Hutton, & Nowak, 2002). Placing a child in sunlight behind a window was an early practice for treatment of neonatal jaundice (Aladag, Filiz, Topsever, & Gorpelioglu, 2006). Sunning infants behind windows continues on into recent times, with one study reporting over one third of

mothers had placed their infant in the sun behind a window for health reasons (Aladag, Filiz, Topsever, & Gorpelioglu, 2006). Glass absorbs UV β photons (Holick, 1995), decreasing transmission of UV radiation by up to 90% (Harrison, Büttner, & Nowak, 2005). To stimulate the synthesis of pre vitamin D₃, skin must be exposed to light wave length of 290-315 nm (Saraff & Shaw, 2016). However, glass does not transmit wavelengths <334nm (Saraff & Shaw, 2016). Therefore, when exposed to sun light behind glass, vitamin D production will be greatly reduced (Saraff & Shaw, 2016). Investigations into mothers' practices of sunning infants behind windows is necessary. Additionally, further research into what is being recommended to mothers by health professionals would be beneficial. If mothers are being instructed by their health professionals to sun their infants behind windows to improve vitamin D status, then there will likely be little improvement to vitamin D status for the infant.

2.8 Current knowledge of vitamin D

Knowledge of vitamin D amongst the general public is largely unknown in New Zealand. One New Zealand study of elite athletes (n=110) identified the majority of participants (66%) were more concerned about skin cancer risk than their vitamin D status (6%), however only 9% of athletes would always apply sunscreen before going out in to the sun (Walker, Love, Baker, Healey, Haszard, Edwards, & Black, 2014). Additionally, only 17% of participants could name another source of vitamin D other than sun light (Walker, Love, Baker, Healey, Haszard, Edwards, & Black, 2014). There are some limitations to this study, the sample size is small, and this population may have a particular interest in health and therefore may not be a good representation of the general population. Although, this population is not representative of mothers in New Zealand, it does highlight potential knowledge gaps and inconsistency in sun exposure practices.

Australian research on this topic is much wider and provides a better insight into vitamin D knowledge of the general population of Australia. An Australian study focusing on the general population of Queensland residents (n=2,000), concluded that 80% of their study participants could not identify a single benefit of vitamin D without a prompt (Janda, Youl, Merollini, Niland, & Kimlin, 2010). There was also confusion regarding the length of time required in the sun to promote vitamin D synthesis. A small portion of participants (15%) did not have any idea of the time required (Janda, Youl, Merollini, Niland, & Kimlin, 2010) and those more knowledgeable participants commonly overestimated the time required in the sun for adequate vitamin D synthesis (Janda, Youl, Merollini, Niland, & Kimlin, 2010). This study had a significantly larger sample size than other Australian studies, therefore the results may have increased accuracy and reliability. However, the sample included only those living in Queensland, Australia and therefore caution must be taken when applying these results to the general population of New Zealand. Furthermore, an Australian study (n=50) found that vitamin D was one of the vitamins participants knew only very little about, mostly due to poor media coverage (Bonevski, Bryant, Lambert, Brozek, & Rock, 2013). The sample size for this study was also small and not a general representation of the entire Australian population. However, from the Australian research it is apparent that there is a lack of knowledge on vitamin D nationwide amongst the populations sampled.

The level of knowledge of pregnant women and mothers regarding vitamin D is unknown in New Zealand. However, international studies are available that provide some insight into

knowledge of mothers around the world. An Irish study investigated vitamin D knowledge of a variety of mothers from different ethnic backgrounds. The majority of mothers (78%) had completed higher level education but most had a poor level of knowledge regarding sources of vitamin D, in particular dietary sources (Toher, Lindsay, McKenna, Kilbane, Curran, Harrington, Uduma, & McAuliffe, 2014). Although, it must be noted this study had a relatively small sample size (n=116) and participants were only recruited from the capital of Ireland. Therefore, this study may not be representative of the entire population of mothers in this country. Findings from a Polish study of mothers with young children found most (75%) of the participants could name at least one role of vitamin D (Zadka, Pałkowska-Goździk, & Rosołowska-Huszcz, 2018). The researchers attributed this knowledge to media coverage of the topic. However, knowledge of vitamin D sources was poor amongst this group, less than half of the participants could correctly identify dietary sources of vitamin D (Zadka, Pałkowska-Goździk, & Rosołowska-Huszcz, 2018). An Australian study found that only 20% of mothers thought it was necessary to expose their baby to sunlight to prevent vitamin D deficiency (Harrison, Nikles, & Nowak, 2013). A 2019 UK based study found parents were not well aware of the importance of vitamin D and were unclear on recommendations for vitamin D intake and supplementation (Day, Krishnarao, Sahota, & Christian, 2019). To make informed choices for themselves and their children, mothers should know the risks involved with vitamin D deficiency and ways in which to prevent deficiency.

Further investigation in to the knowledge of vitamin D amongst New Zealand mothers is required. Improved knowledge and awareness may result in positive behaviour change and will allow mothers to make informed choices for their family's health. Studies have found nutrition education and counselling during pregnancy improved maternal dietary choices and practices (Girard & Olude, 2012). A Polish study found that mothers of primary school aged children who were more aware of sources and roles of vitamin D were significantly more likely to frequently use vitamin D supplements (Zadka, Pałkowska-Goździk, & Rosołowska-Huszcz, 2018). Knowledge gaps must be determined as this will guide health professionals and policy makers towards the appropriate health education required to support mothers. Education will help to improve awareness and attitudes towards vitamin D. When providing education, safe sun exposure messages should still be reiterated to prevent excessive sun exposure and increased skin cancer risk.

Chapter 3. Research study manuscript

Knowledge and attitudes of vitamin D and sun exposure practices amongst New Zealand mothers with children aged five years old and under.

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3.1 Abstract

Aim: To assess the overall knowledge and attitudes for vitamin D and common practices involving sun exposure amongst New Zealand women with children under five years of age.

Methods: Cross-sectional online questionnaire administrated in 2009 to mothers with children aged five years and under across New Zealand. Knowledge was measured against literature and guidelines/recommendations available at this time. Descriptive statistics were performed using SPSS 24 for Windows (SPSS Inc, Chicago IL).

Results: Participants were New Zealand mothers with children aged five and under (N=8032). Mothers' knowledge of vitamin D was lacking; 63.2% of mothers thought breast milk was a good source of vitamin D and less than a quarter thought infant and toddler milk were good sources. Mothers had poor awareness regarding risk factors for deficiency. The large majority (74%) either did not know or thought having dark skin was a low risk factor for deficiency, 89.1% either did not know or thought exclusively breastfed babies were at low risk for deficiency. Although, over half of mothers agreed that children who do not have regular exposure to sunlight are at high risk for deficiency. Mothers were not well aware of the other factors that may impact vitamin D status, 53.6% were unsure or agreed that wearing clothes or sunscreen did not impact vitamin D. Additionally, 67.2% of mothers thought sun through a window was just as effective as outdoor sun in synthesising vitamin D. Only a very small proportion (15.8%) identified health professionals as their main source for vitamin D information. The minority (3.1%) received advice regarding vitamin D supplementation for their infant from a health professional and 30.5% received advice from a health professional regarding safe sun exposure. Mothers were vigilant with their children's sun exposure, especially in summer months and were concerned sun exposure would lead to skin cancer. When mothers were asked how often they put a hat on their child and apply sunscreen to their skin during summer, 86.5% and 78% respectively, said they do so always/usually. Mothers reported feeling concerned and confused about sun exposure and vitamin D, with 50.1% of mothers agreeing they do not know what to do when it comes to vitamin D and sun exposure and 72.4% agreeing skin cancer prevention messages make it confusing to understand messages about vitamin D.

Conclusion: In 2009, knowledge of vitamin D amongst New Zealand mothers was unknown. Particularly in regard to vitamin D sources, risk factors and appropriate sun exposure

practices for adequate vitamin D. At this time, sun protection practices for infants during the summer were extensive, likely due to the fear of skin damage from the sun.

Key words: vitamin D, knowledge, attitudes, mothers, pregnancy, infancy, sun exposure.

3.2 Introduction

Conditions associated with severe vitamin D deficiency such as asthma, obesity and rickets are an issue in New Zealand (Eagleton & Judkins, 2006; Miliku, Felix, Voortman, Tiemeier, Eyles, Burne, McGrath, & Jaddoe, 2019; Mirzakhani, Carey, Zeiger, Bacharier, O'Connor, Schatz, Laranjo, Weiss, & Litonjua, 2019; Wheeler, Dickson, Houghton, Ward, & Taylor, 2015). Poor vitamin D status can have a severe impact on childhood development including impaired growth, limb fracture and pain, increased risk for respiratory illness, hypocalcaemia and body composition (Miliku, Felix, Voortman, Tiemeier, Eyles, Burne, McGrath, & Jaddoe, 2019; Mirzakhani, Carey, Zeiger, Bacharier, O'Connor, Schatz, Laranjo, Weiss, & Litonjua, 2019; Munns, Zacharin, Rodda, Batch, Morley, Cranswick, Craig, Cutfield, Hofman, & Taylor, 2006). In the earliest stages of life and throughout pregnancy poor vitamin D status can have a significant impact on fetal and maternal health. Vitamin D deficiency may also have adverse health outcomes in adulthood. A variety of diseases have been associated with poor vitamin D status in adults including cancer, cardiovascular and respiratory disease (Nowson, McGrath, Ebeling, Haikerwal, Daly, Sanders, Seibel, & Mason, 2012).

Cutaneous synthesis of vitamin D is triggered by UV β radiation from sunlight (Chen, Chimeh, Lu, Mathieu, Person, Zhang, Kohn, Martinello, Berkowitz, & Holick, 2007), this is the main source of vitamin D. Due to lack of food fortification and limited food sources rich in vitamin D, the diet usually provides only 5-10% of estimated requirements (Nowson, McGrath, Ebeling, Haikerwal, Daly, Sanders, Seibel, & Mason, 2012). Safe sun exposure is essential in New Zealand as we have one of the highest rates of sun related skin cancers worldwide (Pondicherry, Martin, Meredith, Rolfe, Emanuel, & Elwood, 2018). With such alarming skin cancer prevalence, it is not surprising that sun safety public health messages are strongly focused on sun avoidance to prevent skin cancer rather than sun exposure for optimal vitamin D status. A New Zealand study identified the main reason given by South Asian women for sun avoidance was fear of skin cancer (von Hurst, Stonehouse, & Coad, 2010). Of this population only 16% had adequate serum 25(OH)D (>50 nmol/L) (von Hurst, Stonehouse, & Coad, 2010). With such high risk for skin cancer it is difficult to strike the right balance of sun exposure. However, in New Zealand there is a lack of readily available information and minimal public health messages that aim to raise awareness or increase knowledge for vitamin D. One of the main sources of information regarding vitamin D is the Consensus Statement on Vitamin D and Sun Exposure in New Zealand and the Companion Statement on vitamin D and Sun Exposure in Pregnancy and Infancy in New Zealand (Ministry of Health, 2012a). These statements were released in 2012 and 2013 respectively, some years after the administration of the survey reported here.

Risk factors such as skin colour, ethnicity, living at different latitudes, and variation in seasons throughout New Zealand alter the likelihood of poor vitamin D status. Health professionals such as midwives or Plunket nurses need to provide targeted education to those women and their children who are at highest risk for deficiency. Women living in New Zealand may be receptive to health-related messages and this may influence behavior change towards practices that promote healthy vitamin D status. However, as the level of knowledge amongst New Zealand mothers is still unknown regarding vitamin D, education and public health messages cannot be tailored to address the most significant knowledge gaps.

3.3 Methods

Online questionnaire design

The online questionnaire planning began with a round table discussion with nutrition experts. Following this, an extensive literature search was conducted, and current guidelines and recommendations were identified. Based on these findings, questions were developed and reviewed by a panel of experts. A piloting of the questionnaire was conducted amongst a small sample of New Zealand mothers, this ensured the level of difficulty was appropriate and the structure easy to follow. The final questionnaire took approximately 15 minutes to complete.

Vitamin D knowledge questions were grouped into categories; sources, importance, risk factors, and general knowledge regarding vitamin D (i.e. barriers to synthesis and sun exposure recommendations) and finally attitudes towards vitamin D. Knowledge questions mostly included statements and participants had the option to select one answer for each statement, for example true, false, unsure or high, moderate or low risk. Questions regarding knowledge, health professional advice, main sources of information and sun exposure practices were single answer only. Free text options were available for some questions such as "Did you receive vitamin D supplementation advice for your infant from your health professional", if participants answered "yes" they were invited to type the advice they had received. For sun exposure practices, participants were asked to choose the frequency in which they followed the practices in the question statement i.e. "in the summer months, did you put a hat on your child", with options for participants such as always, usually or never. See Appendix 1 for the full online questionnaire.

Skin type was determined using the Fitzpatrick skin type scale (Ravnbak, 2010). Participants were asked to choose only one option and skin types were described as follows; skin type I: highly sensitive, nearly always burns, minimal if any tan, possibly freckles, type II: sun sensitive skin, sometimes burns, slowly tans to light brown, type III: minimally sun sensitive, burns minimally, always tans to moderate brown, type IV: sun insensitive skin, rarely burns, tans well and type V: sun insensitive, never burns, deeply pigmented. Participants were able to choose multiple answers for ethnicity. The responses were prioritised using the Ministry of Health ethnicity prioritisation guidelines (Ministry of Health, 2010).

Ethical approval

A low-risk ethics notification was advised to Massey University Human Ethics Committee, Northern A.

Participants

Participants were recruited via ReachMe, a New Zealand based internet marketing company. Permission was granted to promote the research through this site. Participants were screened before they began the survey. They were required to meet the inclusion criteria of either being pregnant or have a child five years old or younger. Participants were not included in the

analysis if they did not have a child aged five or under, if they did not give an age for their child or if they completed the questionnaire more than once.

Data

Data was collected online through a SurveyMonkey link made available through the ReachMe website. Data was collected over a three-month period (May 2009-July 2009). Upon completion of collection, the raw data from SurveyMonkey was stored on a password protected computer and all participants were kept anonymous. Informed consent was given by all participants.

Statistical analysis

Statistical analysis was conducted using SPSS 24 for Windows (SPSS Inc, Chicago IL). Descriptive statistics were conducted for the questionnaire results. The frequency of responses for each particular question was calculated and expressed as N (%). Mean (SD) was calculated for mothers age alone. Answers to knowledge-based questions were deemed correct if they aligned with the literature and guidelines available in 2009.

3.4 Results

The initial number of responses to the online questionnaire was 9,220. After data cleaning, 288 participants were removed as their youngest child was six years or older and a further 872 participants did not provide an answer for their child/children's age. The number of participants who completed the survey more than once was 22, and the duplicate answers were removed. A further six participants were removed as they were pregnant but had miscarried. The final number of participants for analysis was 8,032.

The mean age of participants was 31.7 years old with the majority of mothers (84.4%) reporting their youngest child was aged two years or younger. The level of education amongst participants was varied, however the majority of respondents (52.5%) reported having a university qualification.

Most participants were NZ European (73.3%), and the most common skin type was type 11 (48.2%), only 4.5% of the sample reported their skin type as IV or V and 3.3% reported their child's skin type as IV or V.

Table 3.1: Participant characteristics

Variable	N (%)
Age, years*	31.73 (5.51)
Age of youngest child (n=8,032)	
Pregnant	157 (1.9)
0-6 months	1,821 (22.7)
6-12 months	1,529 (19.0)
1 year old	2,018 (25.1)
2 years old	1,410 (17.6)

3 years old	619 (7.7)
4 years old	334 (4.2)
5 years old	144 (1.8)
Ethnicity (n=8,010)^σ	
NZ European	5,889 (73.3)
Māori	817 (10.2)
Pacific	215 (2.7)
Chinese	232 (2.9)
Indian	130 (1.6)
Other	727 (9.0)
Highest level of education (n=7,983)^Φ	
Secondary school	2,170 (27.0)
University qualification	4,221 (52.5)
Trade or technical certificate	868 (10.8)
Professional qualification	485 (6.0)
Other	239 (3.0)
Maternal skin type (n=8,032) ⁺	
Type I	1,467 (18.3)
Type II	3,870 (48.2)
Type III	2,335 (29.1)
Type IV	342 (4.3)
Type V	18 (0.2)
Child's skin type (n=8,031)[∞]	
Type I	1,339 (16.7)
Type II	3,132 (39.0)
Type III	1,533 (19.1)
Type IV	258 (3.2)
Type V	12 (0.1)
Unsure	1,757 (21.9)

* Mean (SD)

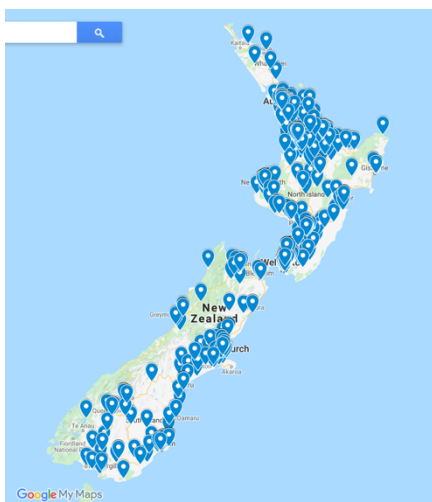
^σ22 participants skipped this question

^Φ49 participants skipped this question

⁺Based on the Fitzpatrick skin type scale (Ravnbak, 2010)

[∞] 1 participant skipped this question

Figure 3.1: Geographical distribution of participants



Knowledge of vitamin D sources

Participants were given a list of potential vitamin D sources and then asked to choose the one source they thought to be the most important. The majority of participants (88.9%) knew that the single most important source of vitamin D for most New Zealanders is via cutaneous synthesis stimulated by exposure to sunlight. However, 10.7% of the participants incorrectly identified natural food sources, fortified food products or supplements as the single most important source of vitamin D for most New Zealanders.

Participants were given a variety of infant feeds i.e. breast milk, infant formula and toddler formula and were asked to rank them based on their vitamin D content. The majority of participants (63.2%) felt that breast milk was a good source of vitamin D compared to 3.8% of participants who felt breast milk was a poor source. From the participants of this study, 92.2% had breastfed their youngest child at some point. Less than a quarter of participants felt infant and toddler formula was a good source of vitamin D, 22.3% and 20.0% respectively. Of the participants, 56.6% thought cow's milk was a poor source of vitamin D or did not know.

Knowledge of the importance of vitamin D

Participants were given a list of potential benefits related to adequate vitamin D and were then asked to choose those which they thought were true. Most participants (63.1%) were aware that vitamin D is important for healthy bones, followed by 29.1% of participants answering immunity. A further 17.4% did not know why vitamin D is important.

Knowledge of risk factors

Mothers were asked to rank the factors in Table 3.2 for their risk of vitamin D deficiency. A large majority of participants (89.4%) felt children who do not have regular exposure to sunlight are at high to moderate risk of vitamin D deficiency. Only a small proportion of participants (27.1%) chose high use of sunscreen as a moderate risk factor for vitamin D deficiency.

Only a small percentage of participants (18.9%) thought living in the South Island of New Zealand put children at high-moderate risk for deficiency, a further 21.5% did not know. Additionally, participants did not perceive having darker skin as a high-risk factor to low vitamin D status, with only 7.0% of participants choosing this factor to be high risk. The majority of respondents (74%) thought having darker skin is a low risk factor or did not know.

The majority of participants (69.6%) thought exclusively breast-fed babies/young children were at low risk for vitamin D deficiency. Only 1.9% of participants considered this factor to place babies/young children at high risk for vitamin D deficiency. Most participants (42.0%) were aware that babies/young children born to vitamin D deficient mothers were at high risk of vitamin D deficiency, although 18.1% were unsure. Table 3.2 shows all responses to risk factor questions.

Table 3.2: Knowledge of risk factors

Factor N=8,031	High risk N (%)	Moderate risk N (%)	Low risk N (%)	Don't know N (%)
Living in South Island of NZ	226 (2.8)	1,296 (16.1)	4,784 (59.6)	1,725 (21.5)
Children who do not have regular exposure to sunlight	4,632 (57.7)	2,543 (31.7)	477 (5.9)	379 (4.7)
High use of sunscreen	1,346 (16.8)	2,177 (27.1)	3,452 (43.0)	1,056 (13.1)
Babies born to vit D deficient mothers	3,373 (42.0)	2,500 (31.1)	702 (8.7)	1,456 (18.1)
Having darker skin	565 (7.0)	1,517 (18.9)	3,729 (46.4)	2,220 (27.6)
Exclusively breast-fed babies	155 (1.9)	720 (9.0)	5,589 (69.6)	1,567 (19.5)
Formula fed babies	225 (2.8)	2,467 (30.7)	3,273 (40.7)	2,066 (25.7)

Knowledge of barriers for vitamin D synthesis

Participants were asked to answer true, false or unsure to the statements mentioned in Table 3.3. Over half of participants (53.6%) thought wearing clothing/sunscreen to protect the skin from sun does not affect vitamin D or they were unsure. When asked if skin colour impacted time required in the sun to synthesise vitamin D, the majority (76.1%) said the statement “People with dark skin need to spend longer in the sun to make enough vitamin D” was false or were unsure.

Additionally, the majority of participants thought sun through a window is just as effective in synthesising vitamin D compared to outdoor sun, 67.2% of participants thought this to be true or were unsure. The majority of mothers (63.8%) did not perceive sun through a window to be safer than outdoor sun.

Table 3.3: Knowledge of barriers to vitamin D synthesis

Statement N=8,032	True N (%)	False N (%)	Unsure N (%)
Wearing clothing/sunscreen to protect the skin from the sun does not affect vitamin D	2,202 (27.4)	3,729 (46.4)	2,101 (26.2)

People with dark skin need to spend longer in the sun to make enough vitamin D	1,918 (23.9)	3,164 (39.4)	2,950 (36.7)
Sun through a window is just as effective as outdoor sun exposure for making vitamin D	2,975 (37.0)	2,629 (32.7)	2,428 (30.2)
Sun through a window is safer than outdoor sun	1,474 (18.4)	5,128 (63.8)	1,430 (17.8)

Sun exposure knowledge

Participants were asked to answer true, false or unsure to the statements mentioned in Table 3.4. The majority of mothers (59.9%) either did not know or answered false to the statement “the amount of time needed in the sun to make enough vitamin D depends on the amount of skin exposed”.

Responses were divided when asked if incidental sun exposure outside of peak hours was sufficient for pregnant women, 42.6% of mothers were unsure. The majority (55.8%) agreed that deliberate sun exposure in the middle of the day was not recommended for pregnant or lactating women but 34.3% were unsure. The majority (70.4%) felt it was true that during winter vitamin D levels may drop below sufficient levels and a further 22.8% were unsure.

Table 3.4: Sun exposure knowledge

Statement	True N (%)	False N (%)	Unsure N (%)
N=8,032			
The amount of time needed in the sun to make enough vitamin D depends on the amount of skin exposed	3,217 (40.1)	1,936 (24.1)	2,878 (35.8)
Most pregnant women will get enough vit D in summer through incidental sun exposure outside peak UV times	3,060 (38.1)	1,553 (19.3)	3,419 (42.6)
Deliberate sun exposure during the middle of the day is	795 (9.9)	4,483 (55.8)	2,754 (34.3)

recommended for pregnant & lactating women			
During winter the body's levels of vitamin D may drop below sufficient levels	5,653 (70.4)	551 (6.9)	1,828 (22.8)

Attitudes towards sun exposure

Participants were asked to rank how they felt about the statements mentioned in Table 3.5. Most participants agreed (87.2%) that sunbathing is harmful to their child. Similarly, the majority (80.9%) agreed with the statement "I worry that the sun will damage my child's skin". However, most respondents (90.3%) still agreed that children need to get some direct sunlight to be healthy.

Attitudes towards vitamin D

When asked "If skin is always protected from the sun it can put people at risk of having low vitamin D" 45.4% either disagreed or were neutral. When participants were presented with the comment "I really don't know what to do when it comes to vitamin D and sun exposure", half of participants agreed. The majority (72.4%) of participants agreed that skin cancer prevention messages make it confusing to understand messages about vitamin D.

Table 3.5: Attitudes towards vitamin D and sun exposure

Statement	Agree N (%)	Neutral N (%)	Disagree N (%)
N=8,032			
Sunbathing is harmful to my child	7,003 (87.2)	689 (8.6)	340 (4.2)
Children need to get some direct sunlight to be healthy	7,251 (90.3)	532 (6.6)	249 (3.1)
I worry that sun exposure is linked to skin cancer	6,948 (86.5)	831 (10.3)	253 (3.1)
I worry that the sun will damage my child's skin	6,501 (80.9)	1,061 (13.2)	470 (5.9)
If skin is always protected from the sun it can put people at risk of having low vitamin D	4,391 (54.7)	2,536 (31.6)	1,105 (13.8)

I really don't know what to do when it comes to vitamin D and sun exposure	4,029 (50.1)	2,467 (30.7)	1,536 (19.1)
Skin cancer prevention messages make it confusing to understand messages about vitamin D	5,820 (72.4)	1,599 (19.9)	613 (7.6)

Sources of information about vitamin D

Participants were asked to choose their most important source of knowledge for vitamin D information. Almost half of the participants (40.8%) identified media as their most important source of information regarding vitamin D, followed by family/friends (25.3%). Only 15.8% of participants chose health professionals as their most important source. The majority of those who chose the "other (please specify)" option reported that their knowledge was from their own general knowledge or that their answers were based on guesses as they had not received education regarding vitamin D.

Sun exposure practices during pregnancy

Participants were asked about their sun exposure practices during pregnancy. The question had a variety of statements and participants were asked to answer the frequency in which they followed these practices. The majority of participants (93.7%) spent time outside during their pregnancy. Most mothers (68.9%) would always/usually protect their skin from the sun with clothing during their most recent pregnancy and the majority of mothers would always/usually use sunscreen. The most commonly used SPF sunblock was more than 15 but less than 45.

Sun exposure practices for children

Participants were asked about their sun exposure practices with their youngest child. The question had a variety of statements and participants were asked to answer the frequency in which they followed these practices for their children. Participants were most likely to respond they would always/usually keep their child in the shade or put protective clothing on their child when outside during summer months (55.9% and 73.2% respectively). The majority of participants said they would always/usually put a hat on their child and apply sunscreen onto their child's exposed skin when they were outside during summer months (86.5 and 78.0% respectively).

These practices changed during the winter months. Majority of participants (55.9%) rarely/never keep their child in the shade when outside. The majority of participants (67.9%) would rarely/never apply sunscreen, however 35.4% still chose to put a hat on their child

always/usually. The majority of participants (49.3%) still put protective clothing on their child always/usually. However, there may have been confusion regarding “protective clothing” in the context of winter months, with participants possibly referring to warm clothing.

Advice received from health professionals

Only a very small proportion of participants (3.1%) received advice from their Plunket nurse or health professional regarding vitamin D supplements for their baby. Open ended responses from those who had received advice said they had been given information on supplementation for their preterm infants or if their child had eczema. Other advice involved supplementation of vitamin D during winter to improve immunity.

Similarly, most mothers (69.4%) did not receive advice from their Plunket nurse or other health professional regarding sun exposure for their baby. For those who did receive advice (30.5%), it was apparent from open ended answers that the general theme for advice was around the “slip, slop, slap” message. Mothers were advised sun exposure can be extremely damaging to their baby so should use sunblock, protective clothing, hats and to keep children in the shade, especially during peak sun hours. Mothers were advised to expose their jaundiced babies to the sun. Mothers reported to have received advice regarding placing their baby by a window indoors for sun exposure. Some mothers had been advised only a very short time in direct sunlight (five to ten minutes) was safe.

3.5 Discussion

The findings from this survey provide the first insight into the knowledge of vitamin D and sun exposure practices of mothers with young children in New Zealand.

Participant characteristics

The large study population provided a diverse variety of participants; however, some characteristics of the sample do not make this group representative of the New Zealand population. The highest level of education was a university qualification for the majority of participants, followed by a secondary school qualification. Research suggests that a higher level of education is often associated with higher health knowledge and literacy (Altindag, Cannonier, & Mocan, 2011). The findings of this study could be skewed, as this population may have better health literacy and knowledge compared to the general population of New Zealand.

New Zealand is an ethnically diverse country, the main ethnic groups within New Zealand include European, Māori, Pacific and Asian (Statistics New Zealand, 2013). The most common ethnicity in this study was NZ European (73.3%), followed by Māori (10.2%), Pacific (2.7%), Chinese (2.9%), and Indian (1.6%). According to the most recent census results, the majority of New Zealanders identify as European (74%), followed by Māori (15%), Asian (12%) and then Pacific (7%) (Statistics New Zealand, 2013). The population of this study did follow the general trends of New Zealand’s population, however the minority groups such as Māori, Pacific and Asian were underrepresented. Additionally, the majority (48.2%) of participants identified their skin colour as type II using the Fitzpatrick skin type scale (Ravnbak, 2010). Skin type III

was the next most popular choice (29.1%). These results reflect the high proportion of NZ European participants in this study, NZ Europeans are more likely to have lighter skin types compared to Māori, Pacific or Indian people. Those with darker skin types were not well represented in this study, with only 4.5% of participants choosing their skin type as IV or V.

Knowledge of sources and importance of vitamin D

The majority of participants appeared to have good understanding of the single most important source of vitamin D, 88.9% of participants correctly identified that synthesis in the skin from sunlight was most important. However, 10.7% participants thought natural or fortified food sources or supplements were the single most important source of vitamin D for most New Zealanders. Although vitamin D rich sources of food such as meat, eggs, fish and dairy may be helpful to include within the diet to help maintain adequate vitamin D status, it should not be considered as the single most important source in New Zealand (Taylor, Patterson, Roseland, Wise, Merkel, Pehrsson, & Yetley, 2014). However, fortified foods and supplements can be very useful in reaching and maintaining adequate vitamin D, especially in pregnant women and their infants. In Finland, fortification of liquid dairy products with vitamin D began in 2002, a cross-sectional study conducted 10 years post-fortification concluded that vitamin D fortification was an effective way to improve serum 25(OH)D amongst the adult population (Jääskeläinen, Itkonen, Lundqvist, Erkkola, Koskela, Lakkala, Dowling, Hull, Kröger, & Karppinen, 2017; Raulio, Erlund, Männistö, Sarlio-Lähteenkorva, Sundvall, Tapanainen, Vartiainen, & Virtanen, 2017). Similarly, a study of Finnish children found fortified milk consumption to be the strongest determinant of serum 25(OH)D (Soininen, Eloranta, Lindi, Venäläinen, Zaproudina, Mahonen, & Lakka, 2016). Milk fortification of vitamin D is mandatory in Canada; in a study of 2,831 Canadian children, achieving adequate serum 25(OH)D was twice as likely amongst those children who drank cow's milk products compared to those who drank non-cow's milk products (Lee, Birken, Parkin, Lebovic, Chen, L'Abbé, & Maguire, 2014). New Zealand is yet to follow countries such as Canada, United States and Finland with mandatory fortification of milk or dairy products, as a result, our intake of vitamin D from foods remains poor.

In New Zealand, adequate intakes of dietary vitamin D for pregnant women and infants is 5µg/day (Ministry of Health, 2017). Table 2.1 demonstrates how unfortified dietary sources of vitamin D contribute very low amounts to this recommended intake. Unfortified milk provides only 0.66µg/100g, whereas 100g of fortified Greek yoghurt provides the daily adequate intake (7.3µg) (Thomson & Cressey, 2011). Dietary vitamin D intakes of New Zealanders have not yet been accurately determined due to poor availability of local food databases (Ministry of Health, 2017), therefore it cannot be concluded whether New Zealanders are meeting adequate intakes for vitamin D. However, from the available data it would appear intakes are not sufficient to maintain adequate serum 25(OH)D.

Supplementation in pregnant women has been associated with improved serum 25(OH)D in both mother and infant (Gallo, McDermid, Al-Nimr, Hakeem, Moreschi, Pari-Keener, Stahnke, Papoutsakis, Handu, & Cheng, 2019) and improved fetal outcomes (Aghajafari, Field, Weinberg, Letourneau, & Team, 2018; Bi, Nuyt, Weiler, Leduc, Santamaria, & Wei, 2018). Vitamin D supplementation is not routinely recommended for all pregnant women or their infants in New Zealand, only those deemed to be high risk for deficiency (Ministry of Health,

2013). Additionally, a safe dosage for all pregnant women has not yet been determined, only a monthly dose of 50,000 IU is recommended for pregnant women who are at risk for deficiency and this dose is the only PHARMAC funded vitamin D supplement in New Zealand (Ministry of Health, 2013). Significant barriers to the efficacy of supplementation may be compliance, as supplements need to be taken continually to maintain adequate vitamin D (Marwaha & Dabas, 2019).

There were clear knowledge deficits regarding the amount of vitamin D in breast milk and infant and toddler formula. Breast milk was clearly identified by the majority (63.2%) of mothers as a good source of vitamin D, with only 3.8% of participants reporting breast milk as a poor source. The majority identified infant formula (43.2%), toddler formula (43.2%) and cow's milk (30.3%) as moderate sources of vitamin D. Breast milk is not a particularly good source of vitamin D (Chang & Lee, 2019; Erick, 2018). Breastfeeding has been proven to provide a wide variety of benefits for infants (Gertosio, Meazza, Pagani, & Bozzola, 2016) and exclusive breast feeding until six months is encouraged in New Zealand. Plunket reports show rates of exclusive breastfeeding at six months have increased 5% from 2014-2018 in New Zealand (Plunket, 2019), and results of this online questionnaire show over 90% of mothers reported to have breastfed their youngest child at some point. Considering the strong public health messages promoting breastfeeding and the increase in breastfeeding rates, improved awareness around potential poor vitamin D levels in breast milk is required. Those who choose to exclusively breastfeed may need to consider vitamin D supplementation for their infant while breastfeeding, especially if themselves or their infant are at risk for vitamin D deficiency (Ministry of Health, 2013). In the UK, United States and Canada, vitamin D supplementation is encouraged for all breast-fed infants (O'Callaghan, Taghivand, Zuchniak, Onoyovwi, Korsiak, Leung, & Roth, 2020), however research identified that the use of supplementation in the United States has been poor (Erick, 2018).

Furthermore, most participants did not regard infant or toddler formula as a good source of vitamin D, although most commercial formulas are fortified with vitamin D. An exclusively formula fed infant will likely meet their recommended daily intake for vitamin D (Ministry of Health, 2017). Cow's milk has some naturally occurring vitamin D (Schmid & Walther, 2013), and as previously mentioned, fortification of milk products in other countries has proven effective in reaching and maintaining adequate serum vitamin D in both adults and children. There are many factors that influence vitamin D content of cow's milk, including seasonal variation and feed type (Schmid & Walther, 2013). Therefore, unless cow's milk is fortified, it should not be relied on as a significant source of vitamin D.

Most participants were able to correctly identify that vitamin D has an important role in healthy bones, similar findings have been made in international research (Arora, Dixit, & Srivastava, 2016; Hussein, Almoudi, Zen, Azmi, Schroth, & Hassan, 2018; O'Connor, Glatt, White, & Revuelta Iniesta, 2018). A proportion of participants (29.1%) reported vitamin D to have a role in immunity. At the time this data was collected the role of vitamin D in immunity had not yet been well established and evidence was only beginning to emerge. Therefore, these responses were considered inaccurate. It would appear participants are mostly aware of the benefits of vitamin D in regard to bone health but are unclear as to what other benefits it may provide. It is important mothers understand potential benefits as this may motivate

them to seek supplementation if they perceive themselves or their infants to be at risk for deficiency.

Knowledge of risk factors

There appears to be a lack of knowledge regarding risk factors for vitamin D deficiency amongst this population of mothers. The majority (42%) could identify that babies born to vitamin D deficient mothers are more likely to be vitamin D deficient and 57.7% knew children who do not have regular exposure to sunshine are at high risk. However, they could not correctly identify other contributing factors that increased likelihood for deficiency.

There was a general lack of awareness regarding dark skin and exclusive-breastfeeding as high-risk factors for deficiency. Routine serum vitamin D testing during pregnancy is uncommon in New Zealand, mostly due to the high cost. Supplementation is often provided on the basis of increased risk; therefore, it is important individuals are aware and can begin supplementation if deficiency is suspected.

New Zealand's ethnically diverse population has resulted in a range of skin types. Awareness of skin type and risk for vitamin D deficiency is an important issue for New Zealanders. We could not conclude whether mothers with darker skin types (IV and V) were more aware of dark skin as a risk factor for deficiency, as our sample of mothers with these skin types was too small in comparison to mothers with lighter skin types. Currently, there is a lack of research investigating differences in response to supplementation between skin types. One study found that children with darker skin had a better response to supplementation over a two-month period compared to light skinned children. However, it was concluded this may be due to darker skinned children having poorer vitamin D status at the beginning of the trial (O'Callaghan & Kiely, 2018). In 2014, 3.5% of babies were prescribed Vitadol-C in New Zealand. One of the biggest predictors for Vitadol-C prescription was dark skin colour, however rates of prescription for this group still remained low, at only 9-17% of total Vitadol-C prescriptions (Nitert & Tuohy, 2018). Considering a recommendation within the Consensus Statement is to supplement at risk populations, including individuals with dark skin, the rates of supplementation still appears to be low for this group.

The poor awareness of risk factors amongst mothers of this study reflects the minimal public health messages regarding vitamin D deficiency in New Zealand at the time this survey was administered. Additionally, low supplementation rates amongst high risk populations such as dark-skinned infants after the release of the Consensus Statement may suggest awareness and knowledge among mothers still remains low. However, further research is required to determine current knowledge of risk factors for vitamin D deficiency amongst mothers.

Knowledge of barriers for vitamin D synthesis

Knowledge regarding barriers to vitamin D synthesis were varied. Half of mothers either agreed or were unsure regarding the statement "wearing clothing/sunscreen to protect the skin from the sun does not affect vitamin D". Similarly, when asked if vitamin D may be compromised if skin is always covered, just under half of mothers were neutral or disagreed with this statement. Previously, the majority of mothers correctly identified sun light as the

single most important source of vitamin D, there appears to be inconsistencies in knowledge on questions with similar ideas. The majority of participants had previously identified dark skin as a low risk factor for vitamin D deficiency earlier in the survey, however when asked the following statement “people with dark skin need to spend longer in the sun to make enough vitamin D” the responses were divided between true, false and unsure. This inconsistency in response to a question with a similar idea may indicate a lack of knowledge and may mean participants were guessing their answers.

Mothers may know sunlight is a source of vitamin D, but they appear to lack understanding in regard to how vitamin D is synthesised and the barriers to synthesis. There were similar findings related to knowledge deficits of barriers to vitamin D synthesis in other research of general populations (Holman, Berkowitz, Guy Jr, Lunsford, & Coups, 2017; Vu, van der Pols, Whiteman, Kimlin, & Neale, 2010).

Knowledge of sun exposure for vitamin D

Most mothers were unsure whether incidental sun exposure outside of peak sunlight hours is sufficient for pregnant women. Additionally, 10% of mothers agreed and 34.4% were unsure when asked if deliberate exposure to midday sun was recommended for pregnant or lactating women. This indicates a lack of knowledge of appropriate sun exposure during pregnancy to provide adequate vitamin D synthesis. This may be a result of insufficient advice provided by health care professionals or low awareness due to inadequate public health messages at the time this survey was administered. However, this question may have misled some mothers as the recommendation during winter months is to expose arms and legs to midday sun (Ministry of Health, 2012a), however this is not recommended during the summer months.

Due to the high incidence of skin cancer in New Zealand (Pondicherry, Martin, Meredith, Rolfe, Emanuel, & Elwood, 2018), there are strong public health messages relating to safe sun exposure for the prevention of skin cancer. Therefore, it is likely mothers are confused regarding the appropriate amount of sun exposure for adequate vitamin D synthesis whilst also protecting themselves from sun damage. Most mothers (72.4%) agreed that skin cancer prevention messages made it difficult to understand vitamin D messages. This demonstrates the need for simple, clear advice that outlines recommendations for safe sun exposure for skin cancer prevention and adequate vitamin D.

We found that only 30.5% of mothers were given advice by their Plunket nurse or other health professional regarding sun exposure. Of those mothers who had received advice, a common practice suggested to them was to place their infants in the sun behind a window. Sunning infants behind windows is a common treatment for neonatal jaundice (Aladag, Filiz, Topsever, & Gorpelioglu, 2006). Only a very small proportion of mothers who did receive advice were encouraged to place their infant in direct sunlight. Advice from health professionals may be lacking in regard to sun exposure in the context of vitamin D and mothers may be sunning their infants behind windows under the impression this will improve vitamin D status.

Sources of vitamin D knowledge

Media was the main the source of knowledge for mothers regarding vitamin D, followed by family and friends and then health professionals. A study exploring vitamin D knowledge of the general population in France found those that had received their information from a physician or other health professional were more likely to correctly identify vitamin D sources and health conditions related to vitamin D (Deschasaux, Souberbielle, Partula, Lécuyer, Gonzalez, Srour, Guinot, Malvy, Latino-Martel, & Druésne-Pecollo, 2016). However, information from health professionals may not be as accessible as information from media sources. An Australian study identified a variation in the rates in which pregnant women receive nutrition related advice from their health professional. Around half of the pregnant women in the study had received some written information regarding nutrition from their health professional (Charlton, Gemming, Yeatman, & Ma, 2010). Another study identified time with patients was a significant barrier for health professionals when delivering food safety advice to pregnant women and only 34% of health professionals had managed to deliver food safety related advice (Morales, Kendall, Medeiros, Hillers, & Schroeder, 2004). Considering the technological advances over the past 10 years it would be likely there would be an even higher percentage of mothers who will be using media as their main source for health-related information, especially if mothers are not receiving the information from healthcare professionals. When delivering health related messages relating to vitamin D, media may be an effective channel when trying to reach mothers with young children.

Vitamin D supplementation advice

Only a small percentage of mothers (3.1%) received advice from their health professional regarding vitamin D supplements. Those who did receive advice regarding supplementation reported that supplementation was recommended by their health professional if their baby was preterm, if their child had eczema, or to help improve immunity during winter. A recent randomised controlled trial in Denmark investigated the impact nutrition counselling and advice from dietitians had on pregnant women's vitamin D status. They found women who had received counselling on vitamin D throughout their pregnancy had improved vitamin D status compared to those who received no advice. The women received advice on vitamin D supplementation and it was concluded that the improved vitamin D status may have been due to increased uptake and adherence of vitamin D supplements (Tanvig, Jensen, Andersen, Ovesen, Jørgensen, & Vinter, 2019).

We found health professionals did not recommend supplementation based on risk factors for deficiency i.e. skin colour, location of residence, or time spent outside. At the time this data was collected the Consensus Statement for vitamin D and Sun Exposure in New Zealand and the Companion Statement on vitamin D and Sun Exposure in Pregnancy and Infancy in New Zealand had not yet been published. In this document the recommendations for supplementation are outlined, it may have been possible that prior to the publishing of this statement there was a lack of awareness among health professionals regarding supplementation. There is no research available that explores health professional's knowledge of vitamin D in New Zealand. However, a study of Australian dietitians found a lack of knowledge about vitamin D supplementation particularly with dosage, and general supplementation guidelines (Dix, Robinson, Bauer, & Wright, 2017). It would be beneficial to

get a clear understanding of the current knowledge of health professionals in New Zealand regarding supplementation and re-administer this online questionnaire to a new cohort of mothers to understand whether supplementation advice has improved and whether rates of vitamin D supplementation have changed over the past 10 years.

Attitudes towards sun exposure and sun exposure practices

Most mothers were concerned about the potential harmful effects sun exposure may have on their child. The large majority of mothers (90.3%) did agree that children need to get some direct sunlight to be healthy. Therefore, although mothers are aware of the negative impacts sun exposure may have, they still perceive sun exposure as part of a healthy lifestyle. The strong public health messages surrounding sun exposure and skin cancer risk have made it difficult for the majority of mothers (72.4%) to know what to do when it comes to vitamin D. There were similar findings in a UK study, mothers were unsure on how to balance safe sun exposure and adequate vitamin D synthesis (Littlewood & Greenfield, 2018).

It was apparent that when asked about sun exposure practices mothers strongly followed the “slip, slop, slap” policy (Health Promotion Agency, 2019). During the summer months, most mothers always or usually keep their child in the shade, have their child wear a sun hat, put protective clothing on their child and apply sunscreen to their exposed skin. A UK study suggested that mothers are concerned about sun exposure irrespective of their child’s skin colour (Littlewood & Greenfield, 2018). As children grew older, parents became less likely to follow sun protection guidelines and parents of lighter skinned children were more likely to follow ideal sun exposure practices compared to those with darker skinned children (Tan, Nag, & Weinstein, 2018). The comparison between sun exposure practices of mothers with darker skinned children and lighter skinned children could not be analysed in this study, as the population size of mothers with darker skinned children was too small (3.3%).

Mothers reported frequently following these same practices while pregnant, however they appeared to be less vigilant with sun safety for themselves than with their children. These practices are promoted by the SunSmart campaign, especially during the summer months in New Zealand. Currently, there are recommendations regarding vitamin D and safe sun exposure on the SunSmart website (Health Promotion Agency, 2019) with additional links to the Consensus Statement on vitamin D and Sun Exposure in New Zealand and the Companion Statement on vitamin D and Sun Exposure in Pregnancy and Infancy in New Zealand. However, these statements were published in 2012 and 2013 respectively, three to four years after this data was collected. It is difficult to comment on the accessibility and availability of recommendations for safe sun exposure for vitamin D from when this data was collected. However, it was clearly insufficient as half of mothers agreed they did not know what to do when it came to vitamin D and sun exposure.

Conclusion

Overall, there appears to be a knowledge deficit for vitamin D sources, risk factors, barriers to vitamin D synthesis and safe sun exposure practices amongst this sample of mothers. At this time, there also appeared to be a lack of support from health professionals in regard to sun exposure advice for optimal vitamin D status and vitamin D supplementation. Most

mothers appeared to be confused about what are the best practices when it comes to vitamin D and sun exposure. Additionally, other strong public health messages such as the skin cancer prevention campaign has made it even more confusing for mothers.

Since this data was collected there has been the development of the Consensus Statement for vitamin D and Sun Exposure in New Zealand and the Companion Statement on vitamin D and Sun Exposure in Pregnancy and Infancy in New Zealand. These documents concisely outline important aspects of vitamin D including risk factors, deficiency cut offs and supplementation advice, which are likely very helpful for both health professionals and the public. Additionally, the skin cancer prevention website SunSmart now features a section on safe sun exposure for vitamin D.

It would be beneficial to investigate current knowledge of vitamin D amongst a similar group of mothers. Comparing differences in knowledge over the 10 years would help identify whether the current public health messages are strong enough to improve vitamin D knowledge amongst the public. Additionally, it would be useful to assess the knowledge of health professionals as they are a key source of support for mothers. It is clear that 10 years ago there was a lack of support for mothers regarding vitamin D, now we must determine whether this knowledge deficit has improved or remained the same to help guide public health initiatives in current times.

Chapter 4

4.1 Overview and conclusions

The findings of this research allowed good insight into the overall knowledge and common sun exposure practices amongst New Zealand women in 2009. Key knowledge deficits were highlighted in areas such as vitamin D sources, benefits, risk factors for deficiency and barriers to vitamin D synthesis. Popular sources of advice and knowledge were investigated and common sun exposure practices and knowledge and attitudes towards vitamin D and sun exposure were identified.

There is a clear gap in the literature as no current research has investigated mothers' knowledge and attitudes of vitamin D or their sun exposure practices in New Zealand. This research has provided the first insight into the knowledge and attitudes for this population. Knowledge deficits of particular interest included poor awareness of risk factors such as darker skin, exclusive breast feeding or excessive sun protection practices in summer months. These findings addressed the first objective of this study.

The second objective aimed to identify the sources of knowledge for vitamin D amongst mothers. Media was the most popular source of vitamin D related information, followed by friends and family. Health professionals were only the main source of information for 15% of the participants. Additionally, only a very small percentage of mothers (3.1%) had received any advice for vitamin D supplementation from their health professional. Similar findings occurred when it came to sun exposure advice, two thirds had not received any advice from their health professional.

The third objective aimed to assess sun exposure practices and attitudes towards sun exposure of mothers and their children. Mothers appeared to be very vigilant with their children's sun protection, especially with hats, protective clothing and sunblock use during the summer months. During the winter months, mothers were much less vigilant and were more likely to expose their children when outdoors. Mothers were very concerned about sun exposure damaging their child's skin and causing skin cancer. However, mothers were less vigilant with their own skin protection during their pregnancy, although they still followed SunSmart recommendations. Mothers agreed that the skin cancer prevention messages made it confusing when it came to vitamin D and half of mothers did not know what to do when it came to vitamin D and sun exposure.

This data was collected over ten years ago, therefore the findings may not be applicable to current times. However, the results provide a starting point for further research, including changes in knowledge and attitudes amongst mothers over the past ten years. There is also a need for further research into knowledge of health professionals and the level of support they are providing pregnant women/mothers in New Zealand regarding vitamin D.

4.2 Strengths

This survey received over 9,000 responses. Once the data was cleaned, there were 8,032 survey responses analysed. This large population size may increase the reliability of the results and may provide a more accurate representation of knowledge of vitamin D amongst mothers across New Zealand.

As the survey was administrated online it was able to be done anywhere in New Zealand, this allowed for a wide spread of responses across the country. However, the response rates were higher in more population dense areas such as main cities, and responses were lower in more rural areas such as the Northland region or the West Coast of the South Island.

4.3 Limitations

One of the most significant limitations of this study is the age of the collected data. The data analysed was collected in 2009, therefore the findings cannot be applied to current times. Over the past 10 years there has been significant development in research, guidelines and supporting documents, all of which may have improved awareness and knowledge of vitamin D amongst mothers.

The survey was administrated through SurveyMonkey and participation was voluntary. It is likely those mothers who chose to take the survey had a particular interest in health and nutrition, therefore having higher awareness and knowledge of vitamin D compared to the general public. Additionally, a significant percentage of respondents were NZ European. This resulted in an underrepresentation of other ethnic groups, such as Māori and Pacific.

The survey design meant participants were provided with a list of answers to choose from, this may have meant participants chose random answers when they were unsure. To more accurately assess knowledge, it may have been more appropriate to ask respondents to type answers without any prompts. However, this may have increased the time taken to complete

the survey and may have lowered response rates. Additionally, although the questionnaire was well-researched and pilot tested, it was not validated for internal consistency.

4.4 Recommendations for practice

Mothers must be provided with accurate, clear and concise information regarding vitamin D benefits in pregnancy and infancy, risk factors for vitamin D deficiency, supplementation if required and appropriate sun exposure practices that minimise skin cancer risk while promoting optimal vitamin D synthesis.

4.5 Recommendations for further research

Future research could assess knowledge and attitudes of a similar population in 2020. Identifying any key changes in knowledge and attitudes regarding vitamin D over the past 10 years could prove beneficial when evaluating the development of previous guidelines and public health messages.

Investigating the knowledge of health professionals on the roles, sources, supplementation guidelines and risk factors for vitamin D deficiency may be beneficial as they should be the main sources of health-related information.

Future research should include a larger variety of ethnicities, especially those who are at higher risk of vitamin D deficiency. Finally, a consideration for future research may be investigation of the relationship between serum 25(OH)D and level of knowledge amongst a population of mothers.

4.6 Conflicts of interest

The author has no conflicts of interest to declare.

References

- Abbas, S., Linseisen, J., Slinger, T., Kropp, S., Mutschelknauss, E. J., Flesch-Janys, D., & Chang-Claude, J. (2008). The Gc2 allele of the vitamin D binding protein is associated with a decreased postmenopausal breast cancer risk, independent of the vitamin D status. *Cancer Epidemiology and Prevention Biomarkers*, 17(6), 1339-1343.
- Aghajafari, F., Field, C. J., Weinberg, A. R., Letourneau, N., & Team, A. S. (2018). Both mother and infant require a vitamin D supplement to ensure that infants' vitamin D status meets current guidelines. *Nutrients*, 10(4), 429.
- Akbari, S., Khodadadi, B., Ahmadi, S. A. Y., Abbaszadeh, S., & Shahsavari, F. (2018). Association of vitamin D level and vitamin D deficiency with risk of preeclampsia: A systematic review and updated meta-analysis. *Taiwanese Journal of Obstetrics and Gynecology*, 57(2), 241-247.
- Aladag, N., Filiz, T. M., Topsever, P., & Gorpelioglu, S. (2006). Parents' knowledge and behaviour concerning sunning their babies; a cross-sectional, descriptive study. *BMC pediatrics*, 6(1), 27.
- Alagöl, F., Shihadeh, Y., Boztepe, H., Tanakol, R., Yarman, S., Azizlerli, H., & Sandalci, Ö. (2000). Sunlight exposure and vitamin D deficiency in Turkish women. *Journal of endocrinological investigation*, 23(3), 173-177.
- Altindag, D., Cannonier, C., & Mocan, N. (2011). The impact of education on health knowledge. *Economics of Education Review*, 30(5), 792-812.
- Alvarez, J. A., & Ashraf, A. (2010). Role of vitamin D in insulin secretion and insulin sensitivity for glucose homeostasis. *International journal of endocrinology*, 2010.
- Arora, H., Dixit, V., & Srivastava, N. (2016). Evaluation of knowledge, practices of vitamin D and attitude toward sunlight among Indian students. *Evaluation*, 9(1), 308.
- Balasubramanian, S., & Ganesh, R. (2008). Vitamin D deficiency in exclusively breast-fed infants. *Indian Journal of Medical Research*, 127(3).
- Bandura, A. (2004). Health promotion by social cognitive means. *Health education & behavior*, 31(2), 143-164.
- Barrett, H., & McElduff, A. (2010). Vitamin D and pregnancy: an old problem revisited. *Best practice & research Clinical endocrinology & metabolism*, 24(4), 527-539.
- Bhattacharya, S., & Campbell, D. M. (2005). The incidence of severe complications of preeclampsia. *Hypertension in pregnancy*, 24(2), 181-190.
- Bi, W. G., Nuyt, A. M., Weiler, H., Leduc, L., Santamaria, C., & Wei, S. Q. (2018). Association between vitamin D supplementation during pregnancy and offspring growth, morbidity, and mortality: a systematic review and meta-analysis. *JAMA pediatrics*, 172(7), 635-645.
- Bianco, M. E., & Josefson, J. L. (2019). Hyperglycemia During Pregnancy and Long-Term Offspring Outcomes. *Current diabetes reports*, 19(12), 143.
- Bikle, D. D. (2014). Vitamin D metabolism, mechanism of action, and clinical applications. *Chemistry & biology*, 21(3), 319-329.
- Bodnar, L. M., Catov, J. M., Simhan, H. N., Holick, M. F., Powers, R. W., & Roberts, J. M. (2007). Maternal vitamin D deficiency increases the risk of preeclampsia. *The Journal of Clinical Endocrinology & Metabolism*, 92(9), 3517-3522.

- Bonevski, B., Bryant, J., Lambert, S., Brozek, I., & Rock, V. (2013). The ABC of vitamin D: a qualitative study of the knowledge and attitudes regarding vitamin D deficiency amongst selected population groups. *Nutrients*, *5*(3), 915-927.
- Brown, J., Nunez, S., Russell, M., & Spurney, C. (2009). Hypocalcemic rickets and dilated cardiomyopathy: case reports and review of literature. *Pediatric cardiology*, *30*(6), 818-823.
- Bryce, J., Boschi-Pinto, C., Shibuya, K., Black, R. E., & WHO Child Health Epidemiology Reference Group. (2005). WHO estimates of the causes of death in children. *The lancet*, *365*(9465), 1147-1152.
- Cade, C., & Norma, A. W. (1986). Vitamin D3 improves impaired glucose tolerance and insulin secretion in the vitamin D-deficient rat in vivo. *Endocrinology*, *119*(1), 84-90.
- Cairncross, C., Stonehouse, W., Conlon, C., Grant, C., McDonald, B., Houghton, L., . . . von Hurst, P. (2017). Predictors of vitamin D status in New Zealand preschool children. *Maternal & child nutrition*, *13*(3), e12340.
- Callister, P., Galtry, J., & Didham, R. (2011). The risks and benefits of sun exposure: should skin colour or ethnicity be the main variable for communicating health promotion messages in New Zealand? *Ethnicity & health*, *16*(1), 57-71.
- Camargo, C. A., Ingham, T., Wickens, K., Thadhani, R. I., Silvers, K. M., Epton, M. J., . . . Allergy Cohort Study Group. (2010). Vitamin D status of newborns in New Zealand. *British Journal of Nutrition*, *104*(7), 1051-1057.
- Cantorna, M. T., Zhu, Y., Froicu, M., & Wittke, A. (2004). Vitamin D status, 1, 25-dihydroxyvitamin D3, and the immune system. *The American Journal of Clinical Nutrition*, *80*(6), 1717S-1720S.
- Cashman, K. D. (2007). Vitamin D in childhood and adolescence. *Postgraduate medical journal*, *83*(978), 230-235.
- Chang, S.-W., & Lee, H.-C. (2019). Vitamin D and health-The missing vitamin in humans. *Pediatrics & Neonatology*, *60*(3), 237-244.
- Chapuy, M. C., Arlot, M. E., Duboeuf, F., Brun, J., Crouzet, B., Arnaud, S., . . . Meunier, P. J. (1992). Vitamin D3 and calcium to prevent hip fractures in elderly women. *New England Journal of Medicine*, *327*(23), 1637-1642.
- Charlton, K. E., Gemming, L., Yeatman, H., & Ma, G. (2010). Suboptimal iodine status of Australian pregnant women reflects poor knowledge and practices related to iodine nutrition. *Nutrition*, *26*(10), 963-968.
- Charoenngam, N., Shirvani, A., & Holick, M. F. (2019). Vitamin D for skeletal and non-skeletal health: What we should know. *Journal of clinical orthopaedics and trauma*.
- Chen, T. C., Chimeh, F., Lu, Z., Mathieu, J., Person, K. S., Zhang, A., . . . Holick, M. F. (2007). Factors that influence the cutaneous synthesis and dietary sources of vitamin D. *Archives of biochemistry and biophysics*, *460*(2), 213-217.
- Chen, Y.-H., Fu, L., Hao, J.-H., Yu, Z., Zhu, P., Wang, H., . . . Xu, D.-X. (2015). Maternal vitamin D deficiency during pregnancy elevates the risks of small for gestational age and low birth weight infants in Chinese population. *The Journal of Clinical Endocrinology & Metabolism*, *100*(5), 1912-1919.
- Christakos, S., Dhawan, P., Liu, Y., Peng, X., & Porta, A. (2003). New insights into the mechanisms of vitamin D action. *Journal of cellular biochemistry*, *88*(4), 695-705.
- Christakos, S., Dhawan, P., Verstuyf, A., Verlinden, L., & Carmeliet, G. (2015). Vitamin D: metabolism, molecular mechanism of action, and pleiotropic effects. *Physiological reviews*, *96*(1), 365-408.

- Clemens, T., & Holick, M. (1983). Recent advances in the hormonal regulation of calcium and phosphorus in adult animals and humans. *Perinatal calcium and phosphorus metabolism*. New York: Elsevier, 1-23.
- Clifton-Bligh, R., McElduff, P., & McElduff, A. (2008). Maternal vitamin D deficiency, ethnicity and gestational diabetes. *Diabetic medicine*, 25(6), 678-684.
- Crowther, C. A., Hiller, J. E., Moss, J. R., McPhee, A. J., Jeffries, W. S., & Robinson, J. S. (2005). Effect of treatment of gestational diabetes mellitus on pregnancy outcomes. *New England Journal of Medicine*, 352(24), 2477-2486.
- Daly, R. M., Gagnon, C., Lu, Z. X., Magliano, D. J., Dunstan, D. W., Sikaris, K. A., . . . Shaw, J. E. (2012). Prevalence of vitamin D deficiency and its determinants in Australian adults aged 25 years and older: a national, population-based study. *Clinical endocrinology*, 77(1), 26-35.
- Day, R. E., Krishnarao, R., Sahota, P., & Christian, M. S. (2019). We still don't know that our children need vitamin D daily: a study of parents' understanding of vitamin D requirements in children aged 0-2 years. *BMC public health*, 19(1), 1119.
- Delshad, M., Beck, K. L., Conlon, C. A., Mugridge, O., Kruger, M. C., Jensen, B. P., . . . von Hurst, P. R. (2019). Wintertime Vitamin D status and its related risk factors among children living in Auckland, New Zealand. *The New Zealand medical journal*, 132(1504), 67-76.
- Deschasaux, M., Souberbielle, J.-C., Partula, V., Lécuyer, L., Gonzalez, R., Srouf, B., . . . Druesne-Pecollo, N. (2016). What do people know and believe about vitamin D? *Nutrients*, 8(11), 718.
- Dijkstra, S., Van Beek, A., Janssen, J., De Vleeschouwer, L., Huysman, W., & Van den Akker, E. (2007). High prevalence of vitamin D deficiency in newborn infants of high-risk mothers. *Archives of disease in childhood*, 92(9), 750-753.
- Dix, C. F., Robinson, A., Bauer, J. D., & Wright, O. R. (2017). Vitamin D: Australian dietitian's knowledge and practices. *Nutrition & dietetics*, 74(4), 396-407.
- Duignan, M., Signal, L., & Thomson, G. (2014). Good intentions, but inadequate practices—sun protection in early childhood centres, a qualitative study from New Zealand. *NZ Med J*, 127, 40-50.
- Eagleton, C., & Judkins, A. (2006). Vitamin D deficiency in pregnant New Zealand women. *The New Zealand Medical Journal (Online)*, 119(1241).
- Ekeroma, A. J., Camargo Jr, C. A., Scragg, R., Wall, C., Stewart, A., Mitchell, E., . . . Grant, C. C. (2015). Predictors of vitamin D status in pregnant women in New Zealand. *NZ Med. J*, 128, 24-34.
- Engelsen, O., Brustad, M., Aksnes, L., & Lund, E. (2005). Daily duration of vitamin D synthesis in human skin with relation to latitude, total ozone, altitude, ground cover, aerosols and cloud thickness. *Photochemistry and photobiology*, 81(6), 1287-1290.
- Erick, M. (2018). Breast milk is conditionally perfect. *Medical hypotheses*, 111, 82-89.
- Ettridge, K. A., Bowden, J. A., Rayner, J. M., & Wilson, C. J. (2010). The relationship between sun protection policy and associated practices in a national sample of early childhood services in Australia. *Health education research*, 26(1), 53-62.
- Fajuyigbe, D., & Young, A. R. (2016). The impact of skin colour on human photobiological responses. *Pigment cell & melanoma research*, 29(6), 607-618.
- Fayet-Moore, F., Brock, K. E., Wright, J., Ridges, L., Small, P., Seibel, M. J., . . . Mason, R. S. (2019). Determinants of vitamin D status of healthy office workers in Sydney, Australia. *The Journal of steroid biochemistry and molecular biology*, 189, 127-134.

- Figure.nz. (2017). Babies Born Preterm in New Zealand. Retrieved October 24 2019 from <https://figure.nz/chart/1XWj6duDXVTOjiSu>
- Gage, R., Barr, M., Stanley, J., Reeder, A., Mackay, C., Smith, M., . . . Signal, L. (2018). Sun protection and shade availability in New Zealand's outdoor recreation spaces. *The New Zealand Medical Journal (Online)*, 131(1484), 30-37.
- Gallo, S., McDermid, J. M., Al-Nimr, R. I., Hakeem, R., Moreschi, J. M., Pari-Keener, M., . . . Cheng, F. W. (2019). Vitamin D Supplementation during Pregnancy: An Evidence Analysis Center Systematic Review and Meta-Analysis. *Journal of the Academy of Nutrition and Dietetics*.
- George, E. M., & Granger, J. P. (2010). Recent insights into the pathophysiology of preeclampsia. *Expert review of obstetrics & gynecology*, 5(5), 557-566.
- Gertosio, C., Meazza, C., Pagani, S., & Bozzola, M. (2016). Breastfeeding and its gamut of benefits. *Minerva pediatrica*, 68(3), 201-212.
- Gilchrest, B. A. (2008). Sun exposure and vitamin D sufficiency. *The American Journal of Clinical Nutrition*, 88(2), 570S-577S.
- Girard, A. W., & Olude, O. (2012). Nutrition education and counselling provided during pregnancy: effects on maternal, neonatal and child health outcomes. *Paediatric and perinatal epidemiology*, 26, 191-204.
- Godar, D. E. (2005). UV Doses Worldwide. *Photochemistry and photobiology*, 81(4), 736-749.
- Goltzman, D. (2018). Functions of vitamin D in bone. *Histochemistry and cell biology*, 149(4), 305-312.
- Golzarand, M., Hollis, B. W., Mirmiran, P., Wagner, C. L., & Shab-Bidar, S. (2018). Vitamin D supplementation and body fat mass: a systematic review and meta-analysis. *European journal of clinical nutrition*, 72(10), 1345.
- Grigalavicius, M., Iani, V., & Juzeniene, A. (2016). Layer thickness of SPF 30 sunscreen and formation of pre-vitamin D. *Anticancer research*, 36(3), 1409-1415.
- Halhali, A., Acker, G., & Garabedian, M. (1991). 1, 25-Dihydroxyvitamin D3 induces in vivo the decidualization of rat endometrial cells. *Reproduction*, 91(1), 59-64.
- Harrison, S., & Buettner, P. (1999). Why do mothers still sun their infants? *Journal of paediatrics and child health*, 35(3), 296-299.
- Harrison, S., Büttner, P., & Nowak, M. (2005). Maternal beliefs about the reputed therapeutic uses of sun exposure in infancy and the postpartum period. *Australian Midwifery*, 18(2), 22-28.
- Harrison, S., Hutton, L., & Nowak, M. (2002). The Risks of Everyday Life: An investigation of professional advice advocating therapeutic sun exposure. *Australian and New Zealand journal of public health*, 26(2), 108-115.
- Harrison, S. L., Nikles, J., & Nowak, M. (2013). Don't burn the baby: advice from Australian nurses recommending therapeutic sun-exposure during infancy. *Open Journal of Preventative Medicine*, 3, 212-218.
- Hazell, T., Gallo, S., Vanstone, C., Agellon, S., Rodd, C., & Weiler, H. (2017). Vitamin D supplementation trial in infancy: body composition effects at 3 years of age in a prospective follow-up study from Montréal. *Pediatric obesity*, 12(1), 38-47.
- Health Promotion Agency. (2019). Be SunSmart Retrieved December 12 2019 from <https://www.sunsmart.org.nz/be-sunsmart/be-sunsmart>
- Hess, A. F., & Unger, L. J. (1921). The cure of infantile rickets by artificial light and by sunlight. *Proceedings of the Society for Experimental Biology and Medicine*, 18(8), 298-298.

- Hess, A. F., & Weinstock, M. (1924). Antirachitic properties imparted to inert fluids and to green vegetables by ultra-violet irradiation. *Journal of Biological Chemistry*, 62(2), 301-313.
- Hewison, M., Freeman, L., Hughes, S. V., Evans, K. N., Bland, R., Eliopoulos, A. G., . . . Chakraverty, R. (2003). Differential regulation of vitamin D receptor and its ligand in human monocyte-derived dendritic cells. *The Journal of Immunology*, 170(11), 5382-5390.
- Holick, M. F. (1995). Environmental factors that influence the cutaneous production of vitamin D. *The American Journal of Clinical Nutrition*, 61(3), 638S-645S.
- Holick, M. F. (1996). Vitamin D and bone health. *The Journal of Nutrition*, 126(suppl_4), 1159S-1164S.
- Holick, M. F. (2004). Sunlight and vitamin D for bone health and prevention of autoimmune diseases, cancers, and cardiovascular disease. *The American Journal of Clinical Nutrition*, 80(6), 1678S-1688S.
- Holick, M. F. (2007). Vitamin D deficiency. *New England Journal of Medicine*, 357(3), 266-281.
- Holick, M. F. (2008). The vitamin D deficiency pandemic and consequences for nonskeletal health: mechanisms of action. *Molecular aspects of medicine*, 29(6), 361-368.
- Holick, M. F. (2009). Shining light on the Vitamin D-Cancer Connection IARC Report: Cancer connection IARC report. In: Taylor & Francis.
- Holman, D. M., Berkowitz, Z., Guy Jr, G. P., Lunsford, N. B., & Coups, E. J. (2017). The association between beliefs about vitamin D and skin cancer risk-related behaviors. *Preventive medicine*, 99, 326-331.
- Houghton, L. A., Szymlek-Gay, E. A., Gray, A. R., Ferguson, E. L., Deng, X., & Heath, A.-L. M. (2010). Predictors of vitamin D status and its association with parathyroid hormone in young New Zealand children. *The American Journal of Clinical Nutrition*, 92(1), 69-76.
- Howson, C. P., Kinney, M. V., McDougall, L., & Lawn, J. E. (2013). Born too soon: preterm birth matters. *Reproductive health*, 10(1), S1.
- Huldschinsky, K. (1919). Curing rickets by artificial UV radiation. *Deutsche Med Wochenschr*, 45, 712-713.
- Hussein, A. S., Almoudi, M. M., Zen, S. A. N. M., Azmi, N. H., Schroth, R. J., & Hassan, M. I. A. (2018). Parental Awareness and Knowledge of Vitamin D and Its Health Benefits for Children. *Journal of International Dental and Medical Research*, 11(3), 916-924.
- Institute of Medicine. (2011). *Dietary Reference Intakes for Calcium and Vitamin D* Washington, DC.
- Jääskeläinen, T., Itkonen, S. T., Lundqvist, A., Erkkola, M., Koskela, T., Lakkala, K., . . . Karppinen, J. (2017). The positive impact of general vitamin D food fortification policy on vitamin D status in a representative adult Finnish population: evidence from an 11-y follow-up based on standardized 25-hydroxyvitamin D data. *The American Journal of Clinical Nutrition*, 105(6), 1512-1520.
- Janda, M., Youl, P., Merollini, K., Niland, C., & Kimlin, M. G. (2010). Knowledge about health benefits of vitamin D in Queensland Australia. *Preventive medicine*, 50(4), 215-216.
- Janssens, W., Bouillon, R., Claes, B., Carremans, C., Lehouck, A., Buyschaert, I., . . . Lambrechts, D. (2010). Vitamin D deficiency is highly prevalent in COPD and correlates with variants in the vitamin D-binding gene. *Thorax*, 65(3), 215-220.

- Jayarathne, N., Russell, A., & van der Pols, J. C. (2012). Sun protection and vitamin D status in an Australian subtropical community. *Preventive medicine, 55*(2), 146-150.
- Jensen, M. E., Murphy, V., Gibson, P., Mattes, J., & Camargo Jr, C. (2019). Vitamin D status in pregnant women with asthma and its association with adverse respiratory outcomes during infancy. *The Journal of Maternal-Fetal & Neonatal Medicine, 32*(11), 1820-1825.
- Khalid, A. T., Moore, C. G., Hall, C., Olabopo, F., Rozario, N. L., Holick, M. F., . . . Rajakumar, K. (2017). Utility of sun-reactive skin typing and melanin index for discerning vitamin D deficiency. *Pediatric research, 82*(3), 444.
- Kurylowicz, A., Ramos-Lopez, E., Bednarczuk, T., & Badenhop, K. (2006). Vitamin D-binding protein (DBP) gene polymorphism is associated with Graves' disease and the vitamin D status in a Polish population study. *Experimental and clinical endocrinology & diabetes, 114*(06), 329-335.
- Lee, A., Newton, M., Radcliffe, J., & Belski, R. (2018). Pregnancy nutrition knowledge and experiences of pregnant women and antenatal care clinicians: A mixed methods approach. *Women and Birth, 31*(4), 269-277.
- Lee, G. J., Birken, C. S., Parkin, P. C., Lebovic, G., Chen, Y., L'Abbé, M. R., & Maguire, J. L. (2014). Consumption of non-cow's milk beverages and serum vitamin D levels in early childhood. *CMAJ, 186*(17), 1287-1293.
- Li, W., Qin, Z., Gao, J., Jiang, Z., Chai, Y., Guan, L., . . . Chen, Y. (2019). Vitamin D supplementation during pregnancy and the risk of wheezing in offspring: a systematic review and dose-response meta-analysis. *Journal of Asthma, 56*(12), 1266-1273.
- Littlewood, Z., & Greenfield, S. (2018). Parents' knowledge, attitudes and beliefs regarding sun protection in children: a qualitative study. *BMC public health, 18*(1), 207.
- Lovell, A. L., Wall, C. R., & Grant, C. C. (2016). Do maternal dietary vitamin D intake and sunlight exposure affect the vitamin D status of exclusively breastfed infants? *Nutrition & dietetics, 73*(5), 420-426.
- Lucas, J. A., Bolland, M. J., Grey, A. B., Ames, R. W., Mason, B. H., Horne, A. M., . . . Reid, I. R. (2005). Determinants of vitamin D status in older women living in a subtropical climate. *Osteoporosis International, 16*(12), 1641-1648.
- Marks, R., Foley, P. A., Jolley, D., Knight, K. R., Harrison, J., & Thompson, S. C. (1995). The effect of regular sunscreen use on vitamin D levels in an Australian population: results of a randomized controlled trial. *Archives of dermatology, 131*(4), 415-421.
- Marwaha, R. K., & Dabas, A. (2019). Interventions for prevention and control of epidemic of vitamin D deficiency. *The Indian Journal of Pediatrics, 1*-6.
- Mathieu, C., van Etten, E., Decallonne, B., Guilietti, A., Gysemans, C., Bouillon, R., & Overbergh, L. (2004). Vitamin D and 1, 25-dihydroxyvitamin D3 as modulators in the immune system. *The Journal of steroid biochemistry and molecular biology, 89*, 449-452.
- Matsuoka, L. Y., Ide, L., Wortsman, J., Maclaughlin, J. A., & Holick, M. F. (1987). Sunscreens suppress cutaneous vitamin D3 synthesis. *The Journal of Clinical Endocrinology & Metabolism, 64*(6), 1165-1168.
- Mazahery, H., Stonehouse, W., & Von Hurst, P. (2015). The effect of monthly 50 000 IU or 100 000 IU vitamin D supplements on vitamin D status in premenopausal Middle Eastern women living in Auckland. *European journal of clinical nutrition, 69*(3), 367.

- McCullum, E. V., Simmonds, N., Becker, J. E., & Shipley, P. (1922). Studies on experimental rickets XXI. An experimental demonstration of the existence of a vitamin which promotes calcium deposition. *Journal of Biological Chemistry*, 53(2), 293-312.
- McKenzie, R. (2017). *UV radiation in the melanoma capital of the world: What makes New Zealand so different?* Paper presented at the AIP Conference Proceedings.
- Miliku, K., Felix, J. F., Voortman, T., Tiemeier, H., Eyles, D. W., Burne, T. H., . . . Jaddoe, V. W. (2019). Associations of maternal and fetal vitamin D status with childhood body composition and cardiovascular risk factors. *Maternal & child nutrition*, 15(2), e12672.
- Ministry of Health. (2010). Ethnicity code tables. Retrieved November 2019 from <https://www.health.govt.nz/nz-health-statistics/data-references/code-tables/common-code-tables/ethnicity-code-tables>
- Ministry of Health. (2011). *A Focus on Nutrition: Key Findings of the 2008/09 New Zealand Adult Nutrition Survey*. Wellington.
- Ministry of Health. (2012a). *Consensus Statement on Vitamin D and Sun Exposure in New Zealand*. Wellington, New Zealand.
- Ministry of Health. (2012b). *Vitamin D Status of New Zealand Adults: Findings from the 2008/09 New Zealand Adult Nutrition Survey*. Wellington.
- Ministry of Health. (2013). *Companion Statement on Vitamin D and Sun Exposure in Pregnancy and Infancy in New Zealand*. Wellington: Ministry of Health
- Ministry of Health. (2014). *Quick reference guide for health professionals on the screening, diagnosis and treatment of gestational diabetes in New Zealand*. Wellington, New Zealand.
- Ministry of Health. (2017). *Nutrient Reference Values for Australia and New Zealand*. National Health and Medical Research Council.
- Ministry of Health. (2018). Fetal and Infant Deaths 2015. Retrieved December 2019 from <https://www.health.govt.nz/publication/fetal-and-infant-deaths-2015>
- Ministry of Health. (2019). Annual Data Explorer 2017/18: New Zealand Health Survey [Data File]. Retrieved September 2019 from <https://minhealthnz.shinyapps.io/nz-health-survey-2017-18-annual-data-explorer>
- Mirzakhani, H., Carey, V. J., Zeiger, R., Bacharier, L. B., O'Connor, G. T., Schatz, M. X., . . . Litonjua, A. A. (2019). Impact of parental asthma, prenatal maternal asthma control, and vitamin D status on risk of asthma and recurrent wheeze in 3-year-old children. *Clinical & Experimental Allergy*, 49(4), 419-429.
- Mirzakhani, H., Litonjua, A. A., McElrath, T. F., O'Connor, G., Lee-Parriz, A., Iverson, R., . . . Zeiger, R. (2016). Early pregnancy vitamin D status and risk of preeclampsia. *The Journal of clinical investigation*, 126(12), 4702-4715.
- Misra, M., Pacaud, D., Petryk, A., Collett-Solberg, P. F., & Kappy, M. (2008). Vitamin D deficiency in children and its management: review of current knowledge and recommendations. *Pediatrics*, 122(2), 398-417.
- Morales, S., Kendall, P. A., Medeiros, L. C., Hillers, V., & Schroeder, M. (2004). Health care providers' attitudes toward current food safety recommendations for pregnant women. *Applied Nursing Research*, 17(3), 178-186.
- Możowski, W. (1939). Jäccaron; drzej Sniadecki (1768–1838) on the cure of rickets. *Nature*, 143(3612), 121.
- Munns, C., Zacharin, M. R., Rodda, C. P., Batch, J. A., Morley, R., Cranswick, N. E., . . . Taylor, B. J. (2006). Prevention and treatment of infant and childhood vitamin D deficiency

- in Australia and New Zealand: a consensus statement. *Medical Journal of Australia*, 185(5), 268-272.
- Nessvi, S., Johansson, L., Jopson, J., Stewart, A., Reeder, A., McKenzie, R., & Scragg, R. K. (2011). Association of 25-hydroxyvitamin D3 levels in adult New Zealanders with ethnicity, skin color and self-reported skin sensitivity to sun exposure. *Photochemistry and photobiology*, 87(5), 1173-1178.
- Nitert, J., & Tuohy, P. (2018). Assessment of Implementation of the Guideline for Supplementation of at Risk Infants with Vitamin D in New Zealand. In: *Am Acad Pediatrics*.
- Nowak, M., Harrison, S. L., Buettner, P. G., Kimlin, M., Porter, D., Kennedy, L., & Speare, R. (2011). Vitamin D status of adults from tropical Australia determined using two different laboratory assays: implications for public health messages. *Photochemistry and photobiology*, 87(4), 935-943.
- Nowson, C. A., McGrath, J. J., Ebeling, P. R., Haikerwal, A., Daly, R. M., Sanders, K. M., . . . Mason, R. S. (2012). Vitamin D and health in adults in Australia and New Zealand: a position statement. *Medical Journal of Australia*, 196(11), 686-687.
- O'Callaghan, K. M., & Kiely, M. E. (2018). Ethnic disparities in the dietary requirement for vitamin D during pregnancy: considerations for nutrition policy and research. *Proceedings of the Nutrition Society*, 77(2), 164-173.
- O'Callaghan, K. M., Taghivand, M., Zuchniak, A., Onoyovwi, A., Korsiak, J., Leung, M., & Roth, D. E. (2020). Vitamin D in Breastfed Infants: Systematic Review of Alternatives to Daily Supplementation. *Advances in Nutrition*, 11(1), 144-159.
- O'Connor, C., Glatt, D., White, L., & Revuelta Iniesta, R. (2018). Knowledge, attitudes and perceptions towards Vitamin D in a UK adult population: a cross-sectional study. *International journal of environmental research and public health*, 15(11), 2387.
- Ojo, O., Weldon, S. M., Thompson, T., & Vargo, E. J. (2019). The effect of Vitamin D supplementation on glycaemic control in women with Gestational Diabetes Mellitus: A systematic review and meta-analysis of randomised controlled trials. *International journal of environmental research and public health*, 16(10), 1716.
- Palacios, C., Kostyuk, L. K., & Peña-Rosas, J. P. (2019). Vitamin D supplementation for women during pregnancy. *Cochrane Database of Systematic Reviews*(7).
- Parlea, L., Bromberg, I., Feig, D., Vieth, R., Merman, E., & Lipscombe, L. (2012). Association between serum 25-hydroxyvitamin D in early pregnancy and risk of gestational diabetes mellitus. *Diabetic medicine*, 29(7), e25-e32.
- Paxton, G. A., Teale, G. R., Nowson, C. A., Mason, R. S., McGrath, J. J., Thompson, M. J., . . . Munns, C. F. (2013). Vitamin D and health in pregnancy, infants, children and adolescents in Australia and New Zealand: a position statement. *Medical Journal of Australia*, 198(3), 142-143.
- Pike, J. W., & Meyer, M. B. (2012). The vitamin D receptor: new paradigms for the regulation of gene expression by 1, 25-dihydroxyvitamin D3. *Rheumatic Disease Clinics*, 38(1), 13-27.
- Plunket. (2019). Annual breastfeeding statistics. Retrieved 15 October 2019 from <https://www.plunket.org.nz/news-and-research/research-from-plunket/plunket-breastfeeding-data-analysis/annual-breastfeeding-statistics/>
- Poel, Y., Hummel, P., Lips, P., Stam, F., Van Der Ploeg, T., & Simsek, S. (2012). Vitamin D and gestational diabetes: a systematic review and meta-analysis. *European journal of internal medicine*, 23(5), 465-469.

- Pondicherry, A., Martin, R., Meredith, I., Rolfe, J., Emanuel, P., & Elwood, M. (2018). The burden of non-melanoma skin cancers in Auckland, New Zealand. *Australasian Journal of Dermatology*, *59*(3), 210-213.
- Raulio, S., Erlund, I., Männistö, S., Sarlio-Lähteenkorva, S., Sundvall, J., Tapanainen, H., . . . Virtanen, S. M. (2017). Successful nutrition policy: improvement of vitamin D intake and status in Finnish adults over the last decade. *The European Journal of Public Health*, *27*(2), 268-273.
- Ravnbak, M. H. (2010). Objective determination of Fitzpatrick skin type. *Dan Med Bull*, *57*(8), B4153.
- Redman, C. W., & Sargent, I. L. (2005). Latest advances in understanding preeclampsia. *Science*, *308*(5728), 1592-1594.
- Robinson, J. K. (2005). Sun exposure, sun protection, and vitamin D. *Jama*, *294*(12), 1541-1543.
- Rockell, J., Skeaff, C., Williams, S., & Green, T. (2008). Association between quantitative measures of skin color and plasma 25-hydroxyvitamin D. *Osteoporosis International*, *19*(11), 1639.
- Rockell, J. E., Green, T. J., Skeaff, C. M., Whiting, S. J., Taylor, R. W., Williams, S. M., . . . Schaaf, D. (2005). Season and ethnicity are determinants of serum 25-hydroxyvitamin D concentrations in New Zealand children aged 5–14 y. *The Journal of Nutrition*, *135*(11), 2602-2608.
- Rueter, K., Jones, A. P., Siafarikas, A., Lim, E.-M., Bear, N., Noakes, P. S., . . . Palmer, D. J. (2019). Direct infant UV light exposure is associated with eczema and immune development. *Journal of Allergy and Clinical Immunology*, *143*(3), 1012-1020. e1012.
- Salahuddin, N., Ali, F., Hasan, Z., Rao, N., Aqeel, M., & Mahmood, F. (2013). Vitamin D accelerates clinical recovery from tuberculosis: results of the SUCCINCT Study [Supplementary Cholecalciferol in recovery from tuberculosis]. A randomized, placebo-controlled, clinical trial of vitamin D supplementation in patients with pulmonary tuberculosis'. *BMC infectious diseases*, *13*(1), 22.
- Salle, B. L., Delvin, E. E., Lapillonne, A., Bishop, N. J., & Glorieux, F. H. (2000). Perinatal metabolism of vitamin D. *The American Journal of Clinical Nutrition*, *71*(5), 1317S-1324S.
- Samuel, H. (1964). Infantile Hypercalcaemia, Nutritional Rickets, and Infantile Scurvy in Great Britain, a British Paediatric Association Report. *British medical journal*, *1*(5399), 1659-1661.
- Saraff, V., & Shaw, N. (2016). Sunshine and vitamin D. *Archives of disease in childhood*, *101*(2), 190-192.
- Schmid, A., & Walther, B. (2013). Natural vitamin D content in animal products. *Advances in Nutrition*, *4*(4), 453-462.
- Scientific Advisory Committee on Nutrition. (2018). *Feeding in the First Year of Life* (Report).
- Shi, D., Wang, D., Meng, Y., Chen, J., Mu, G., & Chen, W. (2019). Maternal vitamin D intake during pregnancy and risk of asthma and wheeze in children: a systematic review and meta-analysis of observational studies. *The Journal of Maternal-Fetal & Neonatal Medicine*, 1-7.
- Sinotte, M., Diorio, C., Berube, S., Pollak, M., & Brisson, J. (2008). Genetic polymorphisms of the vitamin D binding protein and plasma concentrations of 25-hydroxyvitamin D in premenopausal women. *The American Journal of Clinical Nutrition*, *89*(2), 634-640.

- Soininen, S., Eloranta, A.-M., Lindi, V., Venäläinen, T., Zaproudina, N., Mahonen, A., & Lakka, T. A. (2016). Determinants of serum 25-hydroxyvitamin D concentration in Finnish children: the Physical Activity and Nutrition in Children (PANIC) study. *British Journal of Nutrition*, *115*(6), 1080-1091.
- Statistics New Zealand. (2013). 2013 Census. Retrieved July 2019 from <https://www.stats.govt.nz/infographics/major-ethnic-groups-in-new-zealand>
- Steenbock, H. (1924). The induction of growth promoting and calcifying properties in a ration by exposure to light. *Science*, *60*(1549), 224-225.
- Stocklin, E., & Eggersdorfer, M. (2013). Vitamin D, an essential nutrient with versatile functions in nearly all organs. *Int J Vitam Nutr Res*, *83*(2), 92-100.
- Tan, M. G., Nag, S., & Weinstein, M. (2018). Parental use of sun protection for their children—does skin color matter? *Pediatric dermatology*, *35*(2), 220-224.
- Tanvig, M. H., Jensen, D. M., Andersen, M. S., Ovesen, P. G., Jørgensen, J. S., & Vinter, C. A. (2019). Vitamin D levels were significantly higher during and after lifestyle intervention in pregnancy: A randomized controlled trial. *Acta obstetrica et gynecologica Scandinavica*.
- Taylor, C. L., Patterson, K. Y., Roseland, J. M., Wise, S. A., Merkel, J. M., Pehrsson, P. R., & Yetley, E. A. (2014). Including food 25-hydroxyvitamin D in intake estimates may reduce the discrepancy between dietary and serum measures of vitamin D status. *The Journal of Nutrition*, *144*(5), 654-659.
- The Institute of Environmental Science and Research Ltd. (2018). *Tuberculosis in New Zealand: Annual Report 2016*. Porirua, New Zealand.
- Thomson, B. M., & Cressey, P. J. (2011). *Determination of vitamin D in foods: Current knowledge and data gaps*. Ministry of Primary Industries.
- Toher, C., Lindsay, K., McKenna, M., Kilbane, M., Curran, S., Harrington, L., . . . McAuliffe, F. (2014). Relationship between vitamin D knowledge and 25-hydroxyvitamin D levels amongst pregnant women. *Journal of Human Nutrition and Dietetics*, *27*(3), 261-269.
- Trilok-Kumar, G., Kaur, M., Rehman, A. M., Arora, H., Rajput, M. M., Chugh, R., . . . Filteau, S. (2015). Effects of vitamin D supplementation in infancy on growth, bone parameters, body composition and gross motor development at age 3–6 years: follow-up of a randomized controlled trial. *International journal of epidemiology*, *44*(3), 894-905.
- van der Mei, I. A., Ponsonby, A.-L., Engelsen, O., Pasco, J. A., McGrath, J. J., Eyles, D. W., . . . Jones, G. (2007). The high prevalence of vitamin D insufficiency across Australian populations is only partly explained by season and latitude. *Environmental health perspectives*, *115*(8), 1132-1139.
- Venturini, E., Facchini, L., Martinez-Alier, N., Novelli, V., Galli, L., de Martino, M., & Chiappini, E. (2014). Vitamin D and tuberculosis: a multicenter study in children. *BMC infectious diseases*, *14*(1), 652.
- Vierucci, F., Del Pistoia, M., Fanos, M., Gori, M., Carlone, G., Erba, P., . . . Saggese, G. (2013). Vitamin D status and predictors of hypovitaminosis D in Italian children and adolescents: a cross-sectional study. *European journal of pediatrics*, *172*(12), 1607-1617.
- von Hurst, P. R., Stonehouse, W., & Coad, J. (2010). Vitamin D status and attitudes towards sun exposure in South Asian women living in Auckland, New Zealand. *Public health nutrition*, *13*(4), 531-536.
- Vu, L. H., van der Pols, J. C., Whiteman, D. C., Kimlin, M. G., & Neale, R. E. (2010). Knowledge and attitudes about vitamin D and impact on sun protection practices among urban

- office workers in Brisbane, Australia. *Cancer Epidemiology and Prevention Biomarkers*, 19(7), 1784-1789.
- Walker, N., Love, T. D., Baker, D. F., Healey, P. B., Haszard, J., Edwards, A. S., & Black, K. E. (2014). Knowledge and attitudes to vitamin D and sun exposure in elite New Zealand athletes: a cross-sectional study. *Journal of the International Society of Sports Nutrition*, 11(1), 47.
- Wejse, C., Gomes, V. F., Rabna, P., Gustafson, P., Aaby, P., Lisse, I. M., . . . Sodemann, M. (2009). Vitamin D as supplementary treatment for tuberculosis: a double-blind, randomized, placebo-controlled trial. *American journal of respiratory and critical care medicine*, 179(9), 843-850.
- Wheeler, B., Taylor, B., de Lange, M., Harper, M., Jones, S., Mekhail, A., & Houghton, L. (2018). A longitudinal study of 25-Hydroxy vitamin D and parathyroid hormone status throughout pregnancy and exclusive lactation in New Zealand mothers and their infants at 45 S. *Nutrients*, 10(1), 86.
- Wheeler, B. J., Dickson, N. P., Houghton, L. A., Ward, L. M., & Taylor, B. J. (2015). Incidence and characteristics of vitamin D deficiency rickets in New Zealand children: a New Zealand Paediatric Surveillance Unit study. *Australian and New Zealand journal of public health*, 39(4), 380-383.
- Wilkinson, R. J., Llewelyn, M., Toossi, Z., Patel, P., Pasvol, G., Lalvani, A., . . . Davidson, R. N. (2000). Influence of vitamin D deficiency and vitamin D receptor polymorphisms on tuberculosis among Gujarati Asians in west London: a case-control study. *The lancet*, 355(9204), 618-621.
- Williams, B., Williams, A. J., & Anderson, S. T. (2008). Vitamin D deficiency and insufficiency in children with tuberculosis. *The Pediatric infectious disease journal*, 27(10), 941-942.
- Wilson, R. L., Leviton, A. J., Leemaqz, S. Y., Anderson, P. H., Grieger, J. A., Grzeskowiak, L. E., . . . Bianco-Miotto, T. (2018). Vitamin D levels in an Australian and New Zealand cohort and the association with pregnancy outcome. *BMC pregnancy and childbirth*, 18(1), 251.
- World Health Organisation. (1998). *Complementary feeding of young children in developing countries: a review of current scientific knowledge*. .
- World Health Organisation. (2012). *Born Too Soon: The Global Action Report on Preterm Birth*. Genva: World Health Organisation.
- Yap, C., Cheung, N. W., Gunton, J. E., Athayde, N., Munns, C. F., Duke, A., & McLean, M. (2014). Vitamin D supplementation and the effects on glucose metabolism during pregnancy: a randomized controlled trial. *Diabetes Care*, 37(7), 1837-1844.
- Yeh, E. B., Barbano, D. M., & Drake, M. (2017). Vitamin fortification of fluid milk. *Journal of food science*, 82(4), 856-864.
- Zadka, K., Pałkowska-Goździk, E., & Rosołowska-Huszcz, D. (2018). The state of knowledge about nutrition sources of vitamin D, its role in the human body, and necessity of supplementation among parents in central poland. *International journal of environmental research and public health*, 15(7), 1489.
- Zhang, C., Qiu, C., Hu, F. B., David, R. M., Van Dam, R. M., Bralley, A., & Williams, M. A. (2008). Maternal plasma 25-hydroxyvitamin D concentrations and the risk for gestational diabetes mellitus. *PLoS one*, 3(11), e3753.

- Zhou, S. S., Tao, Y. H., Huang, K., Zhu, B. B., & Tao, F. B. (2017). Vitamin D and risk of preterm birth: Up-to-date meta-analysis of randomized controlled trials and observational studies. *Journal of Obstetrics and Gynaecology Research*, 43(2), 247-256.
- Zittermann, A., Pilz, S., & Berthold, H. K. (2019). Serum 25-hydroxyvitamin D response to vitamin D supplementation in infants: a systematic review and meta-analysis of clinical intervention trials. *European Journal of Nutrition*, 1-11.

Appendix A. Supplementary results

Table A1: Participant knowledge regarding vitamin D sources.

Single most important source of vitamin D (N=8,032)	N (%)
Made in skin from sunshine	7,140 (88.9)
Natural food sources	702 (8.7)
Supplements	112 (1.4)
Fortified food products	51 (0.6)
Other	28 (0.3)

Table A.2: Knowledge of vitamin D sources

Source of vitamin D	Good N (%)	Moderate N (%)	Poor N (%)	Don't know N (%)
Breastmilk (N=8,022)	5,074 (63.2)	1,220 (15.2)	309 (3.8)	1,419 (17.7)
Infant formula (N=7,976)	1,792 (22.3)	3,474 (43.2)	591 (7.4)	2,119 (26.4)
Toddler formula (N=7,966)	1,603 (20.0)	3,468 (43.2)	653 (8.1)	2,242 (27.9)
Cow's milk (N=7,948)	1,063 (13.2)	2,433 (30.3)	1,965 (24.5)	2,487 (32.1)

Table A.3: Importance of vitamin D

What is vitamin D needed for? (N=8032)	Answer chosen N (%)
Healthy bones	5,067 (63.1)
Immunity	2,334 (29.1)
Antioxidant	1,627 (20.3)
Don't know	1,369 (17.4)
Blood clotting	681 (8.5)

Participants were able to choose multiple answers

Table A.4: Vitamin D risk factors

Risk factor	High risk N (%)	Moderate risk N (%)	Low risk N (%)	Don't know N (%)
No dairy in child's diet	1,847 (23.0)	2,948 (36.7)	1,375 (17.1)	1,861 (23.2)

Living in South Island of NZ	226 (2.8)	1,296 (16.1)	4,784 (59.6)	1,725 (21.5)
Children who do not have regular exposure to sunlight	4,632 (57.7)	2,543 (31.7)	477 (5.9)	379 (4.7)
High use of sunscreen	1,346 (16.8)	2,177 (27.1)	3,452 (43.0)	1,056 (13.1)
Babies born to vit D deficient mothers	3,373 (42.0)	2,500 (31.1)	702 (8.7)	1,456 (18.1)
Having darker skin	565 (7.0)	1,517 (18.9)	3,729 (46.4)	2,220 (27.6)
Exclusively breast-fed babies	155 (1.9)	720 (9.0)	5,589 (69.6)	1,567 (19.5)
Formula fed babies	225 (2.8)	2,467 (30.7)	3,273 (40.7)	2,066 (25.7)
Fussy eaters	817 (10.2)	3,140 (39.1)	2,218 (27.6)	1,856 (23.1)
Children with food allergies	927 (11.5)	2,819 (35.1)	2,074 (25.8)	2,211 (27.5)

Table A.5: Main source of information regarding vitamin D

Information source	Answer chosen N (%)
Media	3,276 (40.8)
Family/friends	2,031 (25.3)
Health professional	1,267 (15.8)
Other (please specify)	1,230 (15.3)
Parenting courses	227 (2.8)

Table A.6: Did you spend time outside during your pregnancy?

Did you spend time outside during your pregnancy?	Answer chosen N (%)
Yes	7,528 (93.7)
No	504 (6.3)

Table A.6: Sun exposure practices during pregnancy

During your last pregnancy did you...	Always/Usually (%)	Sometimes (%)	Rarely/Never (%)
protect your skin from sun with clothing (n=7949)	5,475 (68.9)	2,075 (26.1)	399 (5.0)

use sunscreen (n=7917)	4,559 (57.6)	2,242 (28.3)	1,116 (14.1)
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Table A.7: Sun exposure practices for your youngest child during summer months

With your youngest child did you...	Always/Usually N (%)	Sometimes N (%)	Rarely/Never N (%)	Not applicable * N (%)
keep your child in the shade	4,492 (55.9)	2,499 (31.1)	394 (4.9)	645 (8.0)
put a hat on your child	6,949 (86.5)	336 (4.2)	86 (1.1)	659 (8.2)
put protective clothing on your child	5,878 (73.2)	1,213 (15.1)	275 (3.4)	664 (8.3)
Apply sunscreen onto your child's exposed skin	6,266 (78.0)	535 (6.7)	439 (5.5)	790 (9.8)

*Youngest child not yet born

Table A.8: Sun exposure practices for your youngest child during winter months

Did you...	Always/usually N (%)	Sometimes N (%)	Rarely/never N (%)	Not applicable*
keep your child in the shade	1,218 (15.2)	1,950 (24.3)	4,489 (55.9)	375 (4.7)
put a hat on your child	2,843 (35.4)	2,041 (25.4)	2,775 (34.5)	373 (4.6)
put protective clothing on your child	3,961 (49.3)	1,503 (18.7)	2,102 (26.2)	466 (5.8)
Apply sunscreen onto your child's exposed skin	902 (11.2)	1,198 (14.9)	5,453 (67.9)	479 (6.0)

*Youngest child not yet born

Table A.9: Were you given advice on vitamin D supplements for your child from your Plunket nurse or health professional?

Advice given?	Answer chosen N (%)
Yes (please specify)	251 (3.1)
No	7,781 (96.9)

Table A.10: Were you given advice on sun exposure for your child from your Plunket nurse or health professional?

Advice given?	Answer chosen N (%)
Yes (please specify)	2,454 (30.5)
No	5,578 (69.4)

Table A.11: Did you breastfeed your youngest child

With your youngest child did you breastfeed?	Answer chosen N (%)
Yes	7,407 (92.2)
No	307 (3.8)

Table A.12: General knowledge of vitamin D

Statement	True N (%)	False N (%)	Unsure N (%)
N=8,032			
Re-emergence of rickets in New Zealand children	1,937 (24.1)	617 (7.7)	5,478 (68.2)
The sunny climate and outdoor living in NZ means that vitamin D is not an issue	1,032 (12.8)	5,703 (71.0)	11,297 (6.1)
Wearing clothing/sunscreen to protect the skin from the sun does not affect vitamin D	2,202 (27.4)	3,729 (46.4)	2,101 (26.2)
People with dark skin need to spend longer in the sun to make enough vitamin D	1,918 (23.9)	3,164 (39.4)	2,950 (36.7)
Sun through a window is just as	2,975 (37.0)	2,629 (32.7)	2,428 (30.2)

effective as outdoor sun exposure for making vitamin D			
Sun through a window is safer than outdoor sun	1,474 (18.4)	5,128 (63.8)	1,430 (17.8)
The amount of time needed in the sun to make enough vitamin D depends on the amount of skin exposed	3,217 (40.1)	1,936 (24.1)	2,878 (35.8)
Most pregnant women will get enough vit D in summer through incidental sun exposure outside peak UV times	3,060 (38.1)	1,553 (19.3)	3,419 (42.6)
Deliberate sun exposure during the middle of the day is recommended for pregnant & lactating women	795 (9.9)	4,483 (55.8)	2,754 (34.3)
During winter the body's levels of vitamin D may drop below sufficient levels	5,653 (70.4)	551 (6.9)	1,828 (22.8)
It is more important to cover a baby's skin than a toddler's skin	2,775 (34.5)	4,065 (50.6)	1,192 (14.8)

Table A.13: Vitamin D attitudes

Statement	Agree N (%)	Neutral N (%)	Disagree N (%)
N=8,032			
Sunbathing is harmful to my child	7,003 (87.2)	689 (8.6)	340 (4.2)
Children need to get some direct sunlight to be healthy	7,251 (90.3)	532 (6.6)	249 (3.1)
I worry that sun exposure is linked to skin cancer	6,948 (86.5)	831 (10.3)	253 (3.1)

I worry that the sun will damage my child's skin	6,501 (80.9)	1,061 (13.2)	470 (5.9)
If skin is always protected from the sun it can put people at risk of having low vitamin D	4,391 (54.7)	2,536 (31.6)	1,105 (13.8)
I really don't know what to do when it comes to vitamin D and sun exposure	4,029 (50.1)	2,467 (30.7)	1,536 (19.1)
Skin cancer prevention messages make it confusing to understand messages about vitamin D	5,820 (72.4)	1,599 (19.9)	613 (7.6)

Appendix B. Online Questionnaire

New Zealand Mothers' knowledge and attitudes towards sun exposure and Vitamin D

1. About the Study

The Nutrition Team at Massey University is interested in finding out about Mother's knowledge of Vitamin D.

This questionnaire explores the knowledge, attitudes and behaviour of mothers with at least one child towards vitamin D and sun exposure. It should only take a few minutes to complete and we really appreciate your participation. All responses are confidential and data is anonymous.

This questionnaire relates to your most recent pregnancy and your youngest child.

Please be honest about your knowledge we are really interested in finding out what mothers know so that we can make sure that clear messages are getting out there. Don't look up answers or ask anyone else.

Thank you

* 1. Are you the mother to at least one child under the age of 5 years old?

If your answer is NO, thank you for your interest, but please exit the questionnaire.

Yes

No

* 2. Are you currently living in New Zealand?

If your answer is NO, thank you for your interest, but please exit the questionnaire.

Yes

No

New Zealand Mothers' knowledge and attitudes towards sun exposure and Vitamin D

2. Knowledge about Vitamin D

In this section we would like to find out about your knowledge of Vitamin D. Try to be as honest as possible about your current knowledge.

* 1. Have you heard of vitamin D? (Please tick.)

Yes

No

* 2. What do you think is the single most important source of vitamin D for average New Zealanders? (Please tick only one option)

Manufactured in the skin from sunshine

Natural food sources

Fortified food products

Supplements

Other (please specify)

* 3. What is vitamin D needed for? (Please tick all that apply.)

Vitamin D is needed for healthy bones

Vitamin D is an antioxidant

Vitamin D is important for babies and toddlers immunity

Vitamin D is needed for blood clotting

Don't know

* 4. Are the following good, moderate or poor sources of vitamin D?

	Good	Moderate	Poor	Don't know
Breast milk	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Infant formula	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Toddler formula	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Cow's milk	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

* 5. Please rank the following factors for their risk of vitamin D deficiency in babies.

	High risk	Moderate risk	Low risk	Don't know
Babies born to vitamin D deficient mothers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Dark skin	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Babies who are not regularly exposed to sunlight	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Babies who have most of their skin covered by clothing	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Exclusively breast fed babies	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Formula fed babies	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

* 6. Please rank the following factors for the risk of vitamin D deficiency in toddlers and preschoolers?

	High risk	Moderate risk	Low risk	Don't know
Exclusion of dairy products from the diet	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Dark skin	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Living in the south island of New Zealand	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Toddlers and preschoolers who are not regularly exposed to sunlight	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Extensive use of sunscreen	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Fussy eating	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Food allergies	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Toddlers and preschoolers who are vegetarian	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

* 7. Where has your knowledge about vitamin D come from? (Please tick the most important.)

- Health professional (eg Doctor, Lead Maternity Care, Plunket Nurse, Nutritionist, Dietitian)
- Parenting courses (eg Antenatal classes, child care course)
- Media (TV, radio, internet, parenting magazines)
- Family/Friends
- Other (please specify)

* 8. Where would you go if you wanted to find out more information about vitamin D? (Please tick the most important)

- Health professional (eg Doctor, Lead Maternity Care, Plunket Nurse, Nutritionist, Dietitian)
- Parenting courses (eg Antenatal classes, child care course)
- Media (TV, radio, internet, parenting magazines)
- Family/Friends
- Other (please specify)

* 9. Do you think that there is enough information about vitamin D available to parents?

- Yes
- No

New Zealand Mothers' knowledge and attitudes towards sun exposure and Vitamin D

3. Behaviour

For the following questions please think about your typical behavior during your most recent pregnancy while outside in the sun on a sunny day.

* 1. Did you spend time outside in the sun during pregnancy?

- Yes
- No

2. During your most recent pregnancy whilst out in the sun:

	Always	Usually	Sometimes	Rarely	Never
Did you wear protective clothing?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Did you apply sunscreen to exposed skin?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

3. What sun protection factor (SPF) was the sunscreen?

SPF

* 4. Did your Lead maternity carer give you any advice regarding vitamin D supplements during pregnancy? (Please tick.)

- Yes
- No

* 5. Did you follow this advice?

- Yes
- No
- Not applicable

* 6. Did your lead maternity carer give you any advice regarding sun exposure during pregnancy? (Please tick.)

- Yes
- No

7. If you answered yes to question 6, please briefly describe the advice

8. Did you follow this advice?

- Yes
- No
- Not applicable

9. For the following question please think about your behaviour regarding your youngest child when outside on a sunny day during the SUMMER months.

	Always	Usually	Sometimes	Rarely	Never
Do you keep him/her in the shade?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Do you put a hat on him/her?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Do you put protective clothing on him/her?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Do you apply sunscreen on any of his/her exposed skin?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

10. For the following question please think about your typical behaviour regarding your youngest child when outside on a sunny day during the WINTER months.

	Always	Usually	Sometimes	Rarely	Never
Do you keep him/her in the shade?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Do you put a hat on him/her?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Do you put protective clothing on him/her?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Do you apply sunscreen on any of his/her exposed skin?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

11. Did your Plunket nurse or other health professional give you any advice regarding vitamin D supplements for your baby?

- Yes
- No

If yes, please briefly describe the advice

12. Did you follow this advice?

- Yes
- No
- Not applicable

13. Did your plunket nurse or other health professional give you any advice regarding sun exposure for your baby?

- Yes
- No

If yes, please briefly describe the advice

14. Did you follow this advice?

- Yes
- No
- Not applicable

15. Was your most recent pregnancy planned?

- Yes
- No

* 16. During your most recent pregnancy did you do any of the following? (Please tick.)

	Yes	No
Take a folic acid supplement?	<input type="radio"/>	<input type="radio"/>
Exercise during pregnancy	<input type="radio"/>	<input type="radio"/>
Limit fish intake?	<input type="radio"/>	<input type="radio"/>
Drink alcohol?	<input type="radio"/>	<input type="radio"/>
Smoke?	<input type="radio"/>	<input type="radio"/>
Avoid foods containing raw eggs or fish	<input type="radio"/>	<input type="radio"/>
Limit caffeine intake	<input type="radio"/>	<input type="radio"/>

17. During your most recent pregnancy did you take any kind of multi vitamin supplement?

Did you take a supplement?	Name of supplement
Options <input type="text"/>	<input type="text"/>

Other (please state)

18. For your youngest child, did you?

	Options	How old was your baby when you started?	How old was your baby when you stopped?
Breast feed	<input type="checkbox"/>	<input type="text"/>	<input type="text"/>
Formula feed	<input type="checkbox"/>	<input type="text"/>	<input type="text"/>
Other (please specify)	<input type="text"/>		

19. What age did you start solids with your youngest child?

	Options
Age	<input type="text"/>

New Zealand Mothers' knowledge and attitudes towards sun exposure and Vitamin D

4. Sun exposure and vitamin D

* 1. Please answer true, false or unsure for the following statements related to New Zealand:

	True	False	Unsure
In New Zealand we are seeing a re-emergence of rickets in children.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The sunny climate and outdoor living in New Zealand means that vitamin D deficiency is not an issue.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Sun protective behaviours (e.g. wearing clothing and/or sun block) have no affect on vitamin D synthesis.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
People with dark skin e.g. Maori and Pacific Island people need to spend longer in the sun to synthesise adequate vitamin D.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Sun through a window is just as effective as outdoor sun exposure in relation to vitamin D synthesis.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Sun exposure through a window is safer than outdoor sun exposure.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The amount of time required to be spent in the sun to allow synthesis of adequate vitamin D depends on the amount of skin exposed.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Most pregnant women will achieve an adequate vitamin D status in summer through incidental sun exposure outside peak UV times.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Deliberate sun exposure during peak UV times is recommended for pregnant and lactating women.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
During winter vitamin D status may drop below adequate levels.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
It is more important to cover a baby's skin than a toddler's skin.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

* 2. Please rank how you feel about the following statements

	Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
Sunbathing is harmful for my child	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Children need to get some direct sunlight to be healthy	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I worry that sun exposure is linked to skin cancer	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I worry that the sun will damage my child's skin	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
If skin is always protected from the sun it can put people at risk of vitamin D deficiency	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I really don't know what to do when it comes to vitamin D and sun exposure	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Skin cancer prevention messages make it confusing to understand messages about vitamin D	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

5. Please tell us about yourself

1. How old are you?

Years

Age

* 2. How many children do you have under the age of 5 years old?

Options

Number of children

3. How old are your children?

Age

Youngest child

Child

Child

Child

Child

4. For your youngest child what month were they born in?

Month

5. Does your youngest child attend day care or kindy?

- Full time
- Part time
- No

6. What is your ethnicity: (You may tick more than one)

- New Zealand European
- Maori
- Samoan
- Cook Island Maori
- Tongan
- Niuean
- Chinese
- Indian

Other (please specify)

Please compare your skin type to the image below

* 7. What is your skin type (please tick one)

- TYPE I: Highly sensitive, nearly always burns, minimal if any tan, possibly freckles
- TYPE II: Sun sensitive skin, sometimes burns, slowly tans to light brown.
- TYPE III: Minimally sun sensitive, burns minimally, always tans to moderate brown.
- TYPE IV: Sun insensitive skin, rarely burns, tans well.
- TYPE V: Sun insensitive, never burns, deeply pigmented.

* 8. What is your youngest child's skin type? (Please tick one.)

- TYPE I: Highly sensitive, nearly always burns, minimal if any tan, possibly freckles
- TYPE II: Sun sensitive skin, sometimes burns, slowly tans to light brown.
- TYPE III: Minimally sun sensitive, burns minimally, always tans to moderate brown.
- TYPE IV: Sun insensitive skin, rarely burns, tans well.
- TYPE V: Sun insensitive, never burns, deeply pigmented.

9. Do you have a family history of skin cancer?

- Yes
- No

10. What is your highest qualification?

- Secondary School
- Bachelors degree e.g. BA, BSc, LLB
- Bachelors Degree with honours
- Masters degree e.g. MA, MSc
- PHD
- Diploma (not post graduate)
- Diploma (post graduate)
- Trade or technical certificate which took more then 3 months of full time study
- Professional qualifications like ACA, teachers, nurses
- Other please state

* 11. What is your post code? (If unsure please tell us what region you live in.)

12. If you would like to comment on anything concerning vitamin D please feel free to do so