Changes in knowledge, attitudes and behaviours towards vitamin D and sun exposure of parents of infants and young children in New Zealand.

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Abstract

Background: Vitamin D deficiency can have serious health implications in early life, with severe deficiency resulting in rickets. Vitamin D deficiency has also been linked to extra-skeletal conditions during pregnancy, infancy and childhood. Vitamin D is synthesised following exposure to ultraviolet radiation; with factors impacting synthesis increasing the risk of deficiency. Therefore, parents' knowledge about vitamin D is important for optimal vitamin D status in early life. In 2012 and 2013, the Ministry of Health (MoH) released a Consensus Statement on Vitamin D and Sun Exposure, followed by a Companion Statement for Pregnancy and Infancy with subsequent public health messaging. However, there is limited information on parents' vitamin D knowledge in New Zealand.

Aim: To determine the impact of these statements on vitamin D and sun exposure knowledge, attitudes and behaviours of parents of infants and young children in New Zealand.

Methods: This ecological study utilised a cross-sectional questionnaire to collect data at two time points - 2009 and 2021 to compare knowledge, attitudes and behaviours and assess the impact of the MoH statements. Inclusion criteria included: youngest child <5 years, living in New Zealand, and understanding written English.

Results: The analysis included 9,834 parents (2009 N=8,032, 2021 N=1,802). Knowledge of vitamin D roles was similar; however, a higher proportion of parents (48.2%) in 2021 correctly identified the role of vitamin D in immunity compared to 2009 (29.1%). Most parents lacked knowledge of high-risk factors for deficiency, including exclusive breastfeeding (98.1%, 95.1%) and darker skin colour (92.9%, 77.5%). Health professionals were not the main source of information (15.8%, 24.8%), and low advice rates on supplementation and sun exposure were reported. In 2021, 60.2% of parents reported health professionals or the MoH, and 24.5% reported the media or social media as their preferred source of information on vitamin D. Safe sun exposure practices were performed frequently in children during the summer in 2009 and 2021. Most parents (86.9%) in 2021 did not know current vitamin D and sun exposure recommendations.

Conclusion: Overall, the impact of the MoH statements and subsequent public health messaging on parents' knowledge has been minimal. To improve parents' knowledge, the MoH could utilise social media to communicate public health information more effectively.

Key words: vitamin D; sun exposure; knowledge; attitudes; behaviours; parents; infants; children; New Zealand

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List of Abbreviations

***Table 1.1**: List of abbreviations*

Abbreviation	Definition
AI	Adequate Intake
DBP	Vitamin D Binding Protein
EAR	Estimated Average Requirement
GDM	Gestational Diabetes Mellitus
IOM	Institute Of Medicine
IU	International Units
mg	Milligram
MoH	Ministry of Health
NHMRC	National Health and Medical Research Council
nmol/L	Nanomoles per litre
NZ	New Zealand
PHARMAC	The Pharmaceutical Management Agency
RDA	Recommended Dietary Allowance
RDI	Recommended Daily Intake
RNI	Reference Nutrient Intake
SACN	Scientific Advisory Committee on Nutrition
µg	Microgram
UK	United Kingdom
US	United States
UV	Ultraviolet
UVR	Ultraviolet Radiation
UVα	Ultraviolet alpha Radiation
UVβ	Ultraviolet beta Radiation
UVC	Ultraviolet C Radiation
VDR	Vitamin D Receptor
$1,25(OH)_2D_3$	1α,25-dihydroxyvitamin D_3
$24(R)25(OH)_2D_3$	24,25-dihydroxyvitamin D_3
25(OH)D	25-hydroxyvitamin D
$25(OH)D_3$	25-hydroxyvitamin D_3
7-DHC	7-dehydrocholesterol

Chapter 1. Introduction

1.1 Background

Rickets has re-emerged in infants and children in New Zealand in the past decade, with the New Zealand Paediatric Surveillance Unit identifying 58 children with the bone deforming disease from 2010 to 2013 (Wheeler et al., 2015). Rickets is characterised by skeletal abnormalities, poor growth and motor delays, but is often first indicated by hypocalcaemia and cardiomyopathy, which can be life-threatening for the infant (Munns et al., 2016; Yilmaz et al., 2018). The bone deforming disease was first documented during the seventeenth century in children living in industrialised countries, where sunshine was limited (Chesney, 2012; Holick, 2004). This resulted in the discovery of a link between sunshine and rickets, and subsequently a deficiency in vitamin D was identified as the cause of the disease (Chesney, 2012; Holick, 2004; Wheeler et al., 2019). It was found that severe vitamin D deficiency in early life when the skeleton is undergoing rapid growth results in the development of rickets (Pettifor & Prentice, 2011). However, despite these discoveries, both vitamin D deficiency and rickets continues to be a public health issue worldwide (Palacios & Gonzalez, 2014).

Vitamin D deficiency has also been identified to have extra-skeletal effects during pregnancy, infancy and childhood and may result in long term health effects in adulthood (Lucas et al., 2008). The vitamin D status of pregnant women is particularly important, as maternal vitamin D status directly impacts the status of the developing fetus (Grant et al., 2014). During pregnancy, low vitamin D status has been associated with adverse pregnancy outcomes, including gestational diabetes mellitus (GDM) (Hu et al., 2018) and preeclampsia (Akbari et al., 2018). Although evidence is still emerging on the role of vitamin D in the aetiology of these conditions, pregnant women with adequate vitamin D status have been found to have a reduced risk of developing the conditions during pregnancy (Akbari et al., 2018; Wilson et al., 2018). Additionally, these conditions increase the risk of preterm birth, with infants born prematurely at increased risk of low vitamin D status (Aviram et al., 2016; Davies et al., 2016). Low vitamin D status was identified in more than a quarter of pregnant women (N=2800) from a sample population in New Zealand and Australia (Wilson et al., 2018). Despite the prevalence of low vitamin D status during pregnancy and its association with adverse pregnancy outcomes, there is currently no widespread vitamin D supplementation recommendations for pregnant women in New Zealand.

During infancy and early childhood, vitamin D has been identified to have a role in immune system development and function, influencing the development of respiratory and allergic diseases (Antonucci et al., 2018). Vitamin D has been proposed to have several protective effects against developing respiratory tract infections (RTIs), with low vitamin D levels associated with increased risk of RTIs (Bergman et al., 2013; Charan et al., 2012). This is particularly important, as RTIs are the leading cause of morbidity and mortality in children under the age of five years internationally (Nair et al., 2013). Additionally, low vitamin D status has been linked to atopic diseases, including eczema and food allergies, which usually develop within the first year of life (Palmer, 2015). Vitamin D has been found to have a regulatory role in both the immune system and skin barrier function, dysregulation of these systems results in the development of eczema (Palmer, 2015). Low vitamin D status is thought to impact the integrity of the intestinal barrier, allowing food proteins to come into contact with the immune system resulting in upregulation of IgE antibodies (Vassallo & Camargo, 2010). Furthermore, there is emerging evidence of the role of vitamin D in autism spectrum disorders (ASD). It has been hypothesised that low vitamin D status may be a risk factor in the development of ASD; due to its neuroprotective effect on the developing brain (Kocovska et al., 2012). Further research is needed to establish the role of vitamin D in the prevention of these conditions.

There are several factors that influence the vitamin D status of individuals. Vitamin D is primarily obtained from endogenous synthesis within the skin after exposure to ultraviolet β (UVβ) radiation in sunlight (Nowson et al., 2012). Therefore, factors that influence individuals' exposure to ultraviolet radiation (UVR) may increase the risk of low vitamin D status (Nowson et al., 2012). This is particularly relevant in early life, as infants are not recommended to have direct exposure to UVR due to the sensitivity of their skin and increased risk of skin cancer later in life (Ministry of Health, 2020a; Wright et al., 2007). In addition, the preferred method of feeding for infants is breastmilk as it has many benefits for both the infant and mother; however, breastmilk is a poor source of vitamin D for infants whose mothers have low vitamin D status (Wagner & Hollis, 2020). This further increases the risk of low vitamin D status in early life. Several other factors influence the risk of vitamin D deficiency in New Zealand, including geographical latitude, seasonality, skin colour and ethnic diversity (Ekeroma et al., 2015).

To clarify vitamin D and sun exposure recommendations in New Zealand, the Ministry of Health (MoH) released a Consensus Statement on Vitamin D and Sun Exposure in 2012 (Ministry of Health, 2012a). They then released a Companion Statement on Vitamin D and Sun Exposure in Pregnancy and Infancy in 2013 (Ministry of Health, 2013). These statements outline risk factors for deficiency and recommend supplementation for pregnant women and infants at high risk of deficiency. High-risk pregnant women include those with dark skin, those who choose to avoid the sun completely for cultural reasons and those living in southern regions. High-risk infants include those that are breastfed during the winter months or have additional risk factors such as darker skin. In the 2013 statement, the PHARMAC subsidised vitamin D supplement for pregnant women was a monthly 1.25 mg (50,000 IU) cholecalciferol tablet (Ministry of Health, 2013). However, this monthly dose is only indicated for women with diagnosed deficiency due to the limited evidence on its safety in pregnancy. For infants, a combined vitamin supplement, Vitadol-C, was subsidised (Ministry of Health, 2013). However, to provide an adequate dose of vitamin D, the infant would receive excessive concentrations of vitamin A (Ministry of Health, 2013). The Companion Statement was revised in 2020 and now lists the new funded vitamin D supplement for pregnant women and infants at high-risk of deficiency, Puria, which contains 10 µg (400 IU) of vitamin D per drop (Ministry of Health, 2020a). It should be noted that both statements recommend low-risk pregnant women may benefit from supplementation with 10 µg (400 IU) to 15 µg (600 IU) of vitamin D a day, especially in the third trimester of pregnancy (Ministry of Health, 2013, 2020a). However, this is not subsidised by PHARMAC.

In order to ensure optimal vitamin D status during infancy and childhood, parents need sufficient knowledge of the importance of vitamin D in early life and the risk factors for deficiency. However, in New Zealand there is limited information on parents' vitamin D knowledge and their current sun exposure behaviours. To the author's knowledge, no research has been conducted to investigate the impact of the release of the MoH Consensus and Companion Statements in 2012 and 2013, respectively. Therefore, the current study aims to identify parents' knowledge, attitudes and behaviours towards vitamin D and sun exposure and determine the impact of these statements amongst parents. The findings from this study will identify the gaps in parents' knowledge regarding vitamin D and sun exposure. The findings from this study will also establish if public health messages have been sufficient and if they have been delivered effectively to parents in New Zealand.

1.2 Purpose of this study

The purpose of this study is to identify changes in parents' knowledge, attitudes and behaviours towards vitamin D and sun exposure between 2009 and 2021. This will determine the impact of the public health messaging on parents' in New Zealand following the release of the Ministry of Health Consensus Statement on Vitamin D and Sun Exposure in 2012 and the Companion Statement for Pregnancy and Infancy 2013, which was revised in 2020. This study aims to identify parents current and preferred sources of information and provide suggestions to improve the delivery of public health information to parents in New Zealand.

1.3 Aim

To determine the impact of the Ministry of Health Consensus Statement on Vitamin D and Sun Exposure and Companion Statement for Pregnancy and Infancy and the subsequent public health messaging on vitamin D and sun exposure knowledge, attitudes and behaviours of parents of infants and young children in New Zealand.

1.4 Objectives

1. To identify the difference in parents' knowledge of the role of vitamin D, sources and risk factors for deficiency between 2009 and 2021.
2. To investigate if there is a difference in the sources of information for parents on vitamin D and sun exposure between 2009 and 2021 and identify the preferred source of information within this population group.
3. To identify the differences in attitudes and behaviours regarding vitamin D and sun exposure practices between 2009 and 2021.

1.5 Thesis structure

Chapter one provides the background and purpose of the study and outlines the aims and objectives. The second chapter provides a current review of the literature on vitamin D, including the history, metabolism and dietary sources of vitamin D, followed by recommended status and intake in New Zealand along with risk factors for deficiency. This is followed by the role and consequences of low vitamin D in pregnancy, infancy and early childhood, and parents' current knowledge of vitamin D and sun exposure. Chapter three presents the complete research manuscript for publication, including the abstract, introduction, methods, results, discussion and conclusion of the study. Lastly, chapter four provides an overview of the study, including its strengths and limitations and provides recommendations for future public health messaging and research in New Zealand.

1.6 Researcher's contributions

Table 1.1: Researcher's contributions

Researcher	Contributions
Esme Reynolds MSc Nutrition and Dietetics Student	Author of the thesis and primary contributor to 2021 questionnaire; completed ethics notification, adjusted and re-administered questionnaire, recruited participants, collected and cleaned data, conducted statistical analysis, completed research manuscript.
Professor Pamela von Hurst Academic supervisor	Primary contributor to 2009 questionnaire; developed questionnaire, completed ethics application, distributed questionnaire, recruited participants and collected data. Provided feedback and academic support for thesis and research process.
Associate Professor Cathryn Conlon Academic supervisor	Primary contributor to 2009 questionnaire; developed questionnaire, completed ethics application, distributed questionnaire, recruited participants and collected data. Provided feedback and academic support for thesis and research process.

Chapter 2. Literature Review

2.1 History of vitamin D and rickets

During the seventeenth century, the first clear documentation of rickets, a disease characterised by the deformation of bones in infants and children, was recorded by physicians in England (Wheeler et al., 2019). During this time, the industrial revolution saw heavily polluted and overcrowded cities across Northern Europe and America, reducing the amount of sunlight and UV radiation (UVR) available for vitamin D synthesis (Chesney, 2012; Holick, 2004). These conditions resulted in a significant increase in the appearance of the bone deforming disease, affecting up to 60-90% of children in urban settings (Chesney, 2012).

Sniadecki first identified the link between sunshine and rickets in 1822 (Holick, 2004). He noted that children born and residing in a heavily populated city in Poland had a higher prevalence of the bone deforming disease compared to children living outside of the city, who were not as prevalently affected by the disease (Holick, 2004). Similarly, Palm, an English physician, noted a much higher prevalence of rickets in children living in industrialised countries such as the United Kingdom, compared to developing countries, including India and China, where the condition was uncommon (Chesney, 2012; Holick, 2006). Palm concluded that inadequate sunlight was the cause of rickets because although children in developing countries had poor nutrition and living conditions, they were exposed to ample sunshine (Chesney, 2012). However, these findings were largely ignored, and the use of sunshine to prevent and treat rickets went unnoticed for another century (Chesney, 2012).

Further advancements in understanding the pathophysiology and treatment of rickets emerged in the twentieth century. In 1919, exposing children with rickets to mercury lamps containing artificial UVR was discovered by Huldschinsky to effectively treat the disease (Deluca, 2014; Holick, 1995). He also noted that exposure to the artificial UVR to one part of the diseased body improved the condition throughout the body, theorising that in response to UVR, a chemical compound was produced (Holick, 1995). This was later confirmed by Hess and Unger, who significantly improved rickets in seven children by exposing them to periods of sunlight, with x-ray analysis showing calcification of the ends of long bones (Deluca, 2014; Hess & Unger, 1921; Holick, 1995). Additionally, Sir Edward Mellanby, a British physician and pharmacologist, hypothesised the aetiology of rickets was a deficiency of an anti-rachitic factor (Wheeler et al., 2019). This factor was subsequently identified as vitamin D by an American chemist, Elmer McCollum (Deluca, 2014; Wheeler et al., 2019). These new understandings and advancements have led to treatments identified to prevent and cure rickets, including supplements, such as cod liver oil, and fortified foods (Cannell et al., 2008; Rajakumar, 2003). However, rickets continues to be identified in developed countries, including New Zealand, even with increased understanding and the availability of preventative treatments (Wheeler et al., 2015). Additionally, emerging evidence has identified the role of vitamin D in several essential processes throughout the body.

2.2 Vitamin D metabolism

Vitamin D is classified as a pro-hormone, as the active form 1α, 25-dihydroxyvitamin D_3 acts as a sterol hormone, interacting with vitamin D receptors throughout the body (Norman, 2008). Vitamin D exists in two forms, vitamin D_2 and vitamin D_3 (Courbebaisse & Cavalier, 2020). Vitamin D_2, also known as ergocalciferol, is the plant-derived form of vitamin D that is produced by the plant sterol, ergosterol, in response to UVR (Nowson et al., 2012). The animal-derived form of the vitamin, vitamin D_3 or cholecalciferol is produced in the skin.

Within the epidermis layers of the skin, the precursor for the pro-hormone, 7-dehydrocholesterol (7-DHC), is abundant (Lehmann & Meurer, 2010). In the presence of ultraviolet beta (UVβ) rays, 7-DHC isomerises, producing pre-vitamin D (Lehmann & Meurer, 2010; Saraff & Shaw, 2016). This is followed by a heat sensitive reaction that rearranges the three double bonds producing vitamin D_3 (Figure 2.1) (Christakos et al., 2016; Henry, 2011). The vitamin D_3 produced has a short half-life of approximately 12-24 hours and is not biologically active, requiring further reactions in order to perform its many vital functions within the body (Lehmann & Meurer, 2010).

Vitamin D_3 enters the circulatory system and is transported to the liver bound to vitamin D binding protein (DBP) (Lehmann & Meurer, 2010). In the liver, the first hydroxylation reaction occurs catalysed by mitochondrial cytochrome P450 enzyme CYP2R1, converting vitamin D_3 into 25-hydroxyvitamin D_3 (25(OH)D_3) via a hydroxylation at carbon 25 (Lehmann & Meurer, 2010). The resulting 25(OH)D_3 is the major circulating form of vitamin D and has a long half-life; thus, it is used to measure an individual's vitamin D status (Christakos et al., 2016; Lehmann & Meurer, 2010). The 25(OH)D_3 remains inactive and is transported to the kidney bound to DBP, where it undergoes one of two possible hydroxylation's by the cytochrome P450 enzymes, CYP27B1 or CYP24A1 (Henry, 2011). The hydroxylation that produces the active metabolite 1α, 25-dihydroxyvitamin D_3 (1α,25(OH)$_2D_3$), also known as calcitriol, is catalysed by CYP27B1 at the carbon one position within the alpha ring (DeLuca, 2008; Henry, 2011). The alternative hydroxylation is carried out by CYP24A1 and occurs at the carbon 24 position, producing 24,25-dihydroxyvitamin D_3 (24(R)25(OH)$_2D_3$), which is then catabolised (Lips, 2006). The production of the active metabolite is influenced by three main negative feedback systems, a direct input by 1α,25(OH)$_2D_3$ itself, and external regulation via parathyroid hormone and fibroblast growth factor 23 (FGF23) in response to calcium and phosphate status, respectively (Bikle, 2010; Henry, 2011).

It was previously thought that activation of 1α,25(OH)$_2D_3$ only occurred in the kidneys, however it has since been discovered to occur at many sites throughout the body, indicating its importance in many physiological roles (Henry, 2011). Calcitriol acts on target cells by binding to the vitamin D receptor (VDR), activating the regulation of transcription of target genes (Wang et al., 2012).

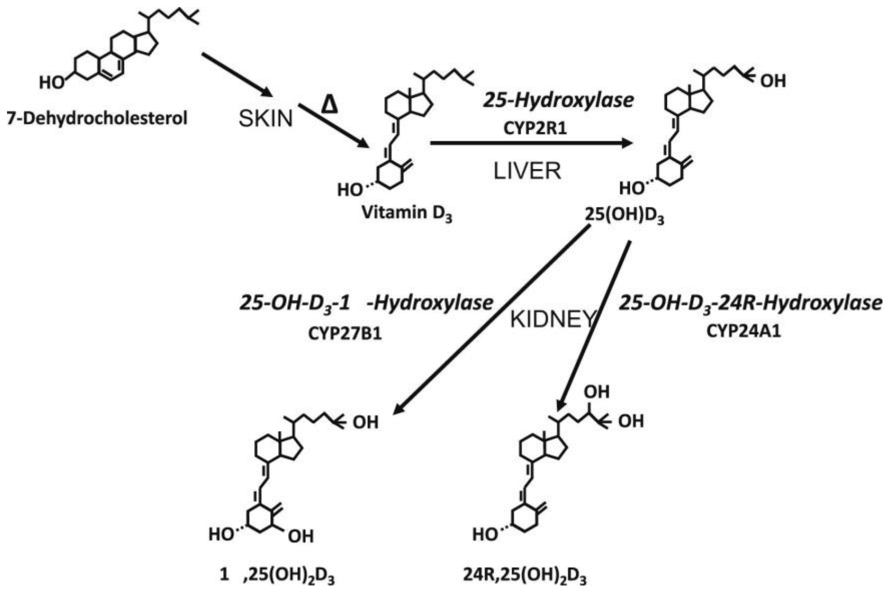

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Figure 2.1.
Vitamin D_3 metabolism in the skin, liver and kidney (Henry, 2011).

2.3 Dietary sources of vitamin D

The main dietary form of vitamin D is vitamin D_3 or cholecalciferol (Borel et al., 2015). There is a very limited number of foods that naturally contain vitamin D_3, with the main sources being oily fish including salmon, herring and mackerel, liver and cod liver oil and eggs (Shrapnel & Truswell, 2006). The other dietary form is vitamin D_2, or ergocalciferol, which is found in very small amounts in plant foods and yeast. However, one exception is mushrooms, which, when exposed to UVβ radiation increase their vitamin D_2 content, providing approximately 10–20 µg per 100g (Cardwell, 2018; Liu, 2012; Nowson et al., 2012).

Foods can also be fortified with vitamin D_2 and D_3 and this is common practice in a few countries including America, Canada and Australia. In New Zealand, foods that are approved to be fortified include dairy products such as milk, cheese and yoghurts, along with margarine and plant-based alternatives (Ministry for Primary Industries, 2014). However, the fortification of these foods remains voluntary, compared to Australia where it is mandatory to fortify all edible oil spreads and margarine with at least 55 µg/kg of vitamin D (Ministry for Primary Industries, 2014).

The absorption of the fat-soluble vitamin from the diet occurs in the small intestine and is assisted by dietary fat (Silva & Furlanetto, 2018). Both forms are incorporated into micelles and cross the apical membrane of enterocytes via passive diffusion, where they are then transported to the circulatory system packaged in chylomicrons (Schmid & Walther, 2013). Although both forms have a similar structure, vitamin D_3 is more rapidly absorbed than vitamin D_2 (Schmid & Walther, 2013; Silva & Furlanetto, 2018).

2.4 Vitamin D status

Vitamin D status is determined by measuring serum 25-hydroxyvitamin D (25(OH)D), the major circulating form of vitamin D. The concentration of 25(OH)D considered optimal remains controversial (Holick, 2017; Pludowski et al., 2018). Current recommendations for serum 25(OH)D concentrations are largely focused on the role of vitamin D in bone health. However, emerging evidence of the role in extra-skeletal actions suggests a higher 25(OH)D concentration is required, with concentrations of 75-125 nmol/L found to be beneficial for overall health (Pludowski et al., 2018).

In New Zealand, the Ministry of Health considers a serum 25(OH)D concentration of 50 nmol/L as adequate, with concentrations from 25-49 nmol/L considered insufficient (Ministry of Health, 2012a). Vitamin D deficiency is diagnosed with serum 25(OH)D concentrations below 25 nmol/L, with severe deficiency less than 12.5 nmol/L (Ministry of Health, 2012a).

2.4.1 Vitamin D status of adults in New Zealand

From the most recent New Zealand Adult Nutrition Survey (ANS) in 2008/9, the overall annual mean serum 25(OH)D concentration was 63 nmol/L (Ministry of Health, 2012b). However, over a quarter of adults (27.1%) had insufficient serum 25(OH)D concentration (<50 nmol/L) and 4.9% of adults were vitamin D deficient (<25 nmol/L) (Ministry of Health, 2012b). The vitamin D status of adults in New Zealand differed between ethnicities, with lower mean 25(OH)D identified in Māori (59.4 nmol/L) and Pacific (47.9 nmol/L) adults (Ministry of Health, 2012b). Recently, similar findings were seen in a randomised control trial (RCT) of adults aged 50-84 years (N=5110) in the vitamin D assessment study (ViDA), with a mean baseline 25(OH)D concentration of 64 nmol/L and a quarter of the participants with 25(OH)D below 50 nmol/L (Scragg et al., 2016). Findings from the national ANS and this large RCT indicate a large percentage of adults in New Zealand have insufficient vitamin D status, particularly amongst Māori and Pacific ethnicities.

The vitamin D status of pregnant women is particularly important, as maternal vitamin D status directly impacts the status of the developing fetus (Grant et al., 2014). Low vitamin D status in pregnant women has been associated with increased risk of complications for both the mother and infant (Akbari et al., 2018; Hu et al., 2018). Women aged 15 years and over in the national ANS had a mean serum 25(OH)D concentration of 62.4 nmol/L, however almost a third of women (28.5%) had concentrations below 50 nmol/L (Ministry of Health, 2012b). Lower vitamin D status was also identified in Māori and Pacific women, with significantly lower mean 25(OH)D concentrations of 57.2 nmol/L and 46 nmol/L, respectively (Ministry of Health, 2012b). Similar findings were seen in a randomised control trial of pregnant women aged 21-32 years living in Auckland (N=259), with a mean serum 25(OH)D concentration of 63 nmol/L (Ekeroma et al., 2015). However, 42% of women had 25(OH)D less than 50 nmol/L (Ekeroma et al., 2015).

2.4.2 Vitamin D status of infants and young children in New Zealand

The vitamin D status of infants and young children in New Zealand has been reported in a handful of studies. A population-based study of 929 healthy newborns from Wellington and Christchurch found the median serum 25(OH)D concentration in cord blood was 44 nmol/L, with more than half of the newborns with a 25(OH)D concentration less than 50 nmol/L (Camargo et al., 2010). However, the median serum 25(OH)D concentration of exclusively breastfed infants (N=94) in Auckland was identified as 53 nmol/L in 2008/9 (Wall et al., 2013). Although the median concentration was above 50 nmol/L, a statistically significant difference in median 25(OH)D concentration was identified between infants enrolled in the study in the summer months (75 nmol/l) compared to the winter months (21 nmol/l) (Wall et al., 2013). This seasonal effect on vitamin D status has also been observed in toddlers in Dunedin (N=193), with a mean 25(OH)D concentration of 74.1 nmol/L during the summer and a mean of 38.7 nmol/L in winter (Houghton et al., 2010). More recently, a cross-sectional study of 1329 preschool aged children from across New Zealand had mean serum 25(OH)D of 52 nmol/L (Cairncross et al., 2016). However, more than 50% of the children had a 25(OH)D concentration less than 50 nmol/L, including 7% with 25(OH)D less than 25 nmol/L (Cairncross et al., 2016).

2.5 Vitamin D in New Zealand

2.5.1 Vitamin D recommendations in New Zealand

For the general population in New Zealand, the recommendations for vitamin D and sun exposure are based on the Consensus Statement published by the Ministry of Health in 2012 (Ministry of Health, 2012a). In addition, a separate Companion Statement was developed for vitamin D and sun exposure recommendations for pregnancy and infancy in 2013 (Ministry of Health, 2013).

In 2020, the Ministry of Health revised its Companion Statement to provide new recommendations on supplementation for pregnant women and their infants (Ministry of Health, 2020a). The new recommendation is for pregnant women at high risk of vitamin D deficiency to take a vitamin D supplement daily containing approximately 10 µg (400 IU) (Ministry of Health, 2020a). Furthermore, women diagnosed with vitamin D deficiency are recommended to take the subsidised monthly dose of 1.25 mg of cholecalciferol (Ministry of Health, 2020a). The statement also recommends that pregnant women at low risk of vitamin D deficiency may benefit from supplementation with 10 µg to15 µg a day, especially in the third trimester of pregnancy (Ministry of Health, 2020a).

The recommendations for supplementation of infants include those who are exclusively breastfed and have an additional risk factor for deficiency (Ministry of Health, 2013, 2020a). The revised companion statement now lists the new PHARMAC subsidised vitamin D supplement recommended for infants at high risk of vitamin D deficiency, Puria, which provides 10 µg (400 IU) of vitamin D per drop (Ministry of Health, 2020a). This replaces the previously subsidised supplement, Vitadol-C, which when administered to provide the correct dose of vitamin D, provided vitamins A and C at levels above the recommended dose for infants.

The Consensus Statement provides recommendations for the general public in New Zealand regarding vitamin D and sun exposure (Ministry of Health, 2012a). It states vitamin D supplementation has not been found to be beneficial for the general public and is therefore not recommended for widespread use (Ministry of Health, 2012a). However, individuals that live in the southern regions of the country and are not exposed to sunlight during winter months may be at an increased risk of vitamin D deficiency and therefore may benefit from supplementation during the winter months (Ministry of Health, 2012a). The report also recommends that vitamin D supplementation would be beneficial for three at-risk groups, including those with naturally very dark skin, those who avoid sun exposure, and those with low mobility (Ministry of Health, 2012a).

2.5.2 Recommended dietary intake of vitamin D

For the general population to meet their vitamin D requirements, they must receive sufficient vitamin D from either UVβ exposure, supplementation or from the diet. However, the exact amount of vitamin D recommended from food remains controversial, with dietary recommendations differing between different health organisations (Table 2.1).

The Nutrient Reference Values for Australia and New Zealand state an adequate intake (AI) of vitamin D from the diet (NHMRC, 2014). An AI is used when insufficient scientific data available to form an estimated average requirement (EAR) and subsequently a recommended dietary intake (RDI), which meets the needs of 50% and 97-98% of a healthy population, respectively. However, the Scientific Advisory Committee on Nutrition (SACN) in the United Kingdom (UK) and Institute of Medicine (IOM) in the United States (US) have set a RDI for vitamin D for most age groups, which is referred to as a reference nutrient intake (RNI) and recommended dietary allowance (RDA) respectively (Del Valle et al., 2011; Scientific Advisory Committee on Nutrition, 2016). Additionally, the Endocrine Society Task force in the US, made up of experts in the field, published recommendations that differ from those set by the IOM (Holick et al., 2011). However, all have set an AI or 'safe intake' for infants due to insufficient evidence on vitamin D intake in this age group.

In New Zealand, the recommended AI for infants and children is 5 µg (200 IU) (NHMRC, 2014). In the UK, the recommended 'safe intake' is 8.5 - 10 µg/day of vitamin D for children under four years (Scientific Advisory Committee on Nutrition, 2016). Similarly, the IOM recommends an AI of 10 µg/day; however, the Endocrine Society recommends up to 25 µg/day infants and children (Del Valle et al., 2011; Holick et al., 2011). Similar findings are seen across all groups, with the recommended AI of vitamin D from the diet in New Zealand lower than the recommendations in the UK and the US.

Table 2.1: *Recommendations for dietary intake of vitamin D in New Zealand, Australia, United Kingdom and United States.*

	Age group					
	Infants >12mos	Children 1-18yrs	Adults 19-50yrs	Older adults 51-70yrs	Older adults >70yrs	Pregnancy and lactation
National Health and Medical Research Council and Ministry of Health (AUS, NZ)	5.0 µg ∅	5.0 µg ∅	5.0 µg ∅	10.0 µg ∅	15.0 µg ∅	5.0 µg ∅
Scientific Advisory Committee on Nutrition (UK)	8.5-10.0 µg∞	10.0 µg¥	10.0 µg¥	10.0 µg¥	10.0 µg¥	10.0 µg¥
Institute Of Medicine (US)	15.0 µg ∅	15.0 µg‡	15.0 µg‡	15.0 µg‡	15.0 µg‡	15.0 µg‡
The Endocrine Society (US)	10.0 µg ∅ 25.0 µg*	15.0 µg‡ 25.0 µg*	15.0 µg‡ 37.5-50.0 µg*	15.0 µg‡ 37.5-50.0 µg*	15.0 µg‡† 37.5-50.0 µg*	15.0 µg‡ 37.5-50.0 µg*

Note. All values are per day.
† 65 years and older
∅ AI – Adequate intake (AI)
∞ 'Safe intake' for children under the age of 4 years
¥ Reference nutrient intake (RNI)
Σ Estimated average requirement (EAR)
‡ Recommended dietary allowance (RDA)
* Endocrine Society recommended intake to maintain 25(OH)D concentration above 75 nmol/L (Holick et al., 2011)

2.5.3 Vitamin D supplements and doses available in New Zealand

In New Zealand, it is current practice to prescribe vitamin D supplementation when there is a known risk factor for an individual to be vitamin D deficient (Ministry of Health, 2012a). This is due to the cost of supplementation being less than the cost to test serum 25(OH)D in the blood (Best Practice Advocacy Centre New Zealand, 2016; Bolland et al., 2012; Ministry of Health, 2012a). The form of vitamin D used in supplements in New Zealand is vitamin D_3 or cholecalciferol. The current recommendations for adults at risk of vitamin D deficiency include supplementation with the PHARMAC funded monthly tablet containing 1.25 mg (50,000 IU) of vitamin D, following a loading dose of two 1.25 mg tablets (Ministry of Health, 2012a). In severe deficiency, the loading dose is increased to one 1.25 mg tablet taken every day for ten days, followed by one 1.25 mg tablet monthly (New Zealand Formulary, 2021). For pregnant women, supplementation with the monthly 1.25 mg dose may be indicated in those with diagnosed vitamin D deficiency (Ministry of Health, 2020a). However, for women at high risk, supplementation with an oral cholecalciferol liquid containing 188 µg per ml (7,500 IU/ml) is recommended (Ministry of Health, 2020a).

PHARMAC also funds this supplement, Puria, for infants and young children, and the recommended dose is one drop per day which provides 10 µg (400 IU) (Ministry of Health, 2020a). Vitamin D supplements can also be brought over the counter and include varying doses of vitamin D up to a maximum of 1000 IU (Garg et al., 2013; New Zealand Government, 2016).

2.6 Vitamin D toxicity

Vitamin D toxicity is identified by elevated concentrations of the circulating 25(OH)D, with symptoms of intoxication found to occur when the concentration of 25(OH)D in the blood is above 375 nmol/L (Marcinowska-Suchowierska et al., 2018; Vogiatzi et al., 2014). Toxicity can cause adverse effects throughout the body, including affecting the cardiovascular system, central nervous system and the kidneys (Marcinowska-Suchowierska et al., 2018). The symptoms of toxicity in children can include hypercalcemia, which in severe cases can result in seizures and death (Taylor & Davies, 2018). Although vitamin D toxicity is rare, there has been some cases of mild symptoms of toxicity from supplementation recommendations for the treatment of rickets (Vogiatzi et al., 2014).

The proposed mechanism that prevents toxicity is the catabolic system, which is regulated by cytochrome P450 CYP24A1 (Jones, 2008). Excess 25(OH)D and $1\alpha,25(OH)_2D_3$ produced in the body is degraded by CYP24A1 via hydroxylation of the side chain and oxidation of carbon 24 (Jones, 2008). In the state of hypervitaminosis D it is hypothesised that an increase in both total 25(OH)D and free $1\alpha,25(OH)_2D3$ occurs, resulting in increased gene transcription (Jones, 2008). However, the exact mechanism that results in gene transcription from vitamin D toxicity has not been established.

2.7 Risk factors for vitamin D deficiency in early life and pregnancy

Since there are limited foods that are fortified or naturally contain vitamin D within the New Zealand food supply, most vitamin D is obtained from endogenous synthesis within the skin after exposure to UVβ radiation in sunlight. Therefore, factors that influence the synthesis of vitamin D in the skin impact individuals' risk of vitamin D deficiency.

2.7.1 Skin colour

Skin colour in humans is determined by the type and amount of melanin present in the skin (D'Orazio et al., 2013).There are two main types of melanin, eumelanin which is a dark pigment and is present in high amounts in those with highly pigmented skin and a lighter pigment, pheomelanin (D'Orazio et al., 2013). Melanin absorbs and filters UVR, blocking UVβ photons from interacting with the vitamin D precursor in the skin (Webb et al., 2018). Therefore, high levels of melanin present in the skin decrease the amount of vitamin D_3 produced from UVβ radiation. Thus, to synthesise the same amount of vitamin D_3, individuals with dark skin need at least three to five times longer exposure to UVβ compared to individuals with lighter skin (Nair & Maseeh, 2012;

Webb et al., 2018). As a result, individuals with dark skin are at a higher risk of vitamin D deficiency (Khalid et al., 2017). Additionally, the Fitzpatrick skin type scale can be used to classify skin types further by its reaction to UVR (Ravnbak, 2010).

Lower 25(OH)D concentrations have been identified in young children with darker skin types in New Zealand, with preschool-age children with darker skin found to have significantly lower mean 25(OH)D concentrations compared to lighter skinned children (Cairncross et al., 2017). Similarly, higher rates of vitamin D deficiency have also been identified in infants with darker skin in the US (N=400), with almost 50% identified with vitamin D deficiency compared to 9.7% of infants with white skin (Bodnar et al., 2007). In pregnant women from a randomly selected sample attending London district general hospital, the median serum 25(OH)D concentration in dark-skinned women (26 nmol/L) was significantly lower than women with light skin (64 nmol/L) (McAree et al., 2013). Similarly, dark skin was identified as a risk factor in women in Switzerland, with a higher prevalence of serum 25(OH)D concentrations below 50 nmol/L compared to women with lighter skin (Richard et al., 2017). In the New Zealand population, Pacific adults had significantly lower 25(OH)D, with a mean concentration of 68 nmol/L compared to 82 nmol/L in New Zealand Europeans (Rockell et al., 2008). This is an issue as individuals with darker skin in New Zealand may be at an increased risk of vitamin D deficiency.

2.7.2 Ethnicity

The New Zealand population is made up of different ethnic groups, with the main groups identified as European (70.2%), Māori (16.5%), Asian (15.1%) and Pacific (8.1%) (Statistics New Zealand, 2018). Amongst the different ethnicities in New Zealand, the prevalence of vitamin D deficiency has been identified to vary across all age groups, including newborns, toddlers, children, adolescents and adults (Delshad et al., 2019; Ekeroma et al., 2015; Houghton et al., 2010; Ministry of Health, 2012b; Rockell et al., 2005).

In New Zealand newborns (N=929), non-European ethnicity was identified as a predictor of low serum 25(OH)D concentration (Camargo et al., 2010). The lowest median serum 25(OH)D concentration was seen in Pacific newborns (32 nmol/L) and newborns ethnicity classified as “other” (31 nmol/L) (Camargo et al., 2010). Similarly, in pre-school children, Pacific and other-European ethnicities were independently associated with low vitamin D status (<50 nmol/L) (Cairncross et al., 2017). More recently, ethnicity was found to be a strong predictor of 25(OH)D status in school-aged children in Auckland, New Zealand (N=507) (Delshad et al., 2019). European children had significantly higher capillary 25(OH)D concentration compared to other ethnic groups included in the study (Delshad et al., 2019). South Asian children were found to have the highest prevalence of 25(OH)D below 50 nmol/L (62%), followed by Pacific children (34%) and Māori children (31%) (Delshad et al., 2019). Similar findings were previously seen in children and adolescents (N=1585) from across New Zealand (Rockell et al., 2005). Population based results from the 2008/9 Adult Nutrition Survey identified that Pacific adults were 2.3 times more likely to be vitamin D deficient (25(OH)D <25 nmol/L) compared to non-Pacific adults (Ministry of Health, 2012b). Additionally, Pacific and Māori women had significantly lower mean 25(OH)D concentrations compared to European women, with a mean of 46 nmol/L and 57.2 nmol/L, respectively (Ministry of Health, 2012b). This was also seen in pregnant women in New Zealand, with Māori, Pacific and 'other' ethnicities at an increased risk of vitamin D deficiency (Ekeroma et al., 2015). Pacific women were at the greatest risk, with 80% identified with 25(OH)D <50 nmol/ (Ekeroma et al., 2015).

Although there is no representative data across all age groups in New Zealand, non-European ethnic groups are at greater risk of low vitamin D status. The greatest risk is seen for Pacific individuals across all age groups. However, there is limited data available on Asian ethnic groups, which are increasing within the New Zealand population, thus risks may be underrepresented within this ethnic group.

2.7.3 Latitude

The amount of UVβ radiation in sunlight that is available for endogenous synthesis of vitamin D within the skin is determined by the solar zenith angle, which is impacted by latitude (Mendes et al., 2020). Populations living at low latitudes are exposed to greater levels of solar UVβ radiation throughout the year compared to those living in higher latitudes. In addition, those living furthest away from the equator will be exposed to even less radiation during the winter months, impacting the amount of vitamin D able to be synthesised within the skin, therefore influencing vitamin D status of the population (Wacker & Holick, 2013).

New Zealand is located in the Southwestern Pacific Ocean between the latitudes of 34ºS – 47ºS (Stats NZ Geographic Data Service, 2021). It is made up of two main Islands, the North Island, which is closer to the equator and South Island, with several cities that are at varying distances away from the equator and thus at differing latitudes. The differences in latitude between New Zealand cities where infants and young children reside has been identified to impact their vitamin D status. Children living in Auckland, which is closer to the equator and subsequently at a lower latitude (36ºS) had a mean serum 25(OH)D concentration almost 10 nmol/L higher than children living in Dunedin, which is at a higher latitude (45ºS) (Grant et al., 2009; Houghton et al., 2010). However, in pre-school aged children (N=1329) no significant difference in mean 25(OH)D concentrations was found between those living in northern and southern regions, although there was a significantly lower mean 25(OH)D in those living in central regions (39–42°S) (Cairncross et al., 2017). Therefore, further studies are required to determine the impact of different latitudes on the vitamin D status of young children in New Zealand.

2.7.4 Seasonality

The amount of UVβ radiation that reaches the earth's surface varies during different months of the year (Godar, 2007). The solar zenith angle is also influenced by seasons, with an increase in the angle during the winter months resulting in less UVβ radiation (Webb et al., 1988). Therefore, the highest rate of endogenous vitamin D synthesis occurs during the summer months, and depending on latitude, a small amount of vitamin D is produced during the winter months (Webb et al., 1988). A study conducted in Christchurch, New Zealand reported that healthy adults synthesised 1200 IU of vitamin D a day in the middle of summer compared to only 60 IU a day in the middle of winter (Livesey et al., 2007).

The vitamin D status of New Zealand infants and children is impacted by seasonality. In infants, a significant difference was found in median serum 25(OH)D concentrations between summer (75 nmol/L) and winter (21 nmol/L) (Wall et al., 2013). In toddlers, almost all (94%) children had 25(OH)D concentrations above 50 nmol/L during summer, however during the winter, nearly 80% of the children had serum concentrations less than 50 nmol/L (Houghton et al., 2010). In school-aged children, the mean serum 25(OH)D concentration (43 nmol/L) during the winter months was below 50 nmol/L, compared to the summer mean of 58 nmol/L (Rockell et al., 2005). It was also identified that three times more children had serum 25(OH)D concentrations less than 50 nmol/L during the winter months (Rockell et al., 2005).

2.7.5 Exclusive breastfeeding

Exclusive breastfeeding (EBF) is recommended by the Ministry of Health for the first six months of an infant's life in New Zealand (Ministry of Health, 2021), which aligns with the recommendations from the World Health Organisation (World Health Organisation, 2002). Breastmilk is the preferred source of nutrition for infants and has many health benefits for both the mother and infant (Victora et al., 2016). However, breastmilk is naturally a poor source of vitamin D, containing approximately 5-80 IU of vitamin D per litre of breastmilk (Bae & Kratzsch, 2018; Hollis et al., 2015). As the recommended adequate intake of vitamin D for infants is 5 µg (200 IU) a day (NHMRC, 2014), EBF infants would not meet this recommendation from breastmilk alone. In comparison, infant formula is fortified with vitamin D and contains approximately 360-520 IU/L (Paxton et al., 2013). Therefore, formula-fed infants will meet their requirements for vitamin D.

Vitamin D is transferred from the mother to the infant through breastmilk; therefore, a mother's vitamin D intake and status impacts the amount of vitamin D transferred to the infant (Hollis et al., 2015). Although mothers may have adequate 25(OH)D concentrations, vitamin D activity of breastmilk may be low if they are not exposed to adequate sunlight or consume vitamin D from food or supplements daily (Hollis et al., 2015). This is because the half-life of vitamin D is approximately 12 to 24 hours, compared to the circulating 25(OH)D, which has a longer half-life of 3 to 4 weeks (Hollis et al., 2015). Consequently, vitamin D has a lower affinity to bind to DBP, allowing it to diffuse into breastmilk more easily than 25(OH)D. Thus, to increase both circulating 25(OH)D and vitamin D concentration in milk of breastfeeding women, a daily dose of vitamin D would be required (Hollis et al., 2015). In the US, the IOM recommends lactating women supplement with 600 IU of vitamin D a day, which is the same dosage recommended for the general population (Del Valle et al., 2011). However, higher daily doses, such as 6400 IU of vitamin D, have been identified as safe and effective to improve the vitamin D content of breastmilk, infant's status and maternal status (Wagner & Hollis, 2020). In New Zealand there is no widespread recommendations for vitamin D supplementation during lactation, however the NHMRC recommends lactating women with reduced exposure to sunlight to supplement with 10 µg/day (400 IU) (Ministry of Health, 2020a).

The vitamin D status of EBF infants and toddlers receiving breastmilk has been identified in New Zealand. EBF infants aged two to three months (N=94) in Auckland had a median serum 25(OH)D concentration of 50 nmol/L (Wall et al., 2013). However, almost a quarter (24%) of infants had serum concentrations <50 nmol/L. Toddlers aged 12-22 months (N=193) who continued to receive breastmilk during complementary feeding had on average 14% lower circulating 25(OH)D compared to toddlers no longer receiving breastmilk (Houghton et al., 2010). This was thought to be linked to the high prevalence of vitamin D insufficiency in mothers, therefore providing low amounts of vitamin D through their breastmilk.

2.8 Vitamin D in pregnancy

During pregnancy vitamin D metabolism is altered and the concentration of circulating 1,25$(OH)_2$D dramatically increases (Lehmann & Meurer, 2010). Although the role of this is not clear, it is thought to be related to immunomodulatory functions during pregnancy (Hollis & Wagner, 2017; Lehmann & Meurer, 2010). Additionally, vitamin D deficiency during pregnancy changes maternal gene expression and has been associated with the development of complications during pregnancy (Hollis & Wagner, 2017).

2.8.1 Requirements during pregnancy

Optimal maternal vitamin D status is essential and deficiency can result in adverse health outcomes for the developing fetus and mother. Low vitamin D status has been associated with an increased risk of complications during pregnancy, including gestational diabetes mellitus (GDM) (Hu et al., 2018) and preeclampsia (Akbari et al., 2018).

During pregnancy 25(OH)D crosses the placenta from the mother to the developing fetus, therefore the vitamin D status of the fetus is determined by the mother (Wheeler et al., 2018). Maternal vitamin D status is especially important during the third trimester, when mineralisation of the fetal skeleton peaks and large amounts of 25(OH)D crosses the placenta (Wheeler et al., 2018). Sufficient maternal vitamin D status is also important to ensure the infant has adequate vitamin D stores at birth (Grant et al., 2014).

The Australia and New Zealand Nutrient Reference Values state an adequate intake (AI) of 5 µg (200 IU) of vitamin D a day for pregnant and lactating women (NHMRC, 2014). However, this recommendation is for women with sufficient vitamin D status, therefore would not provide enough vitamin D to replete stores in deficient or insufficient women. There is currently no recommendation for widespread supplementation with vitamin D during pregnancy in New Zealand. The new MoH Companion Statement states supplementation with vitamin D is unlikely to cause harm during pregnancy and may be beneficial to ensure sufficient maternal vitamin D status to support foetal development (Ministry of Health, 2020a). It recommends that high-risk women consider supplementation with the oral cholecalciferol supplement containing 10 µg (400 IU) per drop, which is subsidised for pregnant women at high-risk of deficiency (Ministry of Health, 2020a). It also recommends that low-risk pregnant women may benefit from supplementing with vitamin D throughout their pregnancy, particularly in the third trimester, at a dose between 10 µg (400 IU) – 15 µg (600 IU) (Ministry of Health, 2020a). Supplementation with the subsidised monthly vitamin D supplement containing 1.25 mg (50,000 IU) is not recommended for use in pregnancy unless vitamin D deficient, as there is limited evidence on safety for use in those that are vitamin D replete.

2.8.2 Pregnancy complications associated with vitamin D deficiency

Vitamin D deficiency has been associated with an increased risk of developing GDM during pregnancy (Alzaim & Wood, 2013; Hu et al., 2018). GDM is a pregnancy complication that occurs as a result of impaired glucose tolerance and can cause adverse health outcomes for both the mother and infant (Moyer & Force, 2014). The association between vitamin D status and GDM risk has been observed in pregnant women living in Australia and New Zealand (Wilson et al., 2018). Women with higher serum 25(OH)D concentrations had a 50% reduction in the risk of developing GDM during their pregnancy (Wilson et al., 2018). Although evidence is still emerging on how vitamin D modulates glucose homeostasis, VDR is present on 1-alpha-hydroxylase and within pancreatic beta-cells (Hu et al., 2018; Ojo et al., 2019; Rizzo et al., 2019; Yoon, 2017). The role of vitamin D supplementation during pregnancy to prevent the development of GDM remains unclear (Hu et al., 2018). However, a systematic review and meta-analysis of women with GDM found that supplementation with vitamin D influenced insulin sensitivity and blood glucose control (Ojo et al., 2019). Although the small sample of studies included impacts the validity of these findings, thus more research is needed to consolidate the role of vitamin D supplementation in controlling blood glucose concentrations in GDM (Ojo et al., 2019).

Another pregnancy complication associated with vitamin D deficiency is preeclampsia. Preeclampsia can affect multiple body systems and results in adverse maternal and neonatal outcomes, which in severe cases can be fatal (Mirzakhani et al., 2016). Although the cause of preeclampsia has not been established, abnormal development of the placenta may be the underlying cause of the disease (Fisher, 2015). It has been hypothesised that vitamin D may play an important role in the integrity and function of the placenta (Liu & Hewison, 2012). Although the development of preeclampsia can also be influenced by body mass index, race, and parity, after adjusting for these confounders, pregnant women who were vitamin D deficient at <26 weeks had an increased risk of developing severe preeclampsia (Bodnar et al., 2014). More recently, a meta-analysis of 23 studies found that low vitamin D status (<50 nmol/L) was significantly associated with the risk of preeclampsia (Akbari et al., 2018).

2.9 Vitamin D in early life

Vitamin D is an essential nutrient in early life and its vital role in normal bone development is well established. More recently, vitamin D deficiency has been linked to non-skeletal conditions, including respiratory diseases, allergic diseases and autism spectrum disorder.

2.9.1 Preterm infants

Prematurity is the term for infants born less than 37 weeks' gestation and can result in serious short and long term complication for the infant (Tucker & McGuire, 2004). Prematurity is further classified into very preterm, born less than 32 weeks' gestation and extremely preterm, born less than 28 weeks' gestation (Tucker & McGuire, 2004). Preterm infants are at an increased risk of low vitamin D status as they were previously dependent on obtaining vitamin D from maternal stores, they may experience feeding difficulties after birth, and lack exposure to sunlight during hospitalisation (McCarthy et al., 2013; Monangi et al., 2014).

Supplementation of preterm infants with 400 IU has been found to maintain adequate vitamin D status (Ambalavanan et al., 2003). However, there is a lack of studies available in preterm infants to guide recommendations (McCarthy et al., 2013). The IOM recommends an intake of 10 µg (400 IU) a day from birth until one year of age (McCarthy et al., 2013). Whereas the European Society for Paediatric Gastroenterology, Hepatology and Nutrition (ESPGHAN) has specific recommendations for preterm infants, including supplementation with 800 IU – 1000 IU a day (Agostoni et al., 2010).

In New Zealand, the clinical guidelines for preterm infants in the neonatal intensive care unit (NICU) at Starship Child Health include supplementation of 400 IU to 1000 IU of vitamin D per day, which is based on the ESPGHAN guidelines (Agostoni et al., 2010; Starship Child Health, 2021). The fully funded vitamin D supplement, Puria, is used and provides 400 IU via one drop and can be administered by dropping into an infant's mouth or placing it on the mother's breast when the infant is breastfeeding (Starship Child Health, 2021).

2.9.2 Vitamin D and bone health

Vitamin D is required for bone mineralisation, as vitamin D regulates the intestinal absorption of calcium alongside parathyroid hormone (Pettifor & Prentice, 2011). Calcium absorption in the intestines occurs through passive and active transport (Pettifor & Prentice, 2011). Active transport is the main form of absorption, accounting for 60-80% of calcium absorption and requires vitamin D to transport calcium across mucosal epithelia cells (Pettifor & Prentice, 2011). Passive transport does not require vitamin D; however, it is only estimated to account for 10-15% of calcium absorption (Pettifor & Prentice, 2011).

Severe vitamin D deficiency results in the inability to maintain serum calcium within the normal ranges, resulting in calciopenic rickets (Pettifor, 2005). Rickets is a bone disorder that develops due to failure or delay in the mineralisation of the growth plate of developing bones, resulting in poor growth and skeletal abnormalities (Prentice, 2013; Shore & Chesney, 2013). One of the first indications of severe vitamin D deficiency in infants is hypocalcaemia, which in severe cases results in convulsions and hypocalcemic cardiomyopathy, which can be life-threatening for the infant (Yilmaz et al., 2018). Rickets has re-emerged in recent years in infants and children in New Zealand. Over a three-year period from 2010 to 2013, 58 children were identified to have the condition by the New Zealand Paediatric Surveillance Unit (Wheeler et al., 2015). The incidence of rickets was higher in children under the age of three, with 10.5 cases per 100,000 children compared to 2.2 cases per 100,000 in older children up to 15 years of age (Wheeler et al., 2015). These figures indicate the importance of increasing parents' knowledge of vitamin D to prevent more infants and young children in New Zealand from being diagnosed with this preventable condition.

2.9.3 Vitamin D and respiratory health

Respiratory tract infections (RTIs) are a significant cause of morbidity and mortality in children under five years of age globally, with the highest rates of RTIs occurring in the first year of life (Nair et al., 2013). Low levels of vitamin D has been associated with an increased risk of RTIs in early childhood (Esposito & Lelii, 2015)**.** This link was first discovered when infants and children with rickets were found to have higher rates of RTIs (Najada, 2004).

There are several proposed protective effects of vitamin D in the prevention of respiratory infections. It is hypothesised that vitamin D influences the production of antibodies within the body and is used by macrophages to kill bacteria (Bergman et al., 2013; Charan et al., 2012). Recent findings from the Growing Up in New Zealand study (N=1920) identified that infants with low vitamin D status (<50 nmol/L) at birth were twice as likely to be admitted to hospital with acute respiratory infections (ARIs) compared to those with optimal vitamin D status (Saraf et al., 2021). In addition, vitamin D supplementation has been found to be protective against respiratory infections. An individual patient data (IPD) meta-analysis of 10,933 participants aged 0-95 years involved in 25 different studies found that vitamin D supplementation reduced the risk of ARIs in all participants (Martineau et al., 2017). Additionally, greater protective effects were observed in individuals with low vitamin D status at baseline (<25 nmol/L) receiving daily or weekly supplementation compared to bolus supplementation (Martineau et al., 2017).

Other respiratory conditions, such as asthma, have been increasing amongst children worldwide, with 13% of children aged 2-14 years in New Zealand taking asthma medication (Health Quality & Safety Commission New Zealand, 2020). Low maternal vitamin D status has been associated with a greater risk of adverse respiratory outcomes for infants, including the development of childhood wheeze and asthma (Jensen et al., 2019). Vitamin D supplementation during pregnancy and in early life influences the risk of developing asthma and recurrent wheeze. Infants aged 18 months and below (N=185) whose mothers received supplementation during pregnancy and were supplemented after birth had significantly fewer visits to a primary care doctor for asthma compared to a control group (Grant et al., 2016). Similar results were seen in pregnant women at high risk of having a child with asthma (N=806) (Litonjua et al., 2016). Lower incidence of asthma and recurrent wheeze was observed in offspring of women supplemented with 4000 IU of vitamin D during pregnancy (Litonjua et al., 2016). However, results from seven randomised control trials on vitamin D supplementation in children found inconsistent results on reducing the risk of asthma wheeze attacks, control of symptoms, medication use along with acute healthcare visits (Stefanidis et al., 2019). Although these findings need to be interpreted with caution as the findings may be impacted by the relatively small sample sizes and varying quality of the studies.

2.9.4 Vitamin D and allergic disease

The rates of eczema in young children in New Zealand are amongst the highest globally (Asher et al., 2006). Eczema usually develops within the first year of life and often presents as the first symptom of allergic disease (Palmer, 2015). Vitamin D has been found to have a regulatory role in both the immune system and skin barrier function, dysregulation of both of these results in the development of eczema (Palmer, 2015).

The rate of allergic diseases amongst infants and children has also been increasing and affects approximately 8% of infants and children (Matsui et al., 2019). The development of food allergies usually occurs in the first year of life. It has been hypothesised that vitamin D deficiency impacts the integrity of the intestinal barrier, allowing small amounts of food proteins to come in contact with the immune system, upregulating the production of the antibody immunoglobulin E (IgE) (Vassallo & Camargo, 2010). The concentration of IgE in the umbilical cord blood of infants was previously identified to fluctuate seasonally, peaking during the winter months (Matsui et al., 2019). Similarly, the rate of food sensitisation has been observed to peak in children born in winter (Matsui et al., 2019). This is thought to be linked to the decrease in serum 25(OH)D concentration during the winter months, leading to increased rates of vitamin D deficiency and insufficiency during this time. In contrast, high 25(OH)D concentrations in preschool children in New Zealand (N=1350) were associated with an increased prevalence of food allergies reported by parents (Cairncross et al., 2016). However, the study included a small number of children with food allergies diagnosed by a doctor (N=153) and relied on parental reports, thus further research is required to determine the relationship between vitamin D and the development of allergies in young children.

2.9.5 Vitamin D and autism spectrum disorder

Autism spectrum disorder (ASD) is a neurodevelopmental disorder characterised by impaired communication and behavioural deficits (Bhat et al., 2014). ASD is usually identified within the first three years of life but can be detected later in life in some individuals. Autism New Zealand reports the prevalence of ASD in New Zealand is similar to the rates seen in the US, with 1 in 59 individuals affected by ASD (Baines & Yates, 2018; Baio et al., 2018).

Low vitamin D status has been hypothesised as a risk factor in the development of ASD (Kocovska et al., 2012). Vitamin D is neuroprotective in the developing brain by influencing antioxidant activity, neuronal calcium homeostasis, neurotransmitter regulation and cell proliferation and differentiation (Máčová et al., 2017). Although the exact biological mechanisms have not yet been established, vitamin D receptors (VDR) and the 1-alpha-hydroxylase enzyme have been found in several regions of the central nervous system, including the brain (Eyles et al., 2005).

Vitamin D supplementation has been found to improve core symptoms of ASD in children. In New Zealand, children with ASD aged 2.5 to 8 years (N=117) had improvements in core symptoms of ASD when supplemented with vitamin D in combination with omega-3 long-chain polyunsaturated fatty acids (Mazahery et al., 2019). However, vitamin D supplementation alone did not result in statistically significant improvements in symptoms of ASD, although significant improvements in social participation were observed (Mazahery et al., 2019). These findings along with inconsistent results from other studies indicate that further research is needed to determine the effect of vitamin D supplementation in ASD.

2.10 Vitamin D knowledge

To ensure infants and young children have optimal vitamin D status, increased knowledge and awareness amongst parents of the importance of vitamin D for health is required. There is limited research available on parents' level of knowledge around vitamin D across the world, including New Zealand.

2.10.1 Current knowledge of parents regarding vitamin D

The small number of studies that have assessed knowledge within this population group is summarised in Table 2.2. From international studies, parents' overall level of knowledge regarding vitamin D is poor. There appears to be a lack of understanding amongst parents on the importance of vitamin D for their child and its functions within the body. A quarter of parents in the UK, Poland and Malaysia reported they did not know why vitamin D was important for their child or they were not aware of the functions of vitamin D and its role in health (Day et al., 2019; Hussein et al., 2018; Zadka et al., 2018). Additionally, 50% of mothers (N=783) in Poland were unable to correctly identify dietary sources of vitamin D (Zadka et al., 2018). Similarly, almost a quarter (23%) of mothers in Ireland reported not knowing a source of vitamin D (Toher et al., 2014). Knowledge of risk factors for vitamin D deficiency is also lacking in this population group. In the UK, many parents did not know their child may be at risk of vitamin D deficiency or were unaware of the risk factors (Drury et al., 2015; Sharma et al., 2011).

The level of vitamin D knowledge has been identified to impact vitamin D status and health. Children and their parents in Saudi Arabia who were healthy had greater knowledge of vitamin D and its health implications compared to children who were vitamin D deficient (Alshamsan & Bin-Abbas, 2016). Additionally, parents with higher education levels had greater awareness around the importance of vitamin D and consequences of deficiency (Robinson et al., 2013; Zadka et al., 2018).

Table 2.2: Studies of vitamin D knowledge of parents of infants and young children

Author and country	**Study cohort**	**Method of assessing knowledge**	**Main findings**	**Limitations**
Al-Qudah (2021) Jordan (Al-Qudah et al., 2021)	783 mothers of children aged 0-6 years	Online questionnaire	Almost all participants (93.9%) were aware that vitamin D is essential for healthy bones and teeth. Most (89.1%) identified sunlight as the main source of vitamin D, with almost all (98.5%) identifying low sun exposure as a risk factor for deficiency. However, only 23.5% identified skin colour impacted synthesis. A third (34.1%) incorrectly stated	High education level of participants, voluntary participation in the online questionnaire.

			that breastmilk contains a large amount of vitamin D.	
Day (2019) United Kingdom (Day et al., 2019)	192 parents of children aged 0-2 years	Online questionnaire (N=192) and focus groups (N=18)	Almost a quarter (23%) did not know why vitamin D was important for health. Parents involved in focus groups were largely unaware of the recommendations for vitamin D intake and supplementation.	Participants were self-selected sample and had higher education and socioeconomic status compared to the national average.
Zadka (2018) Poland (Zadka et al., 2018)	783 mothers of children in year 1-6 attending primary school in Central Poland	In person paper-based questionnaire with open-ended questions	The majority (74.1%) of mothers reported knowing at least one of the functions of vitamin D, almost half (49.7%) could identify food sources. Place of residence and education level had a statistically significant impact on knowledge.	Only conducted in one area in Poland, where health is viewed positively amongst parents and adolescents.
Hussein (2018) Malaysia (Hussein et al., 2018)	344 parents of children attending a paediatric dental clinic	In person paper-based questionnaire	Almost two-thirds of parents reported they had heard of vitamin D, however 25% of parents did not know the role of vitamin D in health and 18% did not know the risk factors for deficiency.	Only conducted in one area in Malaysia.
Alshamsan (2016) Saudi Arabia (Alshamsan & Bin-Abbas, 2016)	100 healthy and 100 vitamin D deficient children aged 2-17 years (and their parents if child <10 years old)	Interviews using multiple choice and short answer questions (Interviews conducted with the parent of the child if < 10 years old)	Healthy children (or their parents') had greater knowledge of vitamin D, sources of vitamin D and its health implications compared to children who were vitamin D deficient (or their parents').	Small sample size, children < 10 years of age requiring parents to answer questions and some participants were not able to read or write.

Drury (2015) United Kingdom (Drury et al., 2015)	203 parents of children 6 months to 5 years attending a hospital clinic	In person paper-based questionnaire	Most (85.7%) of parents were not aware of the vitamin D recommendations in the UK. Almost half (49.3%) of parents were not aware of the benefits of vitamin D for their child.	Participants only included children attending a hospital clinic.
Toher (2014) Ireland (Toher et al., 2014)	116 pregnant women of different ethnicities in Ireland	Interview assisted paper-based questionnaire	The majority (70%) of women agreed they had insufficient knowledge of vitamin D, with 23% reporting they did not know any sources of vitamin D.	Only a small number of participants were included and all lived within Irelands capital city.
Robinson (2013)* Northern Ireland (Robinson et al., 2013)	47 parents of children <5 years	Online questionnaire	Three quarters of parents reported not receiving advice on vitamin D from health professionals and 69% were not aware of the vitamin D supplementation scheme in Northern Island.	Pilot study and small sample size of participants.
Sharma (2011) # United Kingdom (Sharma et al., 2011)	92 parents of children attending a paediatric outpatient clinic and 24 healthcare staff	In person paper-based questionnaire	Around 20% of participants were unable to identify any sources of vitamin D and more than two thirds (39%) were unaware of risk factors. The majority of participants did not know vitamin D supplementation recommendations.	Only abstract available and participants only included parents of children attending a hospital clinic and healthcare staff.

** Pilot study*

 # Abstract only

2.10.2 Sources of information available to parents

There are many sources of information on vitamin D available to parents, including advice from health professionals, media, books, friends and family and the internet. Health professionals appeared to be the greatest source of information for parents in the UK (Drury et al., 2015). Although this is not the case in Malaysia, only 17.7% of parents reported hearing about vitamin D from a health professional (physician/ dentist/ nurse), with the main source of information reported as newspapers and magazines (Hussein et al., 2018).

Although sources of information on vitamin D may differ, many parents are not aware of the current recommendations on vitamin D for their child. The majority of parents (85.7%) in the UK were not aware of the recommendations set by the Department of

Health regarding vitamin D supplementation (Drury et al., 2015). This lack of knowledge appears to remain present, with 80% of parents in 2019 reporting they wanted more information on vitamin D requirements for their child (Day et al., 2019). Parents reported wanting more clear guidelines that were simple and easy to read and provided regularly at routine appointments (Day et al., 2019). Similarly, almost all parents in Malaysia (91.6%) reported wanting more information on the importance of vitamin D for their child (Hussein et al., 2018). It appears that information provided from health professionals is preferred within this population group (Day et al., 2019; Hussein et al., 2018).

2.11 Sun exposure in New Zealand

New Zealand has very high levels of UVR due to the higher solar zenith angle, lower ozone levels, cleaner air and its geographical latitude (Wright et al., 2007). As a result, New Zealanders are exposed to more UVβ radiation, which is required to synthesise vitamin D endogenously in the skin.

2.11.1 Sun exposure recommendations

New Zealand has one of the highest global rates of skin cancers, which develop because of excessive UVR (McKenzie, 2017; Whiteman et al., 2016). UVR is one of the major components of sunlight, which covers the wavelength spectrum from 100-400 nm (Narayanan et al., 2010). UVR is divided into three bands, including ultraviolet α (UVα), ultraviolet β (UVβ) and ultraviolet C (Narayanan et al., 2010). Most of the UVR that reaches the earth is UVα rays, with the majority of UVβ and UVC rays absorbed by ozone as it passes through the atmosphere (Narayanan et al., 2010). UVβ rays, which are responsible for the synthesis of vitamin D in the skin, are further filtered by standard glass (Tuchinda et al., 2006). Therefore, vitamin D cannot be synthesised through windows.

To address the high rates of skin cancers in New Zealand, there is a strong focus on sun protection, including applying sunscreen, wearing clothing and avoiding sun exposure during peak UV levels (Health Promotion Agency, 2021). However, these practices put the New Zealand population at risk of having suboptimal levels of vitamin D. The current sun protection messages produced by the Health Promotion Agency include “Slip, Slop, Slap” and recommend individuals protect themselves outside from September to April and all year round on the water, up mountains or around reflective surfaces such as snow or ice (Health Promotion Agency, 2021).

Current recommendations for the application of sunscreen include when the ultraviolet index (UVI) is three or greater (Whiteman et al., 2019). The average daily maximum UVI for four cities across New Zealand is included in the Sunscreen Summit Policy Group position statement (Whiteman et al., 2019). For both Auckland and Wellington, UVI drops below three in May, but in September, Auckland’s UVI increases to three, whereas the UVI in Wellington remains below three until October (Whiteman et al., 2019). For the southern cities, Christchurch and Invercargill, between the months of April to September, the average daily UVI is less than three (McKenzie, 2017). It is also recommended that the application of sunscreen should be done prior to exposure of sunlight in planned outdoor activities and reapplied as required (Whiteman et al., 2019). However, the use of sunscreen reduces the absorption of both UVα and UVβ radiation and subsequently decreases the synthesis of vitamin D within the skin (Paxton et al., 2013).

2.11.2 Current attitudes and behaviours towards sun exposure

There is limited information available on the attitudes and behaviours of New Zealanders towards sun exposure. In women of South Asian origin living in New Zealand (N=235), the majority reported avoiding sun exposure due to concerns regarding the strength of the sun in New Zealand and the risk of skin cancer (von Hurst et al., 2010). However, almost half of the women reported that if they were not concerned about skin cancer, they would spend more time in the sun (von Hurst et al., 2010). In addition, typical behaviours such as working for long hours indoors contributed to an avoidance of the sun (von Hurst et al., 2010).

The attitudes and behaviours towards sun exposure of parents of infants and young children in New Zealand were assessed in a survey over ten years ago (unpublished). Although there has been increased public health messaging by the Ministry of Health on vitamin D and sun exposure since then, the strong stance on sun protective messages by the Health Promotion Agency continues to be influential. With the increased understanding of conditions associated with low vitamin D status in childhood, greater understanding of the impact of these public health messages on parents is required. Due to a survey on parents' knowledge, attitudes and behaviours towards vitamin D and sun exposure conducted over ten years ago being unpublished and the lack of any subsequent studies in this area in New Zealand, there is a gap in the evidence.

Chapter 3. Research study manuscript

Changes in knowledge, attitudes and behaviours towards vitamin D and sun exposure of parents of infants and young children in New Zealand.

3.1 Abstract

Background: Vitamin D deficiency can have serious health implications for infants and young children. Therefore, parents' knowledge about vitamin D and sun exposure is important to ensure optimal vitamin D status during childhood.

Aim: To identify the impact of the Ministry of Health (MoH) statements on parents' vitamin D and sun exposure knowledge, attitudes and behaviours and investigate their sources of information.

Methods: This ecological study recruited parents of infants and young children throughout New Zealand at two time points - 2009 and 2021 to compare knowledge, attitudes and behaviours and assess the impact of the MoH statements. An online questionnaire was administered to parents. Inclusion criteria included: youngest child <5 years, living in New Zealand, and understanding written English.

Results: The analysis included 9,834 parents of children five years of age and under (2009 N=8,032, 2021 N=1,802). A similar percentage (63.1%, 61.3%) of parents identified the role of vitamin D in bone health, with greater awareness of its role in immunity in 2021 (29.1%, 48.2%). Most parents lacked knowledge of high-risk factors for deficiency, including exclusive breastfeeding (98.1, 95.1%) and darker skin colour (92.9%, 77.5%). Health professionals were not the main source of information to parents (15.8%, 24.8%) and low rates of advice on supplementation and sun exposure were reported. However, 60.2% reported health professionals or the MoH as their preferred source of information on vitamin D, followed by the media, including social media (24.5%). Safe sun exposure practices were performed frequently in children during the summer, with concerns about skin cancer high (86.5%, 83.3%). Additionally, 72.4% and 78.4% found vitamin D and sun exposure recommendations confusing because of skin cancer prevention messages.

Overall, the impact of the MoH statements and subsequent public health messaging on parents' knowledge has been minimal. To ensure public health information is communicated effectively to parents, the MoH and health professionals could utilise emerging tools, including social media, to improve parents' knowledge.

Key words: vitamin D; sun exposure; knowledge; attitudes; behaviours; parents; infants; children; New Zealand

3.2 Introduction

Low vitamin D status during infancy and childhood is a re-emerging public health issue worldwide (Palacios & Gonzalez, 2014). Consequences of low vitamin D status in early life has health implications for the developing fetus and mother, infants and young children and may result in long term health effects in adulthood (Lucas et al., 2008). It has been well established that vitamin D has an essential role in bone mineralisation by regulating calcium and phosphorus homeostasis (Pike & Christakos, 2017). This is particularly important in early life when the skeleton is undergoing rapid growth (Pettifor & Prentice, 2011). Severe deficiency in vitamin D during this time can result in rickets, which has both skeletal and non-skeletal manifestations including bone abnormalities, poor growth and motor delays, hypocalcaemic seizures and cardiomyopathy (Munns et al., 2016). This preventable condition continues to be a significant issue across the world, with rickets still identified amongst infants and children in New Zealand (Creo et al., 2017; Wheeler et al., 2015). Emerging evidence has linked low vitamin D status with extra-skeletal conditions during infancy and childhood, including respiratory and allergic diseases and neurodevelopmental disorders (Ginde et al., 2009; Kocovska et al., 2012; Saggese et al., 2015).

Most vitamin D is obtained from endogenous synthesis within the skin after exposure to ultraviolet β (UVβ) radiation (Nowson et al., 2012). However, excessive exposure to ultraviolet radiation (UVR) is the main cause of skin cancers, putting New Zealanders at an increased risk due to high solar UVR levels (Gage et al., 2018; Wright et al., 2007). Consequently, New Zealand has one of the highest rates of skin cancers globally (Whiteman et al., 2016). Therefore, the promotion of sun safe messages has taken precedence over information on vitamin D, with campaigns such as 'Be SunSmart' and 'Slip, Slop, Slap' promoted to New Zealanders for many years (Signal et al., 2020). In 2012, the Ministry of Health (MoH) released a Consensus Statement on Vitamin D and Sun Exposure in New Zealand, followed by a Companion Statement for Pregnancy and Infancy in 2013 (Ministry of Health, 2012a, 2013, 2020a). This was revised in 2020 and lists the new funded vitamin D supplement for babies and pregnant women at high risk of deficiency (Ministry of Health, 2020a). However, there remains limited public health messaging and educational resources available to parents in New Zealand on the importance of vitamin D and safe sun exposure and the benefits of supplements for high risk groups. In addition, other factors may increase the risk of deficiency, including residing at higher latitudes, winter/spring season, darker skin colour, non-European ethnicity and, particularly for infants and young children, breastfeeding practices (Ekeroma et al., 2015).

The vitamin D status of infants and young children in New Zealand has been influenced by these risk factors, with lower vitamin D status observed among children living in southern cities, during the winter months, from non-European ethnicities, and in breastfed infants (Cairncross et al., 2016; Camargo et al., 2010; Delshad et al., 2019; Grant et al., 2009; Houghton et al., 2010; Wall et al., 2013). In order to ensure optimal vitamin D status during infancy and childhood in New Zealand, there needs to be sufficient knowledge amongst parents about the importance of vitamin D in early life and risk factors for deficiency. There is currently limited information available on parents' level of knowledge on vitamin D and sun exposure behaviours related to vitamin D synthesis, especially in New Zealand. Thus, the aim of the current study is to identify parents' knowledge, attitudes and behaviours towards vitamin D and sun exposure. This study hopes to identify parents current and preferred sources of information and provide suggestions to improve the delivery of public health information to parents in New Zealand.

3.3 Methods

Study design

The current study is an ecological design presenting data collected in 2009 and 2021 on the knowledge, attitudes and behaviours towards vitamin D and sun exposure of parents of infants and young children in New Zealand. Participation in the 2021 questionnaire will not likely include individuals that participated in the 2009 questionnaire. A low-risk ethics notification was approved by the Massey University Human Ethics Committee, Northern A.

Participants

Participants from the 2009 questionnaire were recruited through ReachMe, a marketing website popular with parents in New Zealand at the time. Participants in the 2021 questionnaire were recruited through Facebook groups for parents of young children across New Zealand. This has proven to be a successful platform to promote participation in research within the target group. Both questionnaires in 2009 and 2021 had the same inclusion criteria, and participants were screened to ensure they met the criteria before participation. The inclusion criteria included having a child five years of age or younger, currently living in New Zealand and able to understand written English. Participants were excluded from the analysis if they did not meet the criteria. Prior to participation in the questionnaires, consent was obtained from all participants.

A minimum sample size of 350 participants was calculated in order to achieve a confidence interval of ±5%. The final sample sizes in 2009 and 2021 respectively were determined by the number of parents who participated in the questionnaire over the specified time period and met the inclusion criteria.

Online questionnaire

The online questionnaire used in 2021 was re-administered from 2009 (Appendix A). This allows for a comparison to be made over the two time points. The original questionnaire was developed following a comprehensive review of the literature and identification of guidelines, and a round table consultation with experts in the nutrition field. Once completed, an expert panel reviewed the questionnaire, and it was tested in a sample of mothers in New Zealand to ensure it was suitable for use within this population group. Following the development of the questionnaire in 2009, new guidelines and recommendations on vitamin D and sun exposure have been published in New Zealand by the Ministry of Health. To address this, additional questions were included in the 2021 questionnaire and include; "have you seen the MoH resources on vitamin D and sun exposure for pregnancy and your baby", "do you know the current recommendations for vitamin D and sun exposure?" and "do you know there is a funded vitamin D supplement available for babies at risk of vitamin D deficiency?".

The updated questionnaire consisted of 51 questions and took approximately 10-15 minutes to complete.

The questionnaire was categorised into five sections, including participants' characteristics, general vitamin D and sun exposure knowledge within the New Zealand context, participants' sources of information, attitudes towards vitamin D and sun exposure and typical behaviours related to pregnancy and youngest child. The majority of questions were single answer only and forced response. A small number of questions allowed participants to write a text response, including where 'other' was an option, with participants asked to provide further information. Additional answer responses were included for some questions in the 2021 questionnaire, for example, when assessing participants sources of information, social media was added as an option due to the increase in popularity of this platform over the past decade.

Participants characteristics were determined using a mixture of free text, multiple choice answers and multiple response sets, for example when selecting ethnicity. For participants who selected more than one ethnicity, prioritisation was achieved according to the Ministry of Health ethnicity code tables (Ministry of Health, 2010). For skin type, participants were presented with the following options according to the Fitzpatrick skin type scale; 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. Questions used to assess participants' knowledge were primarily statements which participants were provided with multiple choice answers that they could select, for example; good, moderate, poor or unsure, and true, false or unsure. Additionally, some questions required participants to list answers. Attitude was assessed with statements, and participants were able to select whether they agree, disagree or felt neutral towards the statement. Typical behaviours were assessed by asking how frequently sun protective behaviours were performed, with participants able to select one of the following; always, usually, sometimes, rarely or never.

Data and statistical analysis

Data from the 2009 questionnaire was collected via SurveyMonkey over three months from May to July. Data was exported to Microsoft Excel and was cleaned and stored securely. The 2021 data was collected online through Qualtrics over two months from May to June. Data was exported from Qualtrics to Microsoft Excel for cleaning. Data was analysed using IBM SPSS for Windows, Version 27 (IBM Crop, Armonk NY). Descriptive statistics were conducted for responses to the questionnaire. The proportion of responses to each question was determined and displayed as N (%). Questions with missing data were reported and valid percentages presented, therefore response N did not equal sample size N for these questions. If participants' data was missing for a whole section in the questionnaire, their data was excluded from the entire analysis.

3.4 Results

Participant Characteristics

Responses from 9,834 parents of infants and young children from across New Zealand were included in this study. In 2009, the initial number of responses to the online questionnaire was 9,220, however 1,188 were excluded as they did not currently have a child under five years of age or completed the questionnaire multiple times. In 2021, the initial number of responses to the questionnaire was 2,418, with 616 participants removed as they did not consent to participate, their youngest child was over the age of five, or they did not complete all five sections of the questionnaire. Responses from 8,032 participants in 2009 and 1,802 were presented in this study.

The mean±SD age of participants was similar in both populations; 31.7±5.51 years in 2009 and 33.4±5.15 years in 2021. Most participants (86.4% in 2009, 75.9% in 2021) reported their youngest child was under three years of age. University or professional qualification were held by 58.6% and 78.3% of participants in 2009 and 2021 respectively. Ethnicity and maternal and child skin types were also similar in both groups (Table 3.1). Both groups' rates of breastfeeding were comparable, with 92.2% and 91.1% of parents reporting breastfeeding their youngest child to some degree in 2009 and 2021, respectively.

Table 3.1: Participant characteristics

	2009 N % (N=8,032)		**2021 N % (N=1,802)**	
Age, years[#]	31.73 (5.51)		33.39 (5.15) [∂]	
Age of youngest child				
<1 years old	3,507 (43.7)		543 (30.1)	
1–3 years old	3,428 (42.7)		826 (45.8)	
3–5 years old	1,097 (13.6)		433 (24.0)	
Ethnicity[Δ]				
NZ European	5,889 (73.3)		1,256 (69.7)	
Māori	817 (10.2)		209 (11.6)	
Pacific	215 (2.7)		38 (2.1)	
Other	1,089 (13.6)		299 (16.6)	
Highest level of education[†]				
Secondary school	2,170 (27.0)		249 (13.8)	
University/ professional qualification	4,706 (58.6)		1,410 (78.3)	
Trade or technical certificate	868 (10.8)		128 (7.1)	
Other	239 (3.0)		6 (0.3)	
Maternal[Ø] ***and youngest child's skin type***[∞]				
Type I	1,467 (18.3)	1,339 (16.7)	384 (21.3)	350 (19.4)
Type II	3,870 (48.2)	3,132 (39.0)	850 (47.2)	951 (52.8)
Type III	2,335 (29.1)	1,533 (19.1)	466 (25.9)	406 (22.5)
Type IV	342 (4.3)	258 (3.2)	88 (4.9)	81 (4.5)
Type V	18 (0.2)	12 (0.1)	6 (0.3)	6 (0.3)

[#] *Mean (SD)*
[∂]*6 participants did not answer*
[Δ] *22 participants did not answer in 2009*

† 49 participants did not answer in 2009, 9 participants did not answer in 2021
Ø 8 participants did not answer in 2021
∞ 1 participants did not answer in 2009, 8 participants did not answer in 2021
**21.9% of participants in 2009 were unsure of their youngest child's skin type*

Knowledge of the role and sources of vitamin D

Participants in both groups correctly identified that vitamin D is needed for healthy bones, however the 2021 group were more aware of its role in immunity (29.1% in 2009, 48.2% in 2021. Most parents correctly identified sunshine as the most important source of vitamin D, but a small proportion from each group incorrectly chose food sources or supplements. Confusion about breastmilk as a source of vitamin D was seen, with only a small proportion of both groups correctly identifying it as a poor source (Table 3.2).

Knowledge of risk factors for vitamin D deficiency

Only a small proportion in both groups identified exclusive breastfeeding as a high-risk factor (1.9% in 2009, 4.9% in 2021). Darker skin colour was identified as a high-risk factor by a higher proportion of participants in 2021 (7.0% in 2009, 22.5% in 2021). Additionally, participants in 2021 had greater understanding that babies born to vitamin D deficient mothers and children not regularly exposed to sunlight were at a high risk of vitamin D deficiency (Table 3.2).

Table 3.2 Parent's knowledge about sources of vitamin D and risk factors for vitamin D deficiency in infants and toddlers

		Participant's response N (%)	
		2009	**2021**
Overall role of vitamin D (multiple answers)			
Healthy bones		5,067 (63.1)	1,104 (61.3)
Immunity		2,334 (29.1)	868 (48.2)
Unsure/ incorrect		3,677 (46.2)	916 (51.9)
Single most important source of vitamin D			
Sunshine (manufactured in the skin)		7,140 (88.9)	1,694 (94.0)
Natural and fortified foods		753 (9.4)	84 (4.7)
Supplements		112 (1.4)	22 (1.2)
Other		28 (0.3)	2 (0.1)
Correctly identified good and poor sources of vitamin D for infants and toddlers			
Breastmilk[∂]	Poor source	309 (3.9)	217 (12.1)
Infant formula[Σ]	Good source	1,792 (22.5)	600 (33.7)
Toddler formula[Π]	Good source	1,603 (20.0)	410 (23.0)
Cow's milk[Ø]	Poor source	1,965 (24.7)	777 (43.5)

Correctly identified risk factors for vitamin D deficiency for infants and toddlers			
Born to vitamin D deficient mothers	High-risk factor	3,373 (42.0)	1,277 (70.9)
Being exclusively breastfed	High-risk factor	155 (1.9)	88 (4.9)
Having darker skin	High-risk factor	565 (7.0)	406 (22.5)
Not regularly exposed to sunlight	High-risk factor	4,632 (57.7)	1352 (75.0)
Living in South Island of NZ	Moderate-risk factor	1,296 (16.1)	904 (50.2)
Extensive use of sunscreen	Moderate-risk factor	2,177 (27.1)	798 (44.3)
Being formula fed	Low-risk factor	3,273 (40.8)	1100 (61.0)

∂ 10 participants did not answer in 2009 and 2021
Σ 56 participants did not answer in 2009, 20 participants did not answer in 2021
Π 66 participants did not answer in 2009, 23 participants did not answer in 2021
ø 84 participants did not answer in 2009, 14 participants did not answer in 2021

Sun exposure knowledge and its association with vitamin D synthesis

Participants in both groups correctly identified that vitamin D deficiency is an issue in New Zealand despite our sunny climate and outdoor living and that vitamin D status may drop below adequate concentrations during winter. Confusion around the impact of protective clothing, the amount of skin exposed and skin colour on vitamin D synthesis was observed in both groups. Sun exposure recommendations were not well understood in both groups, and confusion around the effectiveness of sun exposure through a window was observed (Table.3.3).

Table 3.3: Parent's knowledge about sun exposure and its association with vitamin D synthesis

Sun exposure knowledge	**Answer**	**Participant's response N (%)**	
		2009	**2021**
Sunny climate and outdoor living in NZ means that vitamin D deficiency is not an issue	True	1,032 (12.8)	132 (7.3)
	False	5,703 (71.0)	1,298 (72.0)
	Unsure	1,297 (16.1)	372 (20.6)
During winter vitamin D status may drop below adequate levels	**True**	5,653 (70.4)	1,410 (78.2)
	False	551 (6.9)	54 (3.0)
	Unsure	1,828 (22.8)	338 (18.8)
Amount of time needed in the sun to make enough vitamin D depends on the amount of skin exposed	**True**	3,217 (40.1)	948 (52.6)
	False	1,936 (24.1)	236 (13.1)
	Unsure	2,878 (35.8)	618 (34.3)
	True	1,918 (23.9)	772 (42.8)
	False	3,164 (39.4)	202 (17.2)

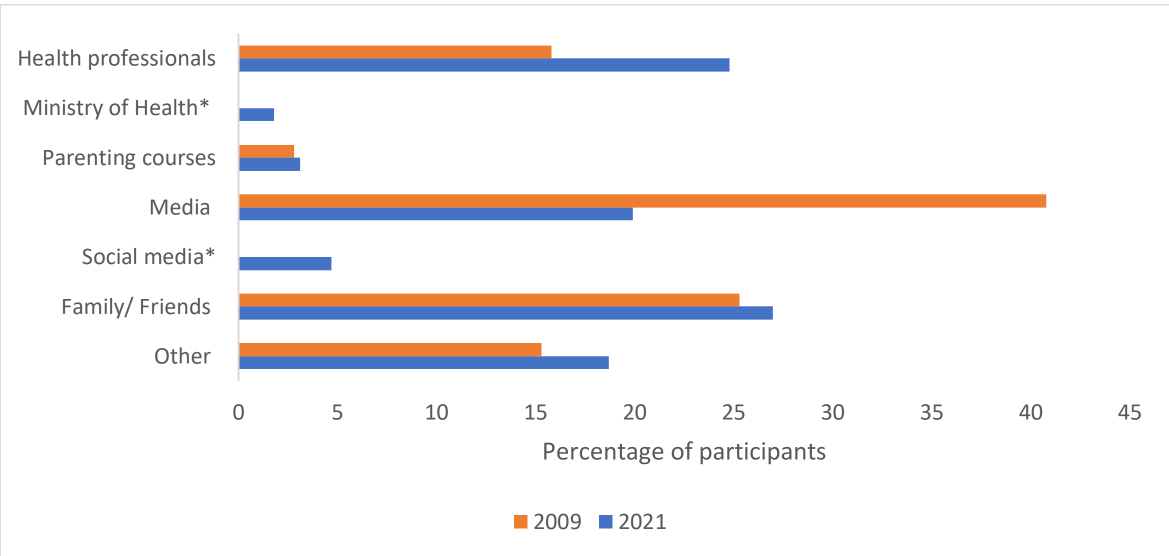
People with dark skin need to spend longer in the sun to make enough vitamin D	Unsure	2,950 (36.7)	720 (40.0)
Sun protective behaviours (wearing clothing/sunscreen) have no effect on vitamin D synthesis	True	2,202 (27.4)	237 (13.2)
	False	3,729 (46.4)	1041 (57.8)
	Unsure	2,101 (26.2)	524 (29.1)
Most pregnant women will get enough vitamin D in summer through incidental sun exposure outside peak UV times	**True**	3,060 (38.1)	789 (43.8)
	False	1,553 (19.3)	239 (13.3)
	Unsure	3,419 (42.6)	774 (43.0)
Deliberate sun exposure during the middle of the day is recommended for pregnant & lactating women	True	795 (9.9)	213 (11.8)
	False	4,483 (55.8)	757 (42.0)
	Unsure	2,754 (34.3)	832 (46.2)
Sun exposure through a window is just as effective as outdoor sun exposure in relation to vitamin D synthesis	True	2,975 (37.0)	540 (30.0)
	False	2,629 (32.7)	712 (39.5)
	Unsure	2,428 (30.2)	550 (30.5)

Note: correct answers in bold.

Sources of information on vitamin D and sun exposure

Health professionals were not the main source of information, with media (40.8%) and friends/family (27.0%) the main source of information in 2009 and 2021, respectively. A similar proportion in both groups reported "other", with participants reporting their knowledge had come from school or tertiary education, general knowledge or guessing answers due to their lack of knowledge on vitamin D (Figure 3.1).

In 2021, 89.7% of parents reported they felt there was not enough information available to parents on vitamin D. Additionally, 86.9% were not aware of the current recommendations for vitamin D and sun exposure for their baby or child, with only 6.6% reporting they had seen the Ministry of Health resources on "vitamin D and your pregnancy" and "vitamin D and your baby".



**Only asked in 2021.*

***Figure 3.1:** Sources of information for the 2009 and 2021 participants.*

Advice from health professionals on vitamin D and sun exposure

In both populations, only a small percentage of participants (3.1% in 2009, 7.1% in 2021) reported receiving advice from a Plunket nurse or health professional on supplementation with vitamin D for their baby (Figure 3.2). In addition, 84.4% in 2021 did not know a funded vitamin D supplement was available for babies at risk of vitamin D deficiency. Of those that did receive advice, the majority reported receiving advice due to their baby being born prematurely or during the winter months and exclusively breastfed.

A higher proportion of parents (30.6%) in 2009 reported receiving advice on sun exposure for their baby compared to 2021 (17.7%). From those who received advice, messages largely focused on skin cancer including safe sun practices, such as using protective clothing and sunscreen. However, there were some reports of conflicting advice on sunscreen application for babies. Additionally, participants reported receiving advice on exposing their baby to sunlight through a window to help with jaundice.

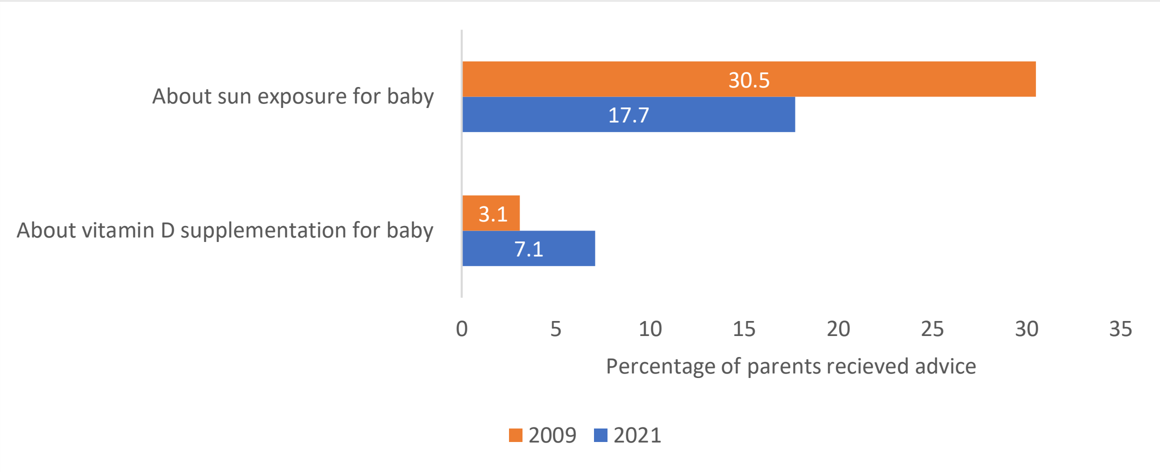


Figure 3.2: *Advice received about vitamin D supplementation and sun exposure from Plunket or health professionals by the 2009 and 2021 participants.*

Preferred source of information for parents

Health professionals were preferred as a source of information by 43.5%, with a further 16.7% reporting they would go to the Ministry of Health for more information. Twenty two percent reported preferring to receive information from the media, with an additional 2.3% reporting they would use social media. Of those that selected “other” (13.0%), the most common responses included the internet or google (Figure 3.3).

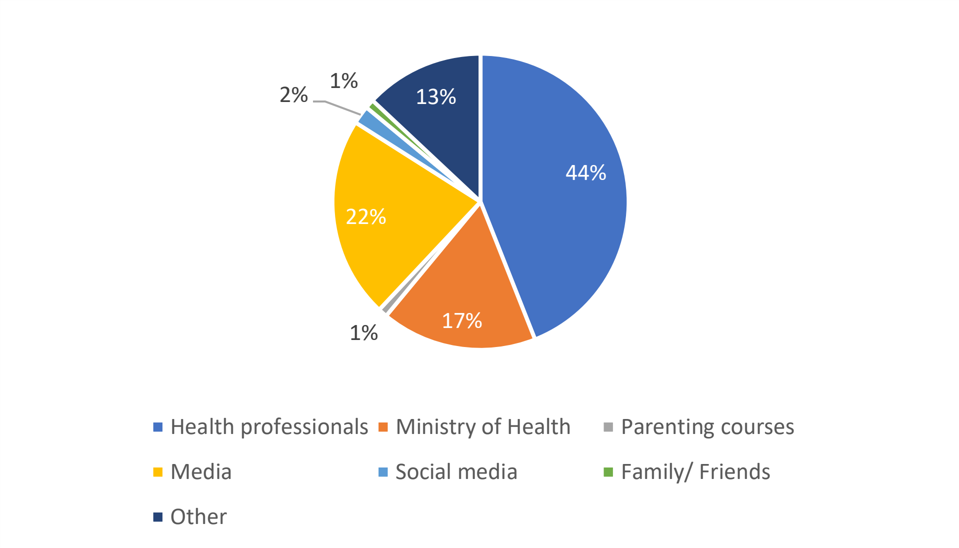


Figure 3.3: *Preferred sources of information in the 2021 parents*

Attitudes regarding vitamin D and sun exposure

In both groups, almost all participants agreed that children need some direct sunlight to be healthy. However, most thought sunbathing was harmful and were worried about the damage to their child's skin (80.9% in 2009, 80.0% in 2021) and the link to skin cancer (86.5% in 2009, 83.3% in 2021). Confusion regarding vitamin D and sun exposure recommendations was observed due to skin cancer prevention messages (Table 3.4).

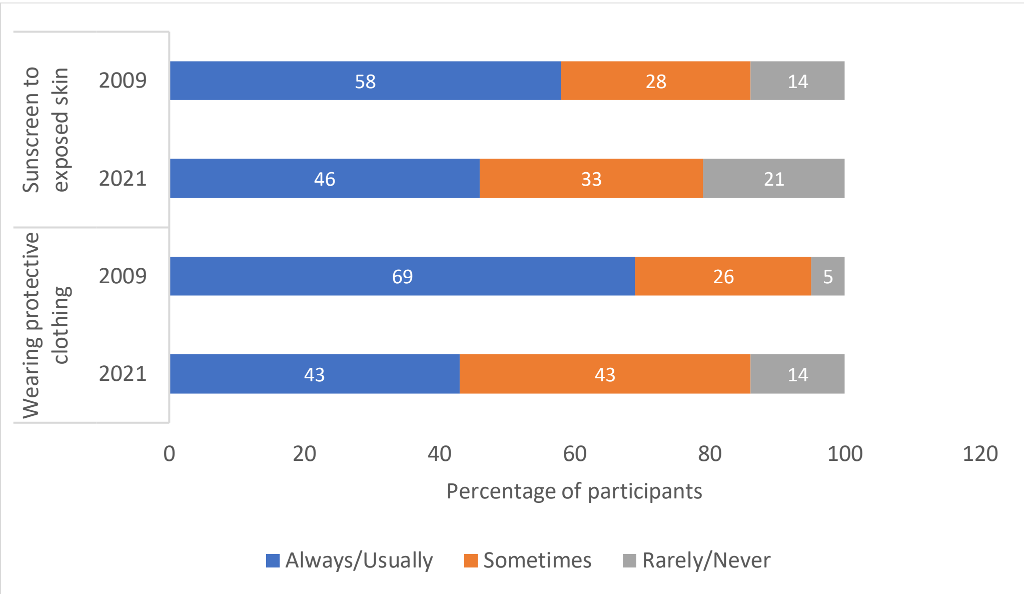
Table 3.4: Parents' attitudes toward vitamin D and sun exposure

Attitudes toward vitamin D and sun exposure	**Answer**	**Participant's response N (%)**	
		2009	**2021**
Children need to get some direct sunlight to be healthy	Agree	7,251 (90.3)	1,602 (89.9)
	Neutral	532 (6.6)	132 (7.3)
	Disagree	249 (3.1)	50 (2.8)
If skin is always protected from the sun it can put people at risk of vitamin D deficiency	Agree	4,391 (54.7)	1,173 (65.1)
	Neutral	2,536 (31.6)	433 (24.0)
	Disagree	1,105 (13.8)	196 (10.9)
Sunbathing is harmful to my child	Agree	7,003 (87.2)	1,396 (77.5)
	Neutral	689 (8.6)	272 (15.1)
	Disagree	340 (4.2)	134 (7.5)
I worry that sun exposure is linked to skin cancer	Agree	6,948 (86.5)	1,501 (83.3)
	Neutral	831 (10.3)	212 (11.8)
	Disagree	253 (3.1)	89 (4.9)
I worry that the sun will damage my child's skin	Agree	6,501 (80.9)	1,442 (80.0)
	Neutral	1,061 (13.2)	234 (13.0)
	Disagree	470 (5.9)	126 (7.0)

Skin cancer prevention messages make it confusing to understand messages about vitamin D	Agree	5,820 (72.4)	1,413 (78.4)
	Neutral	1,599 (19.9)	280 (15.5)
	Disagree	613 (7.6)	109 (6.0)
I really don't know what to do when it comes to vitamin D and sun exposure	Agree	4,029 (50.1)	957 (53.1)
	Neutral	2,467 (30.7)	513 (28.5)
	Disagree	1,536 (19.1)	332 (18.4)

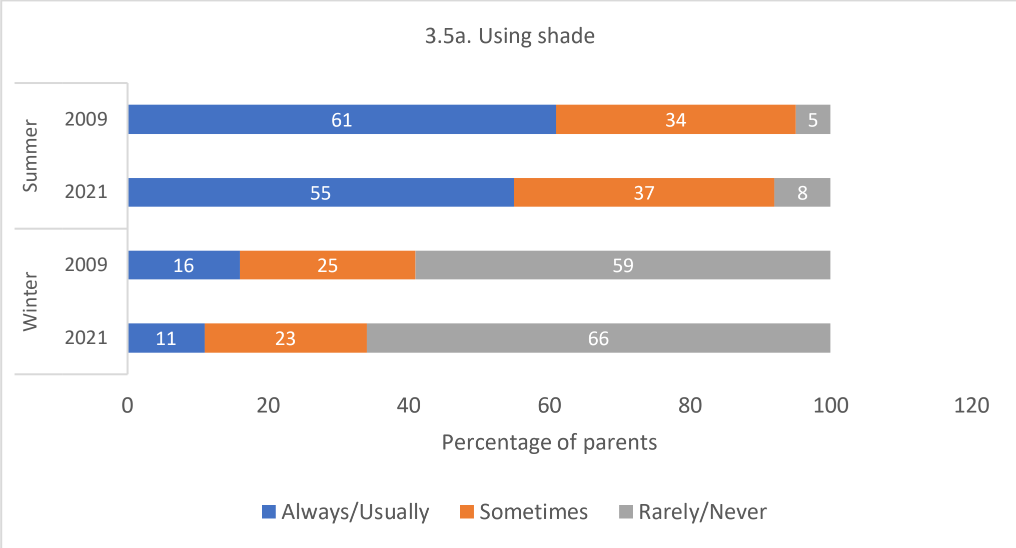
Sun exposure behaviours

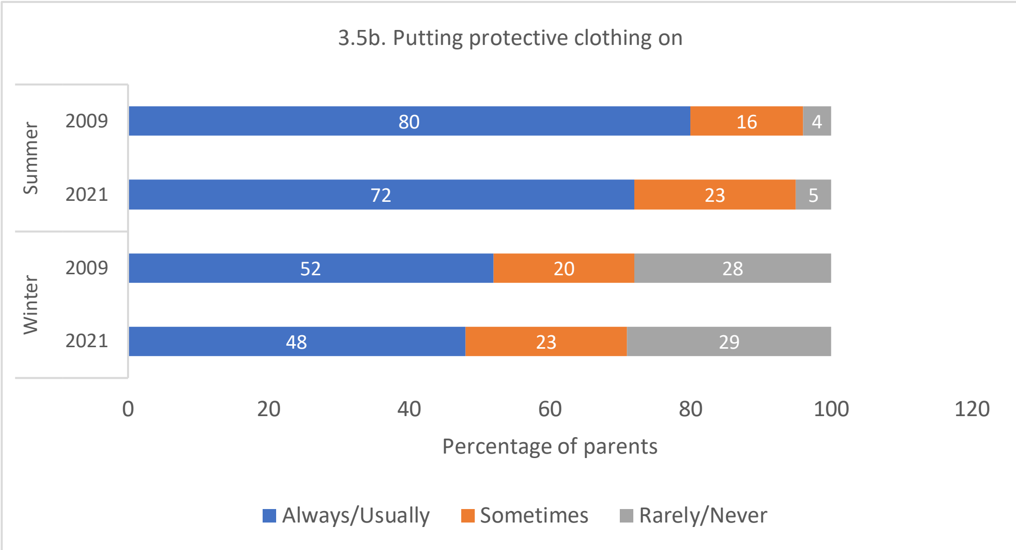
In both groups, almost all participants (93.7% in 2009, 93.0% in 2021) spent time outside in the sun during their most recent pregnancy. Sun protective behaviours (protective clothing/sunscreen) were performed more frequently in 2009 compared to 2021 (Figure 3.4). Sun protective behaviours were performed frequently with participant's youngest child during the summer, with participants always or usually using hats (94.2%, 92.0%), sunscreen (86.5%, 82.4%), protective clothing (79.8%, 71.7%) and using shade (60.8%, 55.0%). During the winter months, these behaviours were performed less frequently (Figure 3.5).

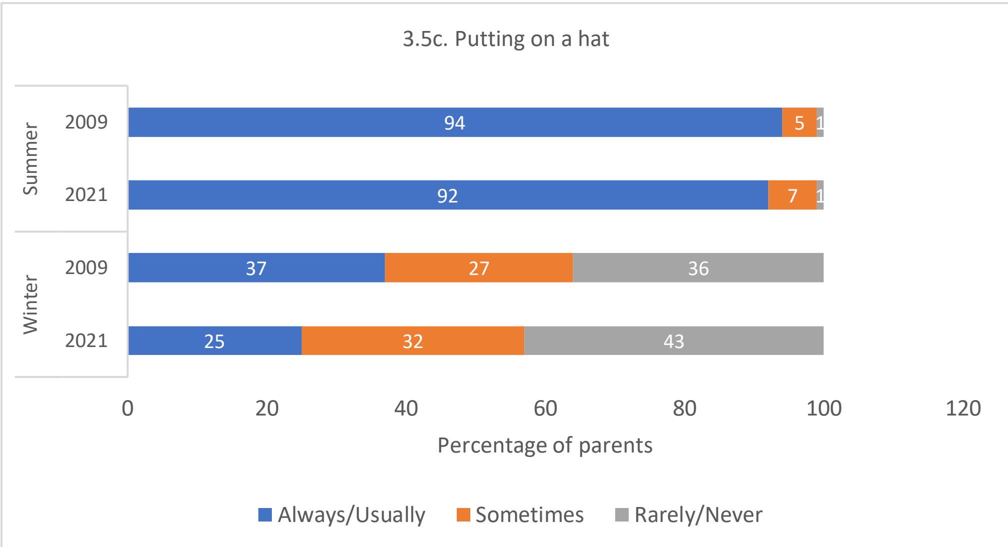


ә 83 participants did not answer in 2009, 5 participants did not answer in 2021
Ø 115 participants did not answer in 2009, 3 participants did not answer in 2021

Figure 3.4: *Sun exposure behaviour during pregnancy in the 2009 and 2021 participants*


3.5a. Using shade
Summer
Winter
2009
2021
2009
2021
61
34
5
55
37
8
16
25
59
11
23
66
0
20
40
60
80
100
120
Percentage of parents
Always/Usually
Sometimes
Rarely/Never


3.5b. Putting protective clothing on
Summer
Winter
2009
2021
2009
2021
80
16
4
72
23
5
52
20
28
48
23
29
0
20
40
60
80
100
120
Percentage of parents
Always/Usually
Sometimes
Rarely/Never


3.5c. Putting on a hat
Summer
Winter
2009
2021
2009
2021
94
5
1
92
7
1
37
27
36
25
32
43
0
20
40
60
80
100
120
Percentage of parents
Always/Usually
Sometimes
Rarely/Never

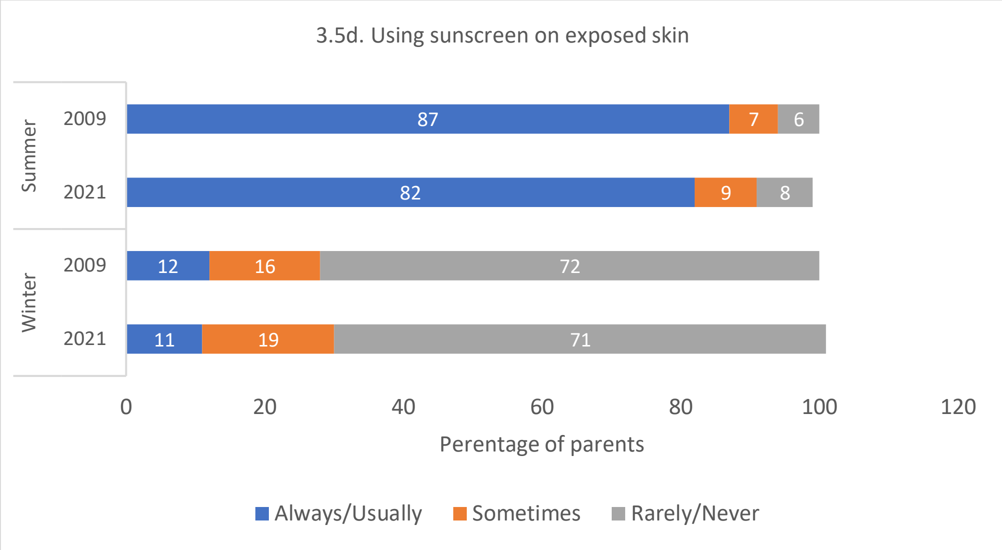


Figure 3.5: *Parents' sun exposure practices for their youngest child during summer and winter months in 2009 and 2021 including; a) using shade, b) putting protective clothing on, c) putting on a hat, d) using sunscreen to the exposed skin*

3.5 Discussion

The present study identifies the knowledge, attitudes and behaviours towards vitamin D and sun exposure amongst parents of infants and young children in New Zealand in 2009 and 2021.

Participant characteristics

A large number of parents participated in the questionnaires in 2009 and 2021, with similar characteristics identified in both population groups. Therefore, this provides some insight into this population group in New Zealand. However, some characteristics were not representative of the wider population within New Zealand. Although the proportion of Māori and Pacific ethnicities was similar across both groups, they were underrepresented in our study compared to their make-up in the New Zealand population (16.5% and 8.1% respectively) (Statistics New Zealand, 2018). Furthermore, almost all participants (95.6%, 94.4%) across both groups reported having type I to III skin types ("white"-skin), according to the Fitzpatrick skin type scale (Ravnbak, 2010). Only a small number of participants reported having type IV and V (brown and dark brown) skin. Although we do not have population statistics available on skin colour in New Zealand (Callister, 2008), individuals with darker skin types are likely to be underrepresented in the present study. Additionally, participants' skin colour was self-reported and potentially subjective.

A high level of education was identified in both groups, with university and professional qualifications held by the majority of participants. This is considerably higher than the general population in New Zealand, with less than half of 25 to 64 year olds holding a university degree in 2014 (OECD, 2014). Thus, the knowledge of parents included in this study may be greater than the level of knowledge within the wider population of parents in New Zealand. Education level influences health knowledge, with greater knowledge of the importance of vitamin D found amongst parents with higher education levels (Robinson et al., 2013; Zadka et al., 2018). However, higher maternal education has negatively impacted vitamin D status in young children in New Zealand (Houghton et al., 2010). Higher education level was thought to increase parents likelihood of performing sun protective behaviours, including using protective clothing and applying sunscreen to their children (Houghton et al., 2010).

Knowledge of the roles of vitamin D

The majority of parents in both 2009 (63.1%) and 2021 (61.3%) correctly identified that vitamin D is required for healthy bones, which is consistent with findings from recent studies on parents' knowledge (Day et al., 2019; Zadka et al., 2018). A larger proportion of parents in 2021 (48.2%) identified the role of vitamin D in immunity, which potentially reflects the increasing evidence for the role of vitamin D in immune function (Sassi et al., 2018). However, the increased awareness has not been observed in research internationally, with a smaller proportion (19%-39%) of parents demonstrating understanding of this role (Day et al., 2019; Hussein et al., 2018; Zadka et al., 2018). Although, approximately 50% of parents in both groups were unsure or selected an incorrect role of vitamin D. This indicates that information on the role and importance of vitamin D for children may not be communicated effectively to parents, leading to confusion. Therefore, further targeted education is needed to improve parents understanding of the role of vitamin D.

Knowledge of sources of vitamin D

Almost all parents in both groups correctly identified that vitamin D manufactured in the skin following exposure to sunlight is the single most important source of vitamin D for New Zealanders. This large awareness of sunlight as a source of vitamin D is consistent with findings from research internationally (Aitken & Mushtaq, 2015; Al-Qudah et al., 2021; Alshamsan & Bin-Abbas, 2016; Drury et al., 2015; Toher et al., 2014). A small number of participants incorrectly stated natural and fortified foods or supplements as the most important source of vitamin D. Only a very limited number of foods naturally contain vitamin D and there is currently no mandatory fortification of food products with vitamin D in New Zealand (Ministry for Primary Industries, 2014). In addition, over the counter vitamin D supplements contain varying concentrations of vitamin D up to a maximum of 1000 IU (New Zealand Government, 2016). Therefore, these sources of vitamin D cannot be relied upon as important sources for New Zealanders. Although, they have proven to be beneficial to prevent vitamin D deficiency, particularly in at-risk groups, including infants and pregnant women (Dijkstra et al., 2007).

Fortified food products have been found to increase vitamin D status safely without increasing serum 25(OH)D to excessive concentrations (Cashman & Kiely, 2016). In particular, fortified toddler milk is an effective method of increasing vitamin D intake in young children. This method of fortification was trialled in toddlers (N=160) in New Zealand and Australia through growing-up milk (GUM) fortified with 1.2 µg/100 mL (480 IU/L) of vitamin D (Lovell et al., 2018). Toddlers who received GUM had significantly higher intakes of vitamin D and decreased prevalence of vitamin D deficiency (Lovell et al., 2018). These findings were consistent with previous research in toddlers in Dunedin (45ºS), with 25(OH)D concentrations maintained above 50 nmol/L all year round in most toddlers receiving vitamin D fortified milk (Houghton et al., 2011). Furthermore, fortified milks have positively impacted vitamin D intake and status internationally (Itkonen et al., 2018). However, for fortified foods to be used effectively, education targeted to parents around the benefits of foods fortified to improve vitamin D intake and status of children would be required.

Vitamin D supplementation for infants and young children is common practice in some countries. For example, in the UK, vitamin D supplementation is recommended for all children under five, unless infants receive more than 500 mL of formula a day. In the United States, supplementation with 400 IU of vitamin D is recommended for all infants under 12 months, with recommendations increasing to 600 IU for children over the age of one (Pramyothin & Holick, 2012). However, in New Zealand, vitamin D supplementation is only recommended for those at high risk of deficiency. The current funded vitamin D supplement for infants is Puria, which is administered daily and provides 10 µg (400 IU) of vitamin D per drop (Ministry of Health, 2020a). Only a very small proportion (3.1% in 2009, 7.1% in 2021) of parents reported receiving advice on vitamin D supplementation for their infant. This indicates that the recommendations for vitamin D supplementation for at-risk groups published in the Ministry of Health Consensus and Companion Statements may not be implemented effectively (Ministry of Health, 2012a, 2013). However, the rates of supplementation advice identified in our study may be underrepresented due to only a small number of individuals with dark skin present. Although reports of supplementation advice were low, in countries with widespread supplementation recommendations such as the UK, a recent study identified that less than a quarter of parents (N=194) reported supplementing their child with vitamin D (Day et al., 2019). This may indicate that parents are not aware the recommendations or do not understand the importance of supplementation.

Knowledge of good sources of vitamin D for infants and toddlers was poor in both population groups. The majority of parents (96.1% in 2009, 87.9% in 2021) were unaware that breastmilk is a poor source of vitamin D for their baby. This suggests that information on the low vitamin D content of breastmilk outlined in the MoH Companion Statement and resources has not been effectively communicated to parents (Ministry of Health, 2013, 2020a, 2020b). Breastmilk is the preferred feeding method for infants and has nutritional, immunological and psychological benefits for both the infant and mother (Dieterich et al., 2013). Breastfeeding rates in New Zealand are high, with 97% of mothers initiating breastfeeding and 66% continuing to breastfeed at six months (Castro et al., 2017). This is consistent with the rates of breastfeeding identified in our study populations. These high rates may reflect the strong promotion of exclusive breastfeeding (EBF) for the first six months of life in New Zealand (National Breastfeeding Advisory Committee of New Zealand, 2009). With most mothers in New Zealand initiating breastfeeding, increased awareness of breastmilk's vitamin D content is needed to ensure parents are aware of the potential risk of deficiency. This is particularly important as rickets peaks within the first 12 months of life when breastmilk is a major energy source for infants (Creo et al., 2017).

Vitamin D supplementation in lactating mothers has been found to increase the vitamin D content of breastmilk, providing adequate concentrations to support infants nutritional requirements (Hollis et al., 2015). Although mothers may have adequate 25(OH)D status, 25(OH)D does not diffuse into breastmilk as easily as the parent compound, vitamin D (Hollis et al., 2015). However, the half-life of vitamin D is approximately 12 to 24 hours; therefore, daily supplementation is ideal to increase the vitamin D content of breastmilk (Hollis et al., 2015). A daily supplementation of 6400 IU for breastfeeding mothers has been identified as a safe and effective way to improve the vitamin D content of breastmilk and the status of both the infant and mother (Wagner & Hollis, 2020). Although widespread recommendations for vitamin D supplementation in lactating women is not established in New Zealand, NHMRC recommends 10 µg/day (400 IU) for lactating women with reduced exposure to sunlight (Ministry of Health, 2020a). The supplements available for adults in New Zealand include a daily oral cholecalciferol liquid containing 7500 IU/mL or a monthly capsule of 50,000 IU (Ministry of Health, 2020a). However, the large intermittent dose would not be effective in increasing the vitamin D content of breastmilk. Additionally, these are only subsidised for individuals at risk of, or diagnosed with, vitamin D deficiency. Alternatively, the funded supplement for at-risk infants is available for breastfed infants who have an additional risk factor (dark skin, sibling with rickets or deficient mother) or are breastfed over the winter months (Ministry of Health, 2020a).

Parents' knowledge of the vitamin D content of other feeding methods for their infant or toddler was also poor in both populations. The majority of parents (77.5% in 2009, 66.3% in 2021) were not aware that infant formula contains vitamin D. Infant formula is fortified with approximately 360-520 IU/L of vitamin D, with the median consumption of formula for infants of one litre a day, infants are likely to meet the recommended adequate intake of 200 IU/day (Fink et al., 2019). Routine supplementation of formula-fed babies is not currently recommended in New Zealand, however, supplementation may be beneficial if babies consume less than 500 mL of formula a day (Ministry of Health, 2020a).

A larger proportion of parents in 2021 (43.5% vs. 24.7%) were aware that cow's milk is a poor source of vitamin D. Although cow's milk does naturally contain a small amount of vitamin D, the content is low (120-140 IU/L) and is impacted by environmental factors (Ministry of Health, 2020a; Weir et al., 2017). Therefore, cow's milk is not considered a good source of vitamin D, although it does provide many other essential nutrients. This makes cow's milk a good option for fortification. In New Zealand, voluntary fortification of cow's milk is permitted to a maximum concentration of 600 IU/L for dried milk and 320 IU/L for skim milk (Food Standards Australia New Zealand, 2016). However, several countries, including the United States and Canada, have introduced mandatory fortification of cow's milk with vitamin D to maintain adequate vitamin D status of their populations (Calvo & Whiting, 2013).

Knowledge of risk factors for deficiency in infants and young children

There were some improvements in parents' knowledge of risk factors for vitamin D in 2021. A larger proportion of parents in 2021 (70.9% vs. 42.0%) correctly identified that babies born to vitamin D deficient mothers were at an increased risk of deficiency. Additionally, greater awareness of the risk of deficiency in children who are not regularly exposed to sunlight was identified in 2021. This increased awareness of low sun exposure as a risk factor is consistent with findings from a recent study of parents in Jordan (N=783), with almost all parents (98.5%) identifying low sun exposure as a risk factor (Al-Qudah et al., 2021). However, we found that parents were unaware that sun protection practices, including extensive use of sunscreen, could put individuals at risk of deficiency, which was also seen in parents in Jordan (Al-Qudah et al., 2021).

Furthermore, a larger proportion of parents in 2021 identified living in the South Island of New Zealand increased the risk of vitamin D deficiency. This improvement in awareness of geographical location affecting an individual's vitamin D status is important, as infants and toddlers residing at higher latitudes in New Zealand were found to have lower serum 25(OH)D concentrations (Grant et al., 2009; Houghton et al., 2010). However, in pre-school aged children (N=1329) no significant difference in mean 25(OH)D concentrations was found between those living in northern and southern regions, although there was a significantly lower mean 25(OH)D in those living in central regions (39–42°S) (Cairncross et al., 2017). Therefore, further studies are required to determine the impact of different latitudes on the vitamin D status of young children in New Zealand.

Knowledge of key risk factors, including EBF and dark skin colour, identified in the Ministry of Health Consensus and Companion Statements (Ministry of Health, 2012a, 2013) was poor in both groups. This suggests that these risk factors have not been communicated effectively to parents. Only a very small proportion of parents (1.9%, 4.9% respectively) thought EBF was a high-risk factor for vitamin D deficiency. The lack of knowledge of this risk factor may be due to parents believing that breastmilk contains all the nutrients required for their infant (Taylor et al., 2010). This is concerning as a quarter of EBF infants aged 2-3 months (N=94) in a New Zealand study had serum 25(OH)D concentrations <50 nmol/L (Wall et al., 2013). Additionally, toddlers in New Zealand (N=193) who continued receiving breastmilk had on average 14% lower circulating 25(OH)D concentrations compared to those who had stopped receiving breastmilk (Houghton et al., 2010). Higher rates of vitamin D insufficiency in EBF infants has been observed internationally, with 75% of EBF infants in the US identified to have serum 25(OH)D <50 nmol/L (Dawodu et al., 2014).

Poor awareness of darker skin colour influencing vitamin D deficiency risk was observed in both groups. This lack of awareness is consistent with findings from a study of parents in Malaysia (N=344) (Hussein et al., 2018). Darker skin contains higher concentrations of the pigment melanin, which interferes with vitamin D synthesis in the skin by absorbing UVβ radiation (D'Orazio et al., 2013; Webb et al., 2018). In New Zealand, preschool children with darker skin had significantly lower 25(OH)D concentrations (41 nmol/L) compared to lighter skinned children (53 nmol/L) (Cairncross et al., 2017). Additionally, higher rates of vitamin D deficiency were seen in Pacific newborns and toddlers, likely due to increased skin pigmentation (Camargo et al., 2010; Grant et al., 2009). Higher rates of vitamin D deficiency have also been identified in infants with darker skin in the US (N=400) with almost 50% identified with vitamin D deficiency compared to 9.7% of infants with white skin (Bodnar et al., 2007). The lack of knowledge of the role of skin colour as a risk factor is concerning as the population in New Zealand is becoming increasingly diverse with regards to skin colour and ethnicity (Callister et al., 2011). Thus, improvements in knowledge of this risk factor are required to decrease the prevalence of vitamin D deficiency in at-risk groups.

Knowledge about sun exposure and its association with vitamin D synthesis

Parents were largely aware that vitamin D deficiency is an issue in New Zealand despite our sunny climate and outdoor lifestyle, with most identifying that vitamin D status may decrease below adequate levels during the winter months. However, parents were largely unaware that individuals with darker skin require prolonged sun exposure to synthesise sufficient vitamin D. This identifies parents' lack of understanding of skin colour's influence on vitamin D synthesis. In contrast, findings from a cross-sectional study of adults in the UK (N=209) identified greater knowledge of the impact of skin pigmentation on vitamin D synthesis (O'Connor et al., 2018). The participants in the study were largely Caucasian (89.5%) and had high education levels, with 20% of participants holding a nutrition degree; therefore, this may have influenced the higher level of knowledge.

The majority of parents were unsure about sun exposure recommendations for sufficient vitamin D synthesis during pregnancy and lactation. This indicates that information on safe sun exposure for vitamin D synthesis is not being communicated effectively to parents, and advice from health professionals may be lacking. Our study identified that the percentage of parents receiving advice on sun exposure from a health professional in 2021 had almost halved since 2009. Additionally, the strong public health focus on safe sun practices to reduce skin cancer risks, such as wearing protective clothing, may impact parents' understanding of vitamin D synthesis. Around 50% of parents across both groups did not believe sun protective behaviours (i.e. wearing protective clothing and using sunscreen) affect vitamin D synthesis. This is consistent with previous research, with strong beliefs identified amongst adults that sun protective behaviours do not affect adequate synthesis of vitamin D (Holman et al., 2017; O'Connor et al., 2018). Furthermore, a similar percentage of parents were unsure or thought the period of sun exposure required to synthesise adequate vitamin D was not impacted by the amount of skin exposed. This may indicate that sun safety messages such as "slip, slop, slap", may potentially mislead the public to believe they do not need direct sun exposure to synthesise vitamin D. Furthermore, there appeared to be confusion surrounding the ability to synthesise vitamin D through windows, with majority of parents unsure or believe it is just as effective as outdoor exposure. Vitamin D cannot be synthesised through windows as UVβ rays, which are required to synthesise vitamin D in the skin, do not penetrate glass (Tuchinda et al., 2006). Therefore, parents' belief that vitamin D can be synthesised through windows is incorrect and may result in unnecessary sun exposure without the benefits of absorbing UVβ.

Sources of information on vitamin D and sun exposure

Health professionals were a greater source of information for parents in 2021 (24.8%) than in 2009 (15.8%). Additionally, a small proportion of parents (1.8%) reported the Ministry of Health as their source of information. These findings are consistent with previous research, identifying that health professionals are not the primary source of information to parents on vitamin D (Drury et al., 2015; Hussein et al., 2018). However, health professionals are a trusted source of information to parents and advice provided by them is more likely to be followed compared to other sources (Moseley et al., 2011). Almost two-thirds of parents in 2021 reported they would prefer to receive further information on vitamin D from health professionals or the Ministry of Health, with similar findings identified in a study of UK parents (Day et al., 2019). A quarter of participants reported they would prefer to receive information from the media or social media.

A small proportion of parents preferred using the internet to google health information. Although health information is readily available online, the large amount of inaccurate information from unreliable sources is concerning (Bianco et al., 2013). Additionally, information online may be misinterpreted by parents, resulting in undesirable impacts on knowledge and behaviours (Bianco et al., 2013). Information from credible and evidence-based sources, including recommendations and resources from the Ministry of Health, may not be reaching parents or the public as a result. We identified only a very small proportion of parents who were aware of the current recommendations or had seen the Ministry of Health resources on vitamin D and your pregnancy/your baby (Ministry of Health, 2020b, 2020c). This lack of awareness of recommendations and guidelines on vitamin D was also identified in parents in the UK (Day et al., 2019; Drury et al., 2015; O'Connor et al., 2018). Therefore, new strategies are needed to make credible sources of information more accessible to parents online. Recommendations from a review of the Ministry of Health website suggested that promoting their resources on social media platforms could help increase public awareness (Burtis, 2011). Social media has increased in popularity in recent years and has proven to effectively disseminate information online (Metzger & Flanagin, 2011; Moorhead et al., 2013; Ventola, 2014). Therefore, with most participants reporting they want more information on vitamin D from these sources, health professionals and the MoH could utilise social media to communicate and provide information to the public. However, more research may be needed to determine the impact of this delivery on parents' knowledge and behaviours.

Attitudes and behaviours towards sun exposure

Almost all parents believed that direct exposure to sunlight is required for their child to be healthy. However, a large proportion of parents expressed their concern about damage to their child's skin following sun exposure and the risk of skin cancer. Excessive sun exposure during childhood may be particularly harmful regarding increased risk of skin cancer later in life, especially in New Zealand with high levels of UVR during the summer months (Council on Environmental Health et al., 2011; Wright et al., 2007). Consequently, New Zealand has one of the highest rates of skin cancer in the World (Whiteman et al., 2016).

Strong public health campaigns focusing on cancer prevention are present to address the increased risk of skin cancer in New Zealand. Approximately three out of four parents reported that these messages make it confusing to understand vitamin D recommendations. Additionally, 50% of parents reported not knowing what to do regarding vitamin D and sun exposure. Similar findings were echoed in a study of parents in the UK, who found it challenging to understand conflicting messages and achieve a balance between vitamin D requirements and the need for sun protection (Littlewood & Greenfield, 2018).

With the firm belief that sunlight is required for health, it is no surprise that almost all pregnant mothers reported spending time outside during their pregnancy. It was identified that sun protective behaviours were performed less frequently amongst mothers in 2021, with less than half wearing protective clothing or applying sunscreen when outside compared to almost two-thirds in 2009. These findings may reflect increased awareness of the benefits of sun exposure for vitamin D synthesis, as sensible sun exposure during pregnancy is recommended in the Companion Statement (Ministry of Health, 2013, 2020a). However, it may also be influenced by reduced funding of SunSmart campaigns in recent years (Signal et al., 2020). Similar behaviours were also observed in pregnant women in Australia (N=164), who are also at an increased risk of skin cancer due to comparable UVR levels (Wu, 2013). Around half of the women reported using protective clothing or sunscreen to cover their bodies when outside (Wu, 2013).

Given the increased risk of skin cancer following excessive sun exposure in childhood, parents frequently performed sun protective behaviours with their child in both groups. Most parents reported always or usually keeping their child in the shade, dressing them in protective clothing, and applying sunscreen during the summer months. The most frequently reported sun protective behaviour was putting a hat on their child. However, these behaviours were performed much less frequently during the winter months, when UVR levels are considerably lower (Reeder et al., 2012). These findings are consistent with previous research in toddlers in Australia (N=664), with more than two-thirds of toddlers found to almost always wear a hat outdoors in the summer (Smith et al., 2013). Furthermore, findings from a randomly selected sample of children in a population-based study in the UK identified that sun protective practices were performed more frequently in children with lighter skin (Bonilla et al., 2014). Therefore, considering the large number of participants with lighter skin included in the present study, sun protective behaviours identified may be higher than the general population in New Zealand.

3.6 Conclusion

Overall, there was minimal change in parents' knowledge of vitamin D over the past 12 years. Therefore, the Ministry of Health Consensus and Companion Statements and subsequent public health messaging has had little impact on parents' knowledge. Our findings indicate that parents are largely unaware of the current recommendations published by the MoH on vitamin D and sun exposure, and very few have seen the MoH resources. This is concerning as the MoH provides evidence-based information online to parents and the public. However, most parents would like to receive more information on vitamin D and sun exposure from the Ministry of Health or health professionals. Therefore, they should consider new strategies to communicate health information to parents and the wider public, including utilising social media to make information and resources more accessible. However, further research would be required to determine the impact of this strategy on increasing parents' knowledge on vitamin D and sun exposure in New Zealand.

Chapter 4. Conclusions and recommendations

4.1 Overview and achievement of study aims and objectives

The aim of this study was to determine the impact of the Ministry of Health (MoH) Consensus Statement and Companion Statement for pregnancy and infancy and subsequent public health messaging on vitamin D and sun exposure knowledge, attitudes and behaviours of parents of infants and young children in New Zealand. To determine this, the objectives of this study were to identify in 2009 and 2021; parents' knowledge of the role of vitamin D, sources and risk factors for deficiency, their attitudes and behaviours and the current and preferred sources of information. These were achieved by re-administering a questionnaire in 2021 to assess parents' knowledge, attitudes and behaviours towards vitamin D and sun exposure that was initially conducted in 2009, prior to the release of the MoH statements.

Parents understanding of the role of vitamin D was similar, with the majority aware of its role in healthy bones. However, there was increased knowledge of the role of vitamin D in immunity amongst parents in 2021, given the increased evidence of this role in recent years. Parents in both populations were largely aware that sunlight is the primary source of vitamin D in New Zealand; however, knowledge of dietary sources of vitamin D for infants and toddlers was poor. Parents were largely unaware that breastmilk is a poor source of vitamin D to infants and that exclusive breastfeeding is a risk factor for deficiency during infancy. Additionally, parents in both groups were largely unaware that dark skin colour influences the risk of vitamin D deficiency.

We identified that health professionals were a greater source of information for parents in 2021 compared to 2009. Additionally, the Ministry of Health were reported as a source of information in 2021. However, low rates of advice from health professionals on supplementation and sun exposure during early childhood were reported by parents. Although, we identified that health professionals and the Ministry of Health were a preferred source of information to parents, followed by the media or social media.

Our findings indicate that parents frequently perform sun protective behaviours with their children, with strong concerns about skin cancer present amongst parents. This is unsurprising given the increased risk of skin cancer following excessive sun exposure in childhood and the strong public health messages in New Zealand. During the summer months, parents almost always performed sun protective behaviours, including using hats or protective clothing, shade and applying sunscreen. However, these practices were performed less frequently amongst pregnant women. Additionally, we found parents were confused about vitamin D and sun exposure recommendations because of skin cancer prevention messages.

The findings from the present study provide valuable insight into the impact of public health messaging from the Ministry of Health and health professionals on parents' knowledge and behaviours in New Zealand. The findings indicate that the current recommendations and resources have not been communicated effectively to parents. As a result, parents are largely unaware of the current recommendations and very few have seen the MoH resources on vitamin D during pregnancy and infancy in 2021.

This indicates a need to improve the delivery of information and educational resources to ensure adequate health information is provided to parents. Without adequate public health messaging, parents may not have the information and knowledge to make choices that optimise the health of themselves and their children.

4.2 Strengths

A strength of the present study included responses from 9,834 parents of infants and young children from across New Zealand in 2009 and 2021. This large sample size provides a closer approximation of the wider population of parents in New Zealand. Therefore, the findings provide some insight into the knowledge, attitudes and behaviours of parents in New Zealand.

The online delivery of the questionnaire allowed for participants from across the country to participate in the study. The social networking platform, Facebook was used to recruit participants and was a cost-effective way to reach a large number of participants.

4.3 Limitations

A limitation of the online questionnaire distributed via Facebook included an uneven spread of participants from around the country. Community Facebook groups in major cities in New Zealand, including Auckland, Wellington and Christchurch, had a larger following compared to groups in rural areas. This resulted in a higher proportion of participants from major cities completing the questionnaire.

Additionally, although specific ethnic community Facebook groups were targeted, these groups typically had a lower following. Consequently, there was disproportionate participation within smaller ethnic groups in New Zealand. Therefore, the results may not be representative of all the ethnic groups within New Zealand.

Participation in the online questionnaire was voluntary. Therefore, parents may have been more likely to participate if they were interested in health and may have a greater health literacy. This would have resulted in an overestimation of parents' knowledge on vitamin D and sun exposure.

4.4 Recommendations for public health

Although the Ministry of Health publishes guidelines and recommendations to improve the health of New Zealanders, if this information is not communicated effectively, it may not positively impact parents' knowledge and their children's health. Our findings indicate that public health information on vitamin D and sun exposure has not been communicated effectively to parents. Therefore, the Ministry of Health and health professionals should pursue new tools to communicate health information to parents. In recent years, social media has increased in popularity within the general public, and it has emerged as an effective tool that can reach a large number of people at a low cost. This could be utilised to make health information more accessible to parents and provide them with the knowledge that can positively impact the health of themselves and their children.

4.5 Recommendations for further research

Further research would be beneficial into the level of knowledge in different ethnic groups, including Māori, Pacific, and South Asian ethnicities in New Zealand, which have been identified as having a higher risk of vitamin D deficiency. These ethnic groups were all underrepresented in the present study, and therefore the findings cannot be used to predict their level of knowledge.

Additionally, further research into the impact of using social media to deliver health information and increase awareness of resources developed by the Ministry of Health would be beneficial. This would determine if this is an effective way to deliver public health messages to parents in New Zealand.

4.6 Conflicts of interest

The author declares there are no conflicts of interest.

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Appendices

Appendix A. Online Questionnaire

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Parent Survey

Parents knowledge, attitudes and behaviours towards vitamin D and sun exposure

Massey University is interested in finding out about parents knowledge of Vitamin D.

This questionnaire explores your current knowledge, attitudes and behaviours towards vitamin D and sun exposure.

The questionnaire is not a test so please do not look up answers or ask anyone else while completing the questions. We are interested in finding out what parents know so that we can make sure that clear messages are getting out there.

It should only take 10 - 15 minutes to complete the questionnaire and we really appreciate your participation. All responses are confidential and data is anonymous.

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

Thank you.

Before you start the questionnaire, please tick yes or no for the following:

Are you a parent to at least one child under the age of 5?

- Yes
- No

Are you currently living in New Zealand?

- Yes
- No

If no, which country are you currently living in?

Do you consent to participate in the questionnaire? By selecting 'Yes' you are giving us permission to use your response in our study. All responses are confidential and data is anonymous.

- Yes, I consent
- No, I do not consent

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Section 1 – Please tell us about your vitamin D knowledge

Have you heard of vitamin D?

- O Yes
- O No

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

- O Sunshine (Manufactured in the skin)
- O Natural food sources
- O Fortified food products
- O Supplements
- O Other (Please specify)

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

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

	Good	Moderate	Poor
Breast milk	O	O	O
Infant formula	O	O	O
Toddler formula	O	O	O
Cow's milk	O	O	O

Please rank the following vitamin D deficiency risk factors in babies? (Please drag the greatest risk factor to the top.)

Babies born to vitamin D deficient mothers

Dark skin

Babies who are not regularly exposed to sunlight

Babies who have most of their skin covered by clothing

Exclusively breast fed babies

Formula fed babies

Please rank the following vitamin D deficiency risk factors in toddlers and pre-schoolers? (Please drag the greatest risk factor to the top.)

Exclusion of dairy products from the diet

Dark skin

Living in the South Island of New Zealand

Toddlers and preschoolers who are not regularly exposed to sunlight

Extensive use of sunscreen

Fussy eating

Food allergies

Toddlers and preschoolers who are vegetarian

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)
- Ministry of Health
- Parenting courses (eg Antenatal classes, child care course)
- Media (TV, radio, internet, parenting magazines)
- Social media (Facebook, instagram, twitter)
- Family/Friends
- Other (Please specify)

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)
- Ministry of Health
- Parenting courses (eg Antenatal classes, child care course)
- Media (TV, radio, internet, parenting magazines)
- Social media (Facebook, instagram, twitter)
- Family/Friends
- Other (Please specify)

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

- Yes
- No

Do you know the current recommendations for vitamin D and sun exposure for your baby or child?

- Yes
- No

Have you seen the Ministry of Health resources on vitamin D and sun exposure for pregnancy and your baby?

- Yes
- No

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Section 2 - Please tell us about your typical behaviours

For the following questions please think about your typical behaviour when outside in the sun on a sunny day during your most recent pregnancy or with your youngest child.

Did you spend time outside in the sun during pregnancy?

- Yes
- No
- Not applicable

During your most recent pregnancy whilst out in the sun:

	Always	Usually	Sometimes	Rarely	Never	Not applicable
Did you wear protective clothing?	O	O	O	O	O	O
Did you apply sunscreen to exposed skin?	O	O	O	O	O	O

What sun protection factor (SPF) was the sunscreen?

- 15 or less
- More than 15 but less than 45
- 45 or more
- Not applicable

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

- Yes
- No
- Not applicable

If you answered yes, please briefly describe the advice.

Did you follow this advice?

- Yes
- No
- Not applicable

Did you know there is a funded vitamin D supplement available for babies at risk of vitamin D deficiency?

- Yes
- No

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

- Yes
- No
- Not applicable

If you answered yes, please briefly describe the advice.

Did you follow this advice?

- Yes
- No
- Not applicable

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 them in the shade?	○	○	○	○	○
Do you put a hat on them?	○	○	○	○	○
Do you put protective clothing on them?	○	○	○	○	○
Do you apply sunscreen on any of their exposed skin?	○	○	○	○	○

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 them in the shade?	○	○	○	○	○
Do you put a hat on them?	○	○	○	○	○
Do you put protective clothing on them?	○	○	○	○	○
Do you apply sunscreen on any of their exposed skin?	○	○	○	○	○

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

Did you follow this advice?

- ○ Yes
- ○ No
- ○ Not applicable

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

Did you follow this advice?

- ○ Yes
- ○ No
- ○ Not applicable

Was your most recent pregnancy planned?

- ○ Yes
- ○ No
- ○ Prefer not to answer
- ○ Not applicable

During your most recent pregnancy did you do any of the following? (Please tick all that apply.)

- ☐ Take a folic acid supplement
- ☐ Exercise during pregnancy
- ☐ Limit fish intake
- ☐ Drink alcohol
- ☐ Smoke
- ☐ Avoid foods containing raw eggs or fish
- ☐ Limit caffeine intake
- ☐ Not applicable

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

- Yes
- No
- Not applicable

If yes, what was the name of the supplement?

- Elevit
- Thompson Pregnacare
- Clinicians PregaVit
- Blackmores Conceive Well Gold (pre-conception and early foetal development)
- Blackmores Pregnancy And Breast Feeding Gold Capsules
- Radiance Preconception And Pregnancy Multi
- NFS Multi Pregnancy Essentials Capsules
- General multi vitamin supplement suitable for women
- Other (Please specify)
- I did not take a supplement

For your youngest child, did you?

- Breast feed
- Formula feed
- Other (Please specify)

How old was your baby when you started?

	From birth	1-2 months	3-4 months	5-6 months	6-8 months	8-9 months	10-11 months	12 months	Over 12 months
Breast feed									
Formula feed									
Other (Please specify)									

How old was your baby when you stopped?

	Birth	Less than 1 month	1-2 months	3-4 months	5-6 months	6-8 months	8-9 months	10-11 months	12 months	Over 12 months
Breast feed										
Formula feed										
Other (Please specify)										

What age did you start solids with your youngest child?

- 2 months
- 3 months
- 4 months
- 5 months
- 6 months
- 7 months
- 8 months or older
- Haven't started yet

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Section 3 - Please tell us what you know about vitamin D and sun exposure from a New Zealand perspective

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

	True	False	Unsure
People living in the South Island are more at risk of vitamin D deficiency than those living in the North Island.	○	○	○
In New Zealand we are seeing a re-emergence of rickets in children.	○	○	○
The sunny climate and outdoor living in New Zealand means that vitamin D deficiency is not an issue.	○	○	○
The amount of time required to be spent in the sun to allow synthesis of adequate vitamin D depends on skin colour.	○	○	○
Sun protective behaviours (e.g. wearing clothing and/or sun block) have no affect on vitamin D synthesis	○	○	○
People with dark skin e.g. Māori and Pacific Island people need to spend longer in the sun to synthesise adequate vitamin D.	○	○	○
Sun through a window is just as effective as outdoor sun exposure in relation to vitamin D synthesis.	○	○	○
Sun exposure through a window is safer than outdoor sun exposure.	○	○	○
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.	○	○	○
Season affects the amount of time needed in the sun to synthesise adequate vitamin D.	○	○	○
In summer, parents are recommended to expose baby's face and arms to 5 (for light skin) to 20 minutes (for dark skin) of direct sunlight per day before 11am and after 4pm.	○	○	○

During winter and spring infants and toddlers should spend some time outside in the sun to maintain vitamin D levels.	O	O	O
Most pregnant women will achieve an adequate vitamin D status in summer through incidental sun exposure outside peak UV times.	O	O	O
Between October and March pregnant and lactating women are recommended to expose their face and arms to 5-20 minutes of sunshine per day.	O	O	O
Deliberate sun exposure during peak UV times is recommended for pregnant and lactating women.	O	O	O
During winter vitamin D status may drop below adequate levels.	O	O	O
It is more important to cover a baby's skin than a toddler's skin.	O	O	O

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Section 4 - Please tell us about your view's towards sun exposure and vitamin D

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	O	O	O	O	O
Children need to get some direct sunlight to be healthy	O	O	O	O	O
I worry that sun exposure is linked to skin cancer	O	O	O	O	O
I worry that the sun will damage my child's skin	O	O	O	O	O
If skin is always protected from the sun it can put people at risk of vitamin D deficiency	O	O	O	O	O
I really don't know what to do when it comes to vitamin D and sun exposure	O	O	O	O	O
Skin cancer prevention messages make it confusing to understand messages about vitamin D	O	O	O	O	O

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Section 5 - Please tell us a little bit about yourself

How old are you?

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

How old is your youngest children?

- 0-6 months old
- 6-12 months old
- 1 year old
- 2 years old
- 3 years old
- 4 years old
- 5 years old

For your youngest child what month were they born in?

- January
- February
- March
- April
- May
- June
- July
- August
- September
- October
- November
- December

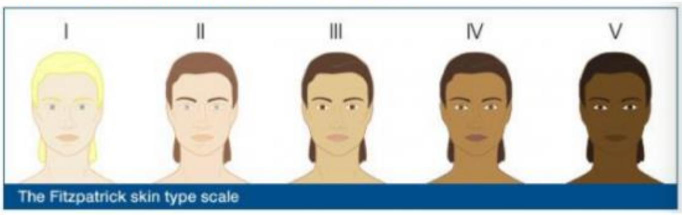
Does your youngest child attend day care, kindy or Te Kura?

- Full time
- Part time
- No
- Other (Please specify)

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

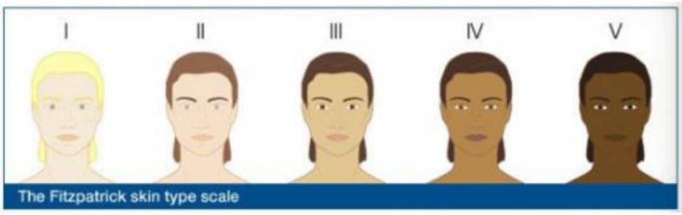
- New Zealand European
- Māori
- Samoan
- Cook Island Maori
- Tongan
- Chinese
- Indian
- Other (please specify)

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.

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.

Do you have a family history of skin cancer?

- Yes
- No
- Not sure