Health Professionals' Knowledge and Attitudes Toward Vitamin D in the General Population, Pregnancy, and Infancy

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Abstract

Background: Vitamin D is now recognised as having a role in in immune system functioning and in protection against several complications of pregnancy and common diseases of childhood. In 2012, a Consensus Statement was released by the New Zealand Ministry of Health that described the populations who are at risk of deficiency, how to manage vitamin D status whilst being conscious of the harsher ultraviolet environment in New Zealand and outlined who may benefit from vitamin D supplementation. Furthermore in 2013, a Companion Statement was released which provided additional information about vitamin D specific to the pregnant, lactating and infant populations. These documents were designed primarily for use by health professionals. There is limited literature available that explores health professionals' knowledge of vitamin D in New Zealand. International literature is conflicting with some studies reporting good knowledge of vitamin D deficiency risk factors, sun exposure guidelines and supplement guidelines while others report limited knowledge in these areas. International studies have reported on health professionals' knowledge of vitamin D supplement guidelines for infants with conflicting results. Identifying areas where knowledge is lacking will help to identify where New Zealand health professionals require further education.

Aims: The aim of this study is to explore health professionals' knowledge, attitudes and current practices toward vitamin D for the general population, pregnancy and infancy. Furthermore, this study aims to explore whether knowledge and attitudes have changed between 2010 and 2019.

Methods: In this ecological study, an anonymous online questionnaire was used to collect data from health professionals working in a profession recognised by the Health Practitioners Competence Assurance Act. Professionals working with pregnant women, infants and their caregivers were sought after in particular. This questionnaire was conducted in 2010 and in 2019 with different sample populations. Questions were developed in 2010 and in line with available New Zealand guidelines that detailed management of vitamin D status. These were the Food and Nutrition Guidelines for Healthy Infants and Toddlers and for Healthy Pregnant and Breastfeeding Women, and the Cancer Society Position Statement on the Risks and Benefits of Sun Exposure. Question types were a combination of multiple response sets and true or false and yes or no response options. Knowledge questions were forced response to avoid missing data whereas participant characteristic questions were request response to respect privacy. Descriptive statistics were used to analyse the results.

Results: A total of 283 HPCAA-recognised health professionals completed this questionnaire (2010 n=193; 2019 n=90). Health professionals have good knowledge of vitamin D sources, functions and risk factors for deficiency. There appears to be confusion surrounding the vitamin D content of breastmilk (44.4% in 2010 and 31.5% in 2019 selected breastmilk as a good dietary source of vitamin D) and exclusive breastfeeding as a risk factor for deficiency (selected by 14.6% in 2010 and 32.9% in 2019). Knowledge of sun exposure guidelines was challenging to ascertain but results indicated a lack of awareness of safe sun exposure guidelines, primarily for infants. Furthermore, participants from both years were largely unsure about vitamin D supplement availability. Majority of participants did not feel there was enough information available to health professionals regarding vitamin D (81.2% in 2010; 74.4% 2019).

Conclusion: Whilst health professionals had good knowledge of deficiency risk factors, functions and sources of vitamin D, the study identified some knowledge deficits. Interventions to improve knowledge are likely to be well received as majority of participants believe there is not enough information available to health professionals about vitamin D. Areas where health professionals need further education are the vitamin D content of breastmilk, recognition of exclusive breastfeeding as a deficiency risk factor in infants, supplement availability and sun exposure guidelines.

Further studies that explore where health professionals' source their information from regarding vitamin D may provide insight as to why these gaps in knowledge have occurred and how to best rectify them. Future studies should include larger population sizes and greater population diversity.

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Abbreviation	Definition
APA	American Paediatric Association
ARTI	Acute Respiratory Tract Infection
BPACNZ	Best Practice Advocacy Centre New Zealand
DBP	Vitamin D Binding Protein
FGF23	Fibroblast Growth Factor 23
GDM	Gestational Diabetes Mellitus
GP	General Medical Practitioner
HPCAA	Health Practitioners Competence Assurance Act
IU	International Units
NRVANZ	Nutrient Reference Values for Australia and New Zealand
PTB	Pre-Term Birth
PTH	Parathyroid Hormone
RANKL	Receptor Activator of Nuclear Factor Kappa-β Ligand
RCT	Randomised Controlled Trial
SGA	Small for Gestational Age
UV	Ultraviolet
UVR	Ultraviolet Radiation
UVα	Ultraviolet α Radiation
UVβ	Ultraviolet β Radiation
VDR	Vitamin D Receptor
1,25$(OH)_2$D	1α,25-hydroxyvitamin D
25(OH)D	25-hydroxyvitamin D/Combined vitamin D_2 & vitamin D_3
7-DHC	7-Dehydorcholesterol/Pro-vitamin D_3

Chapter 1. Introduction

1.1 Background

The discovery of vitamin D was somewhat backwards in that the implications of deficiency where identified first when British physicians published works detailing the bone disease now known as rickets (Holick, 2006). Over time, researchers began to acknowledge the relationship between sun exposure, ultraviolet radiation (UVR) and bone health after rickets was found to be more prevalent in areas of high pollution (Holick, 2006).

More than a century later, the vitamin itself was recognised when biochemist Elmer McCollum treated rachitic rats with an oxidised cod liver oil (Holick, 2006). Following this, a key accomplishment in vitamin D research was contributed by Harry Steenbok. The biochemist identified that foodstuffs reacted to UVR and this finding was used as a basis for the food fortification procedures that helped to eradicate rickets around Europe and The United States in the 1940s (Holick, 2006).

Cutaneous vitamin D synthesis is the main source of vitamin D in counties with ample sunshine such as Australia and New Zealand (Nowson et al., 2012). Dietary sources of the vitamin are limited; these include oily fish or fish oils, offal, meat, eggs and dairy (Shrapnel & Truswell, 2006). Foods fortified with vitamin D provide an additional dietary source however at present, fortification with vitamin D is a voluntary process in New Zealand. Fortification is restricted to margarine and edible oils and certain dairy foods including infant formula (Food Standards Australia New Zealand, 2017; Shrapnel & Truswell, 2006). Internationally, stricter fortification policies have been associated with higher intakes of the vitamin (Shrapnel & Truswell, 2006). Vitamin D supplements are also available both on prescription and over the counter.

The most recognised function of vitamin D relates to the skeletal system as the vitamin has an endocrine function in bone mineral homeostasis by regulating serum concentrations of calcium and phosphate (Pike & Christakos, 2017). More recently however, research has turned toward the potential immunomodulatory role of vitamin D. This follows studies in rachitic children that identified an association between the bone disease and respiratory tract infections (Yakoob, Salam, Khan, & Bhutta, 2016). Following discovery of vitamin D receptor (VDR) expression in several tissues involved with immune system functioning, it is believed that the vitamin influences both the innate and adaptive immune systems (Wei & Christakos, 2015).

In the New Zealand context, vitamin D deficiency is defined as serum 25-hydroxyvitamin D (25(OH)D) at 24nmol/L or below; insufficiency is defined as 49nmol/L or below (Ministry of Health and Cancer Society of New Zealand, 2012). Clinical manifestations of deficiency include delayed growth, delayed standing and walking, and frequent falling in children (Bordelon, Ghetu, & Langan, 2009; Thacher & Clarke, 2011; van Schoor & Lips, 2018). In adults it may present as bone pain, fractures, and muscle weakness (Bordelon et al., 2009; Thacher & Clarke, 2011; van Schoor & Lips, 2018). New Zealand-based studies have identified vitamin D deficiency and insufficiency in several age brackets (Bolland et al., 2006; Camargo et al., 2010; Grant, Wall, Crengle, & Scragg, 2009; Houghton et al., 2010; Lucas et al., 2005; Ministry of Health, 2012; Rockell, Skeaff, Williams, & Green, 2006; Rockell et al., 2005).

Given UVR is the primary source of vitamin D, risk factors for deficiency are based largely on inadequate exposure to UVR (Nowson et al., 2012). Certain populations who are at risk of this include those who are housebound, institutionalised or regularly spend large amounts of daylight hours inside (Nowson et al., 2012). Inhabitants of New Zealand are exposed to greater amounts of UVR due to comparatively minimal amounts of air pollution and depletion of ozone (Pondicherry et al., 2018). Despite this, vitamin D deficiency is well-documented in this nation. Because of the high UVR, New Zealand holds one of the highest rates of skin cancer in the world (Pondicherry et al., 2018). It has been hypothesised that beliefs about skin cancer risk and subsequent sun exposure practices may contribute to vitamin D deficiency (Youl, Janda, & Kimlin, 2009). The literature is conflicting however, with many who report concern about skin cancer risk, not applying regular sunscreen (von Hurst, Stonehouse, & Coad, 2010; Walker et al., 2014). Furthermore, sunscreen use has been associated with higher serum levels of vitamin D as sunscreen use is typically associated with greater time spent outdoors (Fayet-Moore et al., 2019). Concealing clothing worn for both sun protective and religious reasons has been associated with poor vitamin D status however (Springbett, Buglass, & Young, 2010). Additionally, ethnicity influences vitamin D status as those with darker skin tones are less able to cutaneously synthesise vitamin D as effectively (Webb et al., 2018). This is secondary to the melanin pigment in skin competing with 7-dehydrocholesterol (7-DHC) for UVR photons (Webb et al., 2018). Particularly relevant to the New Zealand population is latitude. This is a proposed risk factor for deficiency as locations at higher latitudes are exposed to lesser amounts of UVR due to the earth being further away from the sun (Godar, 2005). For the same reason, season is a risk factor in the colder months of May to August. The effect of latitude on vitamin D status of New Zealanders is conflicting however when combined with the effect of season, the effect appears stronger (Ministry of Health, 2012).

Pregnant women are at greater risk of deficiency as maternal vitamin D stores are responsible for provision of vitamin D to the developing fetus. Maternal vitamin D metabolism is upregulated to support the increased requirements (Pludowski et al., 2013; Wheeler et al., 2018). Vitamin D insufficiency has been assessed in the New Zealand population of pregnant women. Wheeler et al. reported 25(OH)D levels below 50nmol/L in 65% of the 80 pregnant participants (Wheeler et al., 2018). Ekeroma et al. reported 25(OH)D levels below 50nmol/L in 109 of the 259 pregnant participants (Ekeroma et al., 2015). In a sample population of 2800 pregnant women from Australia and New Zealand, 772 women were identified as having 25(OH)D levels below 50nmol/L (Wilson et al., 2018). A recent Cochrane review has suggested that vitamin D supplementation during pregnancy may have a protective role against the development of several pregnancy complications including pre-eclampsia, gestational diabetes (GDM) and birthing an infant who is small for gestational age (SGA) (Palacios, Kostiuk, & Peña-Rosas, 2019). There is evidence to support a link between maternal vitamin D status and pre-term birth (PTB) however the results were not supported in the Cochrane review (Palacios et al., 2019). New Zealand does not incorporate these potential outcomes into supplementation guidelines at present, as the research is conflicting and the mechanisms linking vitamin D to the aetiology of these conditions remains unclear (Ministry of Health, 2013a). Furthermore, PHARMAC does not currently fund a vitamin D supplement designed specifically for pregnant women (Best Practice Advocacy Centre New Zealand, 2011). These women however may be prescribed vitamin D supplements as per preparations available through PHARMAC for the general population, if indicated (Best Practice Advocacy Centre New Zealand, 2011).

Vitamin D insufficiency and deficiency has been explored in the New Zealand population of infants and toddlers. A study of 925 healthy new-borns identified cord blood 25(OH)D levels below 25nmol/L in one out of five participants. An additional 57% of participants had 25(OH)D levels below 50nmol/L (Camargo et al., 2010). Additionally, a study of 55 infants and toddlers between the ages of 12 and 22 months who had blood samples taken in winter, reported that 78% had 25(OH)D levels below 50nmol/L (Houghton et al., 2010). Grant et al. reported that 25(OH)D levels below 27.5nmol/L were identified in 46 of the 353 participants between the ages of six and 23 months (Grant et al., 2009). Similar to pregnant women, infants have additional risk factors for vitamin D deficiency compared to the general population. These include maternal vitamin D deficiency and pre-term birth secondary to the infant's dependence on maternal stores to develop their own (Rigo & Senterre, 2006). Further risk factors are exclusive breastfeeding and limited sun exposure (Ministry of Health, 2013a). New Zealand guidelines recommend that infants who are not independently mobile are not exposed to direct sunlight at any time of the day (Ministry of Health, 2013a). This is secondary to the immaturity of their skin which carries increased susceptibility to damage by UVR (Shafie Pour, Saeedi, Morteza Semnani, & Akbari, 2015); during this time, infants are more reliant on dietary source of vitamin D. Breastmilk is not a rich source of the vitamin (Wheeler, Dickson, Houghton, Ward, & Taylor, 2015). Research suggests, however, that breastmilk may be a good source of vitamin D when the mother is supplemented with a daily dose of vitamin D. Hollis et al. reported that daily maternal supplementation with 6400IU of vitamin D safely increased the breastfed infants' vitamin D status to the same extent as supplementing the infant with a daily dose of 400IU of vitamin D (Hollis et al., 2015). Lovell et al. reported however that maternal vitamin D supplementation, dietary intake and sun exposure were not independently associated with vitamin D status of breastfed infants (Lovell, Wall, & Grant, 2016). This suggests that further evidence is required to support the role of maternal supplementation in improving the vitamin D concentration of breastmilk. Furthermore, this practice is not currently included in New Zealand guidelines (Ministry of Health, 2013a; Ministry of Health and Cancer Society of New Zealand, 2012). Breastmilk should therefore continue to be recognised as a poor source of vitamin D.

In 2019, PHARMAC opted to fund an infant-specific vitamin D-only supplement (PHARMAC, 2018). Current New Zealand guidelines recommend administering supplements to infants and pregnant women prophylactically if they present with one or more risk factors for deficiency (Ministry of Health, 2013a; Ministry of Health and Cancer Society of New Zealand, 2012). Despite this guideline, there is evidence of under-supplementation in the New Zealand paediatric population (Wheeler et al., 2015). As with pregnant women, there is a growing body of evidence which highlights extra-skeletal roles of vitamin D in infant health. It has been suggested that poor vitamin D status in infants has an association with asthma, respiratory tract infections, eczema and food allergies (Saggese et al., 2015). Further randomised controlled trials and subsequent meta-analyses are required to strengthen these findings as the results are currently conflicting (Saggese et al., 2015). The mechanisms by which vitamin D exerts these roles are unclear but thought to be immunomodulatory (Saggese et al., 2015).

Health care professionals help to educate the population about vitamin D. Furthermore, health professionals are in a key position for identifying those who may be at risk of deficiency and subsequently managing vitamin D status. For this to be effective, health professionals must have adequate awareness of this topic and of the evidence-based guidelines devised for practitioners to utilise when discussing vitamin D with patients (Dix, Robinson, Bauer, & Wright, 2017). The guideline currently available in New Zealand is the 2012 New Zealand Consensus Statement on Vitamin D (Ministry of Health and Cancer Society of New Zealand, 2012). For pregnant women and infants, the Companion Statement to the 2012 New Zealand Consensus Statement on Vitamin D is more suitable (Ministry of Health, 2013a). These documents were released in 2012 and 2013 respectively; no further updates have been provided.

Additionally, a shared Australian and New Zealand Bone Mineral Society Position Statement exists pertaining to vitamin D in adult, pregnant women and infant health (Nowson et al., 2012; Paxton et al., 2013). Prior to the release of these guidelines, information about vitamin D in relation to pregnant women and infants could be sourced from Food and Nutrition Guidelines for Healthy Infants and Toddlers (0-2): A Background Paper (Ministry of Health, 2008a) and Food and Nutrition Guidelines for Healthy Pregnant and Breastfeeding Women: A Background Paper (Ministry of Health, 2006a). A New Zealand-based study was conducted in 2010 that assessed GP's knowledge of vitamin D (Reeder, Jopson, & Gray, 2012). The study reported moderate awareness of deficiency risk factors and confusion around sun exposure guidelines during winter for achieving vitamin D adequacy (Reeder et al., 2012). To the authors knowledge, further research into the knowledge of New Zealand health professionals has not been conducted following the release of the Consensus and Companion Statements. Internationally, similar results have been observed with Australian dietitians and GPs lacking knowledge of sun exposure guidelines during winter (Bonevski et al., 2012; Dix et al., 2017). Furthermore, these studies identified that health professionals were advising unsafe sun exposure practices in summer (Bonevski et al., 2012; Dix et al., 2017). Health professionals' knowledge of vitamin D for infancy and pregnancy has been explored internationally. Awareness of supplement guidelines were explored in American health professionals with conflicting results as the outcome. Oberhelman et al. reported that health professionals, in line with American Paediatric Association guidelines (APA), prescribed vitamin D supplements to exclusively breastfed infants 70% of the time, suggesting good awareness of the guideline (Oberhelman, Cozine, Umaretiya, Maxson, & Thacher, 2018). DelGiudice et al., however, reported that health professionals were largely uncertain about vitamin D supplementation guidelines for patients aged 18 years or younger (DelGiudice et al., 2018). Similar to Oberhelman et al., AlBishi et al. reported that 77% of health professionals in their Saudi Arabia-based study prescribed vitamin D supplements to breastfed infants, as per APA guidelines, suggesting health professionals have good knowledge of the guidelines (AlBishi et al., 2018). Jain et al. reported that health professionals in their British study were uncertain about vitamin D supplementation guidelines for infants, pregnant, and breastfeeding women. Furthermore, health professionals reported uncertainty about supplementation guidelines for patients who are at high risk of deficiency (Jain, Raychaudhuri, & Barry, 2011). The aforementioned studies share similar limitations. Sample sizes are small, and the studies reference national guidelines not used in New Zealand. There is a gap therefore, in New Zealand literature relating to health professionals' knowledge of vitamin D for pregnancy and infancy.

1.2 Purpose of Study

Outcomes of recent research have highlighted vitamin D's involvement in immune system functioning, in prevention of complications of pregnancy and in prevention of common childhood diseases (Palacios et al., 2019; Yakoob et al., 2016). Continuing to assess knowledge of vitamin D in health care providers is therefore a justified research avenue, given the seriousness of vitamin D's suggested roles.

According to New Zealand guidelines, testing of serum vitamin D concentration is too costly for conducting on a national level. Guidelines therefore focus on prevention of vitamin D deficiency and identification of those who are most at risk (Ministry of Health and Cancer Society of New Zealand, 2012). Evidence suggests that health professionals in Australia and New Zealand have a varied understanding of deficiency risk factors and sun exposure guidelines that are suitable for managing skin cancer risk whilst achieving vitamin D adequacy (Bonevski et al., 2012; Dix et al., 2017; Reeder et al., 2012; Reeder, Jopson, & Gray, 2013). Furthermore, this research is mostly limited to knowledge of GPs (Bonevski et al., 2012; Reeder et al., 2012) and does not extend to other professions who are likely to work with pregnant women and infants such as midwives and Plunket nurses. Lastly, this evidence is outdated as it was conducted prior to the release of the Consensus and Companion Statements.

To the authors knowledge, there is no New Zealand-based research that specifically assesses health professionals' knowledge of vitamin D for pregnancy and infancy. Internationally, awareness of vitamin D supplement guidelines for infants has been explored with conflicting outcomes (AlBishi et al., 2018; DelGiudice et al., 2018; Jain et al., 2011; Oberhelman et al., 2018). American, Saudi-Arabian and British studies report uncertainty amongst health professionals regarding vitamin D supplementation guidelines for infants (AlBishi et al., 2018; DelGiudice et al., 2018; Jain et al., 2011). An American study reported good awareness of supplementation guidelines in health professionals, however (Oberhelman et al., 2018). These studies are limited by their small sample sizes and use of differing guidelines than those used in New Zealand. As such, this data cannot be extrapolated to the New Zealand population. New Zealand-based research is therefore needed.

This study hopes to build on the understanding of health professional's knowledge of vitamin D for the general population, pregnant women and infants. Results of this study may identify gaps in knowledge and thus can be used to identify where further education is needed for health professionals relating to vitamin D.

1.3 Aim

The aim of this study is to explore health professionals' knowledge, attitudes and current practices toward vitamin D for the general population, pregnancy and infancy. Furthermore, this study aims to explore whether knowledge and attitudes have changed between 2010 and 2019.

1.4 Objectives

1. To assess changes in health professionals' knowledge of vitamin D sources, functions and deficiency risk factors.
2. To assess changes in health professionals' knowledge and attitudes toward New Zealand sun exposure guidelines for vitamin D adequacy.
3. To assess changes in health professionals' awareness of vitamin D supplements in New Zealand for pregnancy and infancy.
4. To explore changes in health professionals' current practices when vitamin D deficiency is suspected in a pregnant or infant patient.

1.5 Thesis Structure

The first chapter of this thesis provides the background and purpose of this study. The aim and objectives of the study are also outlined here. Chapter two is comprised of a review of the literature. This review provides a more in-depth background to the study and covers key aspects of vitamin D physiology as well as guideline content for the general population, pregnancy and infancy. Furthermore, it reviews the available literature pertaining to health professionals' knowledge of vitamin D. In chapter three is the research study manuscript. This chapter includes a full description of the methods employed and results obtained by this study. Chapter four provides a summary of the manuscript in that it provides a conclusion, an overview of the study's contribution to current literature and recommendations for the use of this data. Located in the appendices are additional findings not discussed in chapter three, the documents required for the research's approval and the information provided to participants including a blank copy of the questionnaire.

1.6 Researcher's Contributions

Table 1.1 Researcher's Contributions

Researcher	Contribution
Alex Thomson Master of Science Nutrition and Dietetics Student	Primary researcher and main contributor to 2019 questionnaire process; completed ethics application and associated documents, conducted literature review, recruited questionnaire participants, completed data collection, entry and analysis, including analysis of 2010 data, prepared final manuscript.
Associate Professor Pam von Hurst Academic Supervisor	Main contributor to 2010 questionnaire process; review of literature, designed questionnaire, completed ethics application and associated documents, recruited questionnaire participants, completed data entry. Assisted with 2019 questionnaire recruitment, supervised manuscript development.
Associate Professor Cath Conlon Academic Supervisor	Main contributor to 2010 questionnaire process; review of literature, designed questionnaire, completed ethics application and associated documents, recruited questionnaire participants, completed data entry. Assisted with 2019 questionnaire recruitment, supervised manuscript development.

Chapter 2. Literature Review

In this chapter is a review of the literature relating to vitamin D's history, sources, physiology and roles in human health. Furthermore, it covers vitamin D in relation to pregnancy and infancy, and health professionals' knowledge of this topic. PubMed and Google Scholar were used with search terms that had been determined based on the aims and objectives of this study. Filters were used to improve applicability of large search returns. The following filters were applied: past two years, past five years, past 10 years. Journal articles were used only if they were published in English and had the full-text available. The following search terms were used:
Vitamin D
AND functions
AND deficiency
AND insufficiency
AND risk factors
AND New Zealand
AND supplementation
AND pregnancy OR maternal
AND infancy OR child
AND healthcare professional OR healthcare practitioner OR health professional OR health practitioner
AND knowledge
AND attitude

2.1 Brief History of Vitamin D:

The journey of vitamin D's discovery, unbeknownst to researchers at the time, dates back to the 1600s where Britain-born physicians Daniel Whislter and Francis Glisson published independent works that described one of the more serious outcomes of vitamin D deficiency, rickets (Holick, 2006; Norval, 2005; O'riordan & Bijvoet, 2014; Wolf, 2004). Jędrzej Śniadecki, a Poland-born physician, provided the next publication that alluded to vitamin D. His work, published in the 1800s, identified a higher prevalence of rickets amongst children living in polluted areas of Warsaw and he attributed this to a lack of sun exposure (Holick, 2006; Norval, 2005; O'riordan & Bijvoet, 2014; Wolf, 2004). Śniadecki's research, however, went largely unnoticed (Holick, 2006; Norval, 2005; O'riordan & Bijvoet, 2014; Wolf, 2004).

Much later in the 1920s, paediatrician Kurt Huldschinsky hypothesised that artificial sunlight would be sufficient for treating rickets (DeLuca, 2014; Holick, 2006; Wierzbicka, Piotrowska, & Żmijewski, 2014; Wolf, 2004). Huldschinsky was able to confirm his hypothesis after exposing rachitic children to UVR emitted from mercury lamps. There was an improvement in their symptoms without any exposure to natural sunlight or use of supplements (DeLuca, 2014; Holick, 2006; Wierzbicka et al., 2014; Wolf, 2004). Two years following this work, physicians Alfred Hess and L. J. Unger were able to alleviate symptoms of rickets in children by exposing them to sunlight (DeLuca, 2014; Holick, 2006; Wierzbicka et al., 2014; Wolf, 2004). Vitamin D as the key piece of this puzzle had not yet been alluded to.

Another arm of vitamin D's discovery was being undertaken by physician Sir Edward Mellanby circa 1920 (DeLuca, 2014; Holick, 2006; Norval, 2005; Wierzbicka et al., 2014; Wolf, 2004). By this point, the scientific community had an understanding that trace elements within foods, namely vitamins A, B and C, were essential for human health. Captivated by this work, Mellanby suspected that, like xeropthalmia, beri beri and scurvy, rickets may be a disease that occurs due to a deficiency in the diet (DeLuca, 2014; Holick, 2006; Norval, 2005; Wierzbicka et al., 2014; Wolf, 2004). Mellanby went on to successfully treat rachitic Beagles with cod liver oil.

It was not until Elmer McCollum, a biochemist, repeated the experiment with rats however, that the antirachitic component was correctly determined. Mellanby attributed the antirachitic effect to the already-discovered vitamin A; McCollum however, following oxidation of the cod liver oil and thus degradation of its vitamin A content, concluded that a new vitamin was responsible (DeLuca, 2014; Holick, 2006; Norval, 2005; Wierzbicka et al., 2014; Wolf, 2004). This new vitamin was aptly named with the next available letter in the alphabet, vitamin D (DeLuca, 2014; Holick, 2006; Norval, 2005; Wierzbicka et al., 2014; Wolf, 2004).

The research took a different direction when Harry Steenbok, a professor of biochemistry, discovered in 1924 that not only humans but foodstuffs reacted to UVR; irradiation of the food given to rachitic rats successfully alleviated their symptoms (DeLuca, 2014; Holick, 2006; Norval, 2005; Wierzbicka et al., 2014; Wolf, 2004). This work was extremely important in development of food fortification procedures that aided in the eradication of rickets in Europe and the United States by the 1940s (Holick, 2006).

One of the final, key pieces of work in vitamin D's discovery was identification of the differing vitamin D structures (DeLuca, 2014; Holick, 2006; Norval, 2005; Wierzbicka et al., 2014; Wolf, 2004). This research was led by German chemist Adolf Windaus and his research team in the 1930s (DeLuca, 2014; Holick, 2006; Norval, 2005; Wierzbicka et al., 2014; Wolf, 2004). In 1955, Harry Steenbok, previously mentioned for his contribution to the eradication of rickets, retired and handed his laboratory over to his graduate chemistry student Hector DeLuca (Wierzbicka et al., 2014). DeLuca later joined forces with Michael Holick, an endocrinologist; the pair contributed many advancements in the field of vitamin D research, both independently and collaboratively (Wierzbicka et al., 2014). DeLuca and Holick were pioneers in understanding vitamin D metabolism and they continue with this work today (Wierzbicka et al., 2014).

2.2 Sources and Metabolism:

There are two chemical forms of this fat-soluble vitamin; ergocalciferol or Vitamin D_2 and cholecalciferol or Vitamin D_3 (Gil, Plaza-Diaz, & Mesa, 2018; Holick, 2017; Tripkovic, Wilson, & Lanham-New, 2017). The two forms differ only by their sidechain structure; they share the same activation mechanism and prohormone activity (Gil et al., 2018).

2.2.1 Radiation

Both vitamin D_2 and vitamin D_3 can be synthesised via action of ultravioletβ radiation (UVβ) (Gil et al., 2018; Holick, 2007; Lehmann & Meurer, 2010; Tuckey, Cheng, & Slominski, 2018). This mechanism is the primary source of vitamin D_3 for humans. In human skin, 7-DHC, otherwise known as pro-vitamin D_3 and is predominantly located in the plasma membrane of cells within the epidermis layer, absorbs UVβ at wavelengths of 290-315nm and is converted to biologically inactive pre-calciferol, otherwise known as pre-vitamin D_3 (Gil et al., 2018; Holick, 2007; Lehmann & Meurer, 2010; MacLaughlin, Anderson, & Holick, 1982; Tuckey et al., 2018; Wacker & Holick, 2013). Vitamin D intoxication from UVβ-stimulated synthesis is not possible. This is because prolonged exposure to UVβ causes pre-calciferol to isomerise into lumisterol$_3$ and tachysterol$_3$, both of which are biologically inactive, or back to 7-DHC (Buckley, Hannoun, Lessan, Holick, & Barakat, 2017; Wacker & Holick, 2013).

In a heat-dependent reaction, pre-calciferol isomerizes to cholecalciferol (Gil et al., 2018; Tian, Chen, Matsuoka, Wortsman, & Holick, 1993; Tuckey et al., 2018; Wacker & Holick, 2013). This change in structure causes cholecalciferol to be released from the plasma membrane where it was once incorporated in the phospholipid bilayer (Holick, 1988, 2003, 2008b). To enter the circulatory system, cholecalciferol diffuses from the epidermis layer to the dermal capillary bed and is carried to the liver bound to vitamin D binding protein (DPB) (Holick, 1988, 2008b; Osmancevic et al., 2015).

In a similar manner to vitamin D_3 metabolism, ergosterol, a membrane-bound sterol otherwise known as provitamin D_2, is converted to biologically inactive pre-ergocalciferol (pre-vitamin D_2) which further isomerises to ergocalciferol (Gil et al., 2018; Jäpelt & Jakobsen, 2013; Keegan, Lu, Bogusz, Williams, & Holick, 2013). Synthesis of vitamin D_2 by radiation is not a metabolic function that humans are capable of but instead occurs in fungi. For this reason, humans are able to obtain vitamin D_2 only from the diet.

2.2.2 Dietary

Although not the primary source for humans, vitamin D can be obtained from the diet in small amounts via a limited number of foods (Shrapnel & Truswell, 2006). Natural food sources of vitamin D_2 are of plant-origin and primarily include members of the Kingdom Fungi, namely mushrooms and yeast. These foods however must undergo UVβ exposure in order for vitamin D_2 to become utilisable for human metabolism (Hayes & Cashman, 2017; Keegan et al., 2013). Vitamin D_3 is naturally present without need for radiation in oily fish and or fish oils, offal, meat, eggs and dairy (Holick, 2008b, 2017; Schmid & Walther, 2013; Tripkovic et al., 2017; Wilson, Tripkovic, Hart, & Lanham-New, 2017). There is concern that healthy eating guidelines both in New Zealand and around the world typically do not support an intake of dietary vitamin D that is sufficient to meet adequate intake reference ranges (Shrapnel & Baghurst, 2007; Shrapnel & Truswell, 2006). This is secondary to the guidelines supporting reduced dietary fat intakes as a means of preventing obesity and cardiovascular disease (Shrapnel & Truswell, 2006). The 2008/09 New Zealand Adult Nutrition Survey did not analyse dietary vitamin D intake as food composition data for this nutrient was deemed unreliable (Ministry of Health, 2011).

The Nutrient Reference Values for Australia and New Zealand (NRVANZ) recommend a dietary intake of 5μg per day as this figure safely accounts for minimal sunlight exposure (Ministry of Health, 2006b). There is variation in the vitamin D content of foods within each of the aforementioned, vitamin D-rich food groups which highlights the need for specificity when discussing dietary modifications to ensure adequate vitamin D intake (The New Zealand Institute for Plant and Food Rsearch Limited & The Ministry of Health, 2016).

Dietary vitamin D_2 and vitamin D_3, are absorbed in the small intestine and arrive at the liver via transport in chylomicrons (Gil et al., 2018; Jäpelt & Jakobsen, 2013).

2.2.3 Food Fortification

In 1996, the New Zealand government permitted voluntary vitamin D fortification of margarine and edible oil spreads, as well as dairy foods including infant milk formulas but excluding full-fat milk (Food Standards Australia New Zealand, 2017). Infant formulas in New Zealand are required to contain 0.25-0.63μg of vitamin D per 100kJ (Grant et al., 2009). Fortification policies vary around the world; more wide-spread or mandated rather than voluntary fortification is associated with higher intakes of vitamin D (Calvo & Whiting, 2013; Cashman & Kiely, 2016; Itkonen, Erkkola, & Lamberg-Allardt, 2018; Nowson & Margerison, 2002; Nowson et al., 2012; Shrapnel & Truswell, 2006). Similarly to naturally occurring food sources of vitamin D, fortified foods are unable to provide adequate vitamin D to meet requirements when UVR is lacking (Green, Skeaff, & Rockell, 2010; Itkonen et al., 2018). In a 2010 randomised controlled trial (RCT) with 73 New Zealand-based females, participants receiving fortified milk had significantly higher levels of vitamin D than the controls. This increase was unable to buffer the seasonal decline in vitamin D levels, however that occur secondary to changes in intensity of UVR (Green et al., 2010).

2.2.4 Supplements

Supplementation is effective in meeting vitamin D requirements when dietary intake and UVR is inadequate (Płudowski et al., 2013). Over-the-counter dietary vitamin D supplements are readily available to the New Zealand population. For groups at risk of deficiency however, part- or fully-subsidised preparations are available with prescription. The 2012 New Zealand Consensus Statement on Vitamin D and The Best Practice Advocacy Centre New Zealand (BPACNZ) recommend prescription of vitamin D supplements prophylactically to these at-risk groups without need for testing vitamin D status (Best Practice Advocacy Centre New Zealand, 2011; Ministry of Health and Cancer Society of New Zealand, 2012). These publications were released in 2012 and 2011 respectively. No further supplement guidelines have since been released in New Zealand. BPACNZ states that supplements should be prescribed when an at-risk individual is unable to increase their amount of direct sun exposure or increase their intake of dietary vitamin D. Furthermore, the 2012 New Zealand Consensus Statement advises that dietary vitamin D supplements that are non-PHARMAC-subsidised are not recommended. This is due to the unpredictability in manufacturing quality, variation of dose and safety of co-ingredients.

2.2.5 Activation

In the form of vitamin D_2 or vitamin D_3, the vitamin has little biological activity. Vitamin D_2 and vitamin D_3 must first undergo two hydroxylation reactions catalysed by enzymes from the cytochrome p450 family (Bikle, 2016; Gil et al., 2018; Lips, 2006). In the liver, vitamin D is converted to 25(OH)D; the circulating and storage form of vitamin D (Gil et al., 2018; Jablonski & Chaplin, 2018). 25(OH)D bound to DPB arrives at the kidneys where it is converted to 1α,25-hydroxyvitamin D ($1,25(OH)_2D$) in the renal proximal tubules. It is in this form that vitamin D is biologically active and able to exert its hormone functions via stimulation of gene expression within target tissues (Gil et al., 2018; Jablonski & Chaplin, 2018). Tissues that require calcitriol express VDR, a nuclear receptor (Jablonski & Chaplin, 2018).

2.3 Function of Vitamin D

The roles of vitamin D in human health can be divided into two categories, classic and non-classic. The former being the well-established, endocrine role in bone mineral homeostasis and the latter being a wider range of extra-skeletal functions. Non-classical roles include involvement in the immune system, the central nervous system, cell proliferation and in cardiovascular health (Gil et al., 2018; Humble, 2010; Pike, Meyer, Lee, Onal, & Benkusky, 2017; Wang et al., 2017). At this point in time there is no general consensus around the mechanisms behind these non-classical roles thus are not included in public health initiatives.

2.3.1 Bone

Vitamin D's endocrine function in bone mineral homeostasis ensures that the serum concentration of calcium and phosphate remains stable (Gil et al., 2018; Pike & Christakos, 2017). These two minerals give rise to hydroxyapatite; a mineral matrix that gives bone its rigidity and strength (Bonjour, 2011). In its active form of calcitriol, vitamin D upregulates intestinal absorption and renal reabsorption of these minerals thus preserving skeletal stores (Christakos, Dhawan, Porta, Mady, & Seth, 2011; Gil et al., 2018; Pike & Christakos, 2017). Calcitriol can also act to regulate bone mineralisation. Given that bone is a large reservoir of these minerals, bone mineral resorption will increase serum calcium levels when dietary intake of the mineral is lacking (Gil et al., 2018; Pike & Christakos, 2017). Osteoblastic expression of RANKL is stimulated by calcitriol which in turn activates osteoclasts and thus promotes mineral resorption from bone (Anderson, Turner, & Morris, 2012; Takeda et al., 1999).

To maintain normal function, calcitriol is regulated by the enzymes responsible for its activation and degradation; 1α-hydroxylase and 24-hydroxylase respectively (Gil et al., 2018; Pike & Christakos, 2017). Two hormones, fibroblast growth factor 23 (FGF23), secreted predominantly by osteoblasts, and parathyroid hormone (PTH), secreted from the parathyroid gland, regulate the expression of the two enzymes and are released in response to extracellular phosphate and calcium levels respectively (Gil et al., 2018; Pike & Christakos, 2017).

2.3.2 Immune Function

Studies in rachitic children began to note an association between this condition and respiratory tract infections. Originally this was thought to be a result of bone deformities impacting lung function. Advancements in this field of research however, have identified the cellular mechanisms by which vitamin D impacts the immune system functioning (Yakoob et al., 2016). A key advancement being identification of VDR and 1α-hydroxylase expressed in tissues that do not have an association with bone mineral homeostasis (Prietl, Treiber, Pieber, & Amrein, 2013; Wei & Christakos, 2015). From here, many cells of the immune system were identified as having a relationship with vitamin D. Within the innate immune system, vitamin D appears to promote differentiation of monocytes into macrophages and enhance their antimicrobial functions, phagocytosis and chemotaxis (Baeke, Takiishi, Korf, Gysemans, & Mathieu, 2010; Prietl et al., 2013). Furthermore, the vitamin may promote transcription of cathelicidin and beta-defensin; antimicrobial peptides that functions by destroying the integrity of microbial membranes (Baeke et al., 2010; Prietl et al., 2013).

Within the adaptive immune system, it has been proposed that vitamin D may downregulate B cell function. In doing so, vitamin D may have a protective role against autoimmune conditions given that B cells secrete antibodies. When autoreactive, these antibodies contribute to the aetiology of autoimmunity (Prietl et al., 2013; Walker & Modlin, 2009; Wu, Lewis, Pae, & Meydani, 2018). Secondly, vitamin D may influence T cell function in that it down regulates T cell secretion of pro-inflammatory cytokines. Vitamin D also promotes differentiation of T cells into Th2 cells and regulatory T cells which function to be anti-inflammatory and to prevent hyper- or misdirected immune responses (Prietl et al., 2013; Walker & Modlin, 2009; Wu et al., 2018).

The 2012 New Zealand Consensus Statement on Vitamin D concluded that there was not enough evidence to develop public health messages that incorporate vitamin D for immune health. The consensus statement has not since been reviewed however much of the evidence around vitamin D for immune function evolved after this time.

2.4 Outcomes of Vitamin D Deficiency

2.4.1 Classic Outcomes

Similar to the functions of vitamin D, outcomes of deficiency can be classified as classic and non-classic. Classically, vitamin D deficiency has been associated with diseases of the skeletal system that effect the integrity and function of bone; this includes rickets in children and osteomalacia or osteoporosis in adults (Theodoratou, Tzoulaki, Zgaga, & Ioannidis, 2014). Outside of bone structure, calcium and phosphate have a variety of roles such as in cell signalling, neurotransmission and in muscle function (Shaker & Deftos, 2018). Serum levels of calcium, and to a slightly lesser extent phosphate, are tightly regulated within a very narrow range to preserve the variety of roles these minerals have (Shaker & Deftos, 2018). When vitamin D is insufficient, serum calcium and phosphate concentrations cannot be maintained at an adequate level and will be resorbed from bone (Civitelli & Ziambaras, 2011; Silva & Bilezikian, 2015; van Driel & van Leeuwen, 2017). Receptors located in the membrane region of the cells of the parathyroid gland detect serum calcium levels and secrete PTH in response to hypocalcaemia (Civitelli & Ziambaras, 2011; Silva & Bilezikian, 2015).

PTH acts to increase serum calcium via upregulation of renal calcium resorption and calcium liberation from bone via stimulation of osteoclastic bone remodelling (Civitelli & Ziambaras, 2011; Silva & Bilezikian, 2015). Chronic vitamin D deficiency therefore results in weakened bone structure secondary to bone lacking sufficient mineral density (Anderson et al., 2008).

2.4.2 Non-Classic Outcomes

In more recent years, research has turned towards non-classical outcomes outside of the skeletal system. The potential implications of vitamin D deficiency include increased risk of certain cancers such as colon, breast and prostate (Baggerly et al., 2015; Holick, 2008a); autoimmune conditions such as rheumatoid arthritis, multiple sclerosis, inflammatory bowel disease and type 1 diabetes (Feng et al., 2015; Harrison, Li, Jeffery, Raza, & Hewison, 2019; Kabbani et al., 2016; Pierrot-Deseilligny & Souberbielle, 2017); infectious diseases, mental health disorders and cardiovascular disease (Gil et al., 2018; Humble, 2010; Pike & Christakos, 2017; Theodoratou et al., 2014). At present, the evidence for prophylactic or interventional use of vitamin D is largely inconclusive and screening for vitamin D deficiency is not a front-line strategy for prevention of the aforementioned conditions (Holick, 2011; Theodoratou et al., 2014).

2.5 Prevalence of Vitamin D Deficiency

2.5.1 Defining Deficiency

To explore the prevalence of vitamin D deficiency, sufficiency and deficiency must first be defined. The gold standard for measurement of vitamin D status is high performance liquid chromatography tandem mass spectrometry (Holick, 2009). This method is used to measure serum 25(OH)D, the preferred metabolite used to define vitamin D status. Although no globally accepted guideline exists, most organisations, including the New Zealand Ministry of Health, agree that serum 25(OH)D is adequate when at a level of 50 nmol/L or above; a level of 24 nmol/L or below signals deficiency (Ministry of Health and Cancer Society of New Zealand, 2012). Other organisations such as the Endocrine Society believe that vitamin D deficiency should be defined as a serum 25(OH)D level below 50nmol/L and insufficiency as a serum 25(OH)D level below 75nmol/L (Holick et al., 2011). For the purpose of this study, vitamin D levels defined by the New Zealand Ministry of Health have been used for reference when discussing vitamin D status. Clinical manifestations include bone pain, delayed growth, delayed standing and walking and frequent falling in children. In adults, it may present as bone pain, fractures and muscle weakness (Bordelon et al., 2009; Thacher & Clarke, 2011; van Schoor & Lips, 2018).

2.5.2 Prevalence of Vitamin D Deficiency in New Zealand

Given the array of method of determining vitamin D status, nor is there a universally accepted range by which vitamin D status is defined, comparing trends in deficiency between populations can be problematic. Despite these challenges, there is evidence to suggest that vitamin D deficiency is making a resurgence on a global level (Hilger et al., 2014; Mithal et al., 2009). In New Zealand, sub-optimal vitamin D concentrations have been observed in several age brackets. In a study of 925 healthy new-borns, one in five were found to have cord blood concentrations of 25(OH)D below 25nmol/L (Camargo et al., 2010). A further two studies that included children between the ages of six and twenty three months of age identified prevalent vitamin D insufficiency in early childhood dependent on ethnicity and the season in which the status was measured (Grant et al., 2009; Houghton et al., 2010). The chemiluminescence immunoassay and radioimmunoassay methods used for determining 25(OH)D levels in these studies however, have been shown to produce results of poorer accuracy compared to the preferred method, high performance liquid chromatography (Snellman et al., 2010). Delshad et al. reported that 25.6% of the 507 participants between the ages of eight and 11 years had 25(OH)D concentrations below 50nmol/L (Delshad et al., 2019).

Using lower cut off values, in a study of 1585 children aged five to fourteen 31% were identified as being vitamin D insufficient (<37.5nmol/L) and a further 4% as deficient (<17.5nmol/L) (Rockell et al., 2005). The generalisability of this study is strengthened by the relatively even representation of New Zealand European, Māori and Pacific ethnicities within the sample population.
Using the same cut off of 17.5nmol/L, a study of 2946 men and women aged 15 years and over found that 4% of the participants were deficient; 48% were found to be insufficient when using the common cut off of 50nmol/L (Rockell et al., 2006). The latter value is much higher than findings from the 2008/09 Adult Nutrition Survey where 27.1% of participants within this age group were identified as being deficient (Ministry of Health, 2012). Suboptimal vitamin D levels have been identified in post-menopausal women but were less common in men of similar age (Bolland et al., 2006; Lucas et al., 2005).

2.6 Risk Factors for Deficiency in the General Population

2.6.1 Sun Exposure

Australasian adults acquire 90-95% of their daily vitamin D dose via endogenous synthesis following exposure to UVβ (Nowson et al., 2012). Therefore, the greatest risk factor for vitamin D deficiency is inadequate exposure to sunlight (Nowson et al., 2012). Groups at risk of inadequate sunlight exposure include those who are housebound, institutionalised or regularly spend large amounts of daylight hours inside (Nowson et al., 2012).

Inhabitants of New Zealand are exposed to greater amounts of UVR due to a comparative lack of air pollution and depletion of ozone (McKenzie, 2017; Pondicherry et al., 2018). Despite the higher levels of UVR, vitamin D deficiency is possible and increasingly prevalent within this country (Nowson et al., 2012).

2.6.2 Sun Protection Behaviours

Rates of skin cancer in New Zealand are some of the highest in the world (Apalla, Lallas, Sotiriou, Lazaridou, & Ioannides, 2017; McKenzie, 2017; Pondicherry et al., 2018). This is secondary to the aforementioned depletion of ozone, the atmospheric gas which absorbs UVR thus reducing its mutagenic effects (Abbasi & Abbasi, 2017). Beliefs about skin cancer risk may therefore influence sunlight exposure behaviours and subsequently, the vitamin D status of New Zealand populants.

A study of 110 New Zealand-based outdoor athletes found that participants expressed greater concern about skin cancer risk than their vitamin D status. Only 10% of participants however reported always applying sunscreen before spending time in the sun suggesting that awareness of skin cancer risk may not be correlated to changing sun exposure behaviours (Walker et al., 2014). A study of 140 South Asian women living in New Zealand reported similar results with 20% of participants commenting on the strength of New Zealand's sunshine, ozone depletion and skin cancer risk. Furthermore, 49% of participants indicated they would spend more time in the sun if they were not concerned about skin cancer. Only 17% of participants however reported always using sunscreen when going outside (von Hurst et al., 2010). Despite growing concern that skin cancer and sun avoidance messages are contributing to an increase in vitamin D deficiency, the evidence linking beliefs about skin cancer and sun exposure practices doesn't appear to support this hypothesis in the New Zealand population. These two studies are limited by their small sample sizes, however.

In Australian-based studies however, where the UVR environment is similar, beliefs and subsequent behaviours appear to share a stronger correlation. A study of 2001 residents from Queensland, Australia found that participants who agreed that regular protection of their skin from the sun increased the risk of an inadequate vitamin D status, were more likely to never use sunscreen. Similarly, participants who did not agree were more likely to use sunscreen always or most of the time (Youl et al., 2009). Again, a study of 1971 office workers residing in Brisbane, Australia reported that participants who believed sun protective behaviours may cause vitamin D deficiency, indicated less frequent use of sunscreen (Vu, van der Pols, Whiteman, Kimlin, & Neale, 2010).

Whilst in a laboratory setting sunscreen greatly reduces the cutaneous production of vitamin D (Matsuoka, Ide, Wortsman, Maclaughlin, & Holick, 1987), several non-experimental studies have yielded conflicting results. In a 2019 review of 75 international studies, four experimental studies were able to associate sunscreen use with decreased vitamin D production. The remaining observational and field studies found no effect on or higher vitamin D levels associated with sunscreen use (Neale et al., 2019). A further study of 103 Sydney-based adults found a statistically significant association between sunscreen use and higher vitamin D levels (Fayet-Moore et al., 2019). It was concluded that sunscreen application outside of an experimental setting does not typically adhere to recommended application frequency and concentration, thus a reduction in cutaneous vitamin D production is not observed (Fayet-Moore et al., 2019). Use of long clothing for protection against the sun however has been associated with reduced cutaneous vitamin D production (Springbett et al., 2010).

The evidence surrounding sun protection behaviours and their impact on vitamin D status is conflicting. Individuals should continue to use protective clothing and apply sunscreen when outdoors as per the Cancer Society guidelines to reduce the risk of developing skin cancer (Cancer Society of New Zealand, 2017). This is particularly important within the hours of 10am to 4pm during the warmer months of September through to April where UVR is at its strongest in New Zealand. During these warmer months, the 2012 New Zealand Consensus Statement recommends partaking in some form of outdoor physical activity outside of these hours to allow for cutaneous vitamin D synthesis with less risk of sun damage. Sun exposure outside of the peak sunlight hours is necessary as UVβ must come into contact with the skin directly to stimulate cutaneous vitamin D synthesis; UVβ cannot penetrate through glass windows. Exposure to sunlight is not safer behind glass however, as the more carcinogenic UVα is able to penetrate glass (Khan, Travers, & Kemp, 2018).

2.6.3 Ethnicity

Aside from sun protection, long clothing may be worn for cultural or religious regions. A 2019 study of 90 Kuwait females found that participants wearing a hijab or veil were more likely to be deficient in vitamin D (Al-Yatama, AlOtaibi, Al-Bader, & Al-Shoumer, 2019). These findings are very applicable given the continuing growth of the Middle Eastern population in New Zealand (Statistics NZ, 2019). In a New Zealand based study, vitamin D levels below 50nmol/L were identified in Middle Eastern women. Mazahery et al. reported that the mean serum 25(OH)D concentrations amongst 61 Middle Eastern female participants in two experimental groups was 44±16nmol/L and 48±11nmol/L (Mazahery, Stonehouse, & Von Hurst, 2015).

It is important to note the skin tone of the participants in the 2019 study as all were olive skinned (skin type IV). The concentration of an individual's melanin pigmentation influences their capability to cutaneously synthesise vitamin D. This is because melanin acts as a natural sunscreen by absorbing UVβ thus preventing damage to the underlying layers of the skin. As a result, UVβ photons are less available for absorption by 7-DHC. Individual's with darker skin tones and thus more melanin are therefore at greater risk of vitamin D deficiency despite achieving regular sunlight exposure (Webb et al., 2018).

Delshad et al. reported that children in their study with dark or brown skin colour had lower mean 25(OH)D levels (51±18nmol/L) than the New Zealand European participants (75±20nmol/L) (Delshad et al., 2019).

In New Zealand's UVR conditions, it has been proposed that individuals with darker skin tones require sun exposure that is three to six times longer in duration than their fairer skinned counterparts (Nowson et al., 2012). Ethnicity is often used to categorise skin tone in New Zealand guidelines (Nowson et al., 2012). Migration and inter-ethnic marriages however, have led to a disassociation between ethnicity and skin colour (Callister, Galtry, & Didham, 2011). This highlights need for caution and specificity when promoting safe sun exposure guidelines for vitamin D synthesis and skin cancer prevention (Callister et al., 2011).

2.6.4 Season and Latitude

Winter months and higher latitudes reduce the intensity of UVβ as a result of the earth being at a greater distance from the sun, therefore impacting cutaneous vitamin D synthesis (Godar, 2005). It has been documented that cutaneous vitamin D synthesis may not occur for some months out of the year at latitudes of 50° and above as UVR is inadequate to stimulate production (Engelsen, Brustad, Aksnes, & Lund, 2005).

During New Zealand's winter, the southern region which sits at 40-47° receives half the amount of UVR than the northern region which sits at 35-40° (McKenzie, Bodeker, Keep, Kotkamp, & Evans, 1996; Rockell et al., 2005). In 2015, a New Zealand prospective surveillance study identified greater incidence of rickets in children living in southern regions of the country (Wheeler et al., 2015). A more recent 2017 New Zealand study however found no geographical differences in vitamin D levels between the 1329 children under five years old that were recruited (Cairncross et al., 2017). The former study found the greatest number of cases following winter highlighting the impact of seasonality, whereas the latter study was itself conducted during late winter, so the seasonal patterns were not able to be analysed. In a New Zealand study of 1606 healthy women who were post-menopausal and over the age of 54, seasonal differences in vitamin D levels were statistically significant with 0-3% of the participants deficient in summer versus 6-15% in winter (Lucas et al., 2005).

The evidence for latitude alone appears conflicting however in conjunction with seasonality, the impact is more defined. Findings from the 2008/09 New Zealand Adult Nutrition Survey highlighted that latitude and season had a combined effect as inhabitants of South New Zealand were 3.1 times more likely to be deficient in vitamin D from August through to October (Ministry of Health, 2012). Latitude alone did not yield statistically significant differences in vitamin D status (Ministry of Health, 2012).

The 2012 New Zealand Consensus Statement on Vitamin D recommends participating in outdoor physical activity around midday with face, arms and hands exposed to optimise cutaneous vitamin D synthesis during the colder months of May through to August. Furthermore, inhabitants of the Southern region of New Zealand who spend minimal time outdoors from May to August are recognised as an at-risk population (Ministry of Health and Cancer Society of New Zealand, 2012).

2.7 Vitamin D in Pregnancy

Maternal vitamin D stores provide the sole source of vitamin D for the developing fetus. During pregnancy, maternal vitamin D metabolism is upregulated and is characterised by increased serum calcitriol, DPB and renal 1α-hydroxylase. Furthermore, there is expression of placental VDR and 1α-hydroxylase (Agarwal, Kovilam, & Agrawal, 2018; Pludowski et al., 2013).

2.7.1 Supplementation with Vitamin D During Pregnancy

Primarily, upregulation of maternal vitamin D metabolism occurs to ensure adequate calcium provision for fetal bone mineralisation (Agarwal et al., 2018; Pludowski et al., 2013). As research has developed beyond the skeletal function however, maternal vitamin D deficiency has been associated with several adverse health outcomes in both the mother and neonate (Agarwal et al., 2018; Pludowski et al., 2013). The Companion Statement to the 2012 New Zealand Consensus Statement on Vitamin D concluded there was not enough evidence in support of vitamin D supplementation during pregnancy for the prevention of these outcomes.

The Cochrane Review however, which this conclusion was based on, has since been updated (Palacios et al., 2019). Vitamin D supplementation during pregnancy may reduce the risk of pre-eclampsia, gestational diabetes meletus (GDM) and severe post-partum haemorrhage. Risk of pre-term birth is unlikely to be reduced with vitamin D supplementation. The Cochrane review reported however, that when vitamin D and calcium were supplemented together, the risk of pre-term birth was increased (Palacios et al., 2019). This highlights the need for both further research and clear supplementation guidelines. For the neonate, maternal vitamin D supplementation may reduce the risk of low birthweight (Palacios et al., 2019).

The 2012 New Zealand Consensus Statement on Vitamin D reported that prophylactic supplementation may be beneficial however, if a pregnant woman meets one or more of the at-risk criteria for deficiency. Pregnant women share the same risk factors for deficiency as the general population (Ministry of Health and Cancer Society of New Zealand, 2012).

A PHARMAC-funded vitamin D supplement designed specifically for at-risk pregnant women does not exist, however these women may be prescribed vitamin D as per preparations available for the general population (Best Practice Advocacy Centre New Zealand, 2011; Ministry of Health, 2013a). The standard supplement being a once monthly 1.25mg cholecalciferol tablet (Ministry of Health, 2013a; Ministry of Health and Cancer Society of New Zealand, 2012). Over-the-counter multi-vitamin preparations designed for pregnant women contain vitamin D; these are available without prescription however tend to carry a greater cost and additional risks as outlined in previously.

2.7.2 Prevalence of Deficiency in Pregnant Women

Pregnant women are more susceptible to deficiency secondary to the fetus requiring vitamin D for growth and development; accrual of fetal bone mass occurs primarily in the third trimester therefore risk of maternal deficiency is greater during this time (Wheeler et al., 2018). Furthermore, infant vitamin D status has been found to correlate with maternal vitamin D status, particularly during the third trimester (Wheeler et al., 2018). It is recommended however, that at-risk pregnant women in Australia and New Zealand undergo measurement of serum vitamin D levels early in their first trimester (Paxton et al., 2013); deficiency that develops later in pregnancy or in women that are not classified as at risk, may therefore go undetected (Wheeler et al., 2018), suggesting that more widespread and increased frequency of testing may be beneficial. Additionally, the NRVANZ for vitamin D throughout pregnancy is 5μg as per the general population. This value is based on research articles from 1978 and 2004 therefore does not account for recent advancements in understanding the role of vitamin D during pregnancy (Ministry of Health, 2006b).

A longitudinal study of 80 pregnant, New Zealand-based women living at a latitude of 45° identified vitamin D levels below 50nmol/L in 65% of the participants (Wheeler et al., 2018). This study also noted that deficiency was frequent in women categorised as low-risk, suggesting current guidelines to screen only at-risk pregnant women may not be a sufficient (Wheeler et al., 2018). In a study of 259 pregnant women living at a latitude of 36° in New Zealand, 109 women had vitamin D levels below 50nmol/L whilst 11 had levels below 25nmol/L (Ekeroma et al., 2015).

Vitamin D levels below 50nmol/L were identified in 772 pregnant women from a study population of 2800 recruited in both Auckland, New Zealand and Adelaide, Australia (Wilson et al., 2018). Finally, findings from the 2008/09 New Zealand Adult Nutrition Survey identified one third of the 2204 women of childbearing age involved in the study as having vitamin D levels below 50nmol/L (Ministry of Health, 2012). Evidence of vitamin D deficiency amongst pregnant women has been observed in the New Zealand population, despite the availability of prevention guidelines (Ministry of Health, 2013a; Ministry of Health and Cancer Society of New Zealand, 2012).

2.7.3 Extra-Skeletal Adverse Maternal Health Outcomes of Vitamin D Deficiency

2.7.3.1 Pre-Eclampsia

Characterised by hypertension and proteinuria, pre-eclampsia is a life-threatening condition for both mother and fetus. As well as mortality, the developing fetus is at risk of intrauterine growth restriction secondary to restricted blood supply; the mother is at risk of pulmonary oedema, organ damage and defective blood coagulation (Yuan et al., 2019). The mechanisms by which vitamin D is involved in prevention of pre-eclampsia are not clear however may relate to vitamin D's proposed immunomodulatory function (Agarwal et al., 2018). Furthermore, it has been suggested that vitamin D influences the Renin Angiotensin System and angiogenesis thus aiding in blood pressure regulation (Agarwal et al., 2018; Ullah, Uwaifo, Nicholas, & Koch, 2010).

Much of the evidence linking vitamin D with pre-eclampsia has highlighted association opposed to causation. A French case-control study of 402 pregnant women found no statistically significant association between low levels of vitamin D and pre-eclampsia risk in the first trimester. During the third trimester however, vitamin D levels exceeding 75nmol/L were associated with a significantly lower risk of pre-eclampsia (Benachi et al., 2019). A Canadian prospective cohort study of 221 women who were deemed high risk for pre-eclampsia found a high prevalence of vitamin D insufficiency and deficiency. The study was unable to associate the lower levels of vitamin D to their pre-eclampsia risk, however (Shand, Nassar, Von Dadelszen, Innis, & Green, 2010). In more recent years, several meta-analyses have been published that report a significant association between vitamin D levels below 50nmol/L and increased pre-eclampsia risk (Akbari, Khodadadi, Ahmadi, Abbaszadeh, & Shahsavar, 2018; Palacios et al., 2019; Yuan et al., 2019).

2.7.3.2 Gestational Diabetes Meletus

Glucose intolerance and subsequent hyperglycaemia during pregnancy is a risk factor for developing type two diabetes later in life for both the mother and infant; furthermore, the infant is at greater risk of childhood obesity (Ojo, Weldon, Thompson, & Vargo, 2019). VDR is expressed in pancreatic β cells; it has been suggested that vitamin D has a role in regulation of insulin secretion (Amraei et al., 2018). Furthermore it has been suggested that replenishing Vitamin D in deplete pregnant women improves tissue sensitivity to insulin (Amraei et al., 2018). Several recent meta-analyses that included 75 observational studies and over forty-five thousand participants between them, found significant associations between low levels of vitamin D and increased risk of GDM (Amraei et al., 2018; Hu et al., 2018; Lu, Xu, Lv, & Zhang, 2016). Furthermore, vitamin D levels were significantly lower in women with GDM (Amraei et al., 2018). In a 2019 meta-analysis of five, randomized controlled trials, there was a significant association between vitamin D supplementation and improved glycaemic control in pregnant women with GDM (Ojo et al., 2019).

2.7.3.3 Pre-Term Birth

Babies born before 37 weeks' gestation are at risk of severe developmental disabilities and mortality (Qin, Lu, Yang, Xu, & Luo, 2016). In the year 2017, 7.5% of live births in New Zealand were pre-term (Ministry of Health, 2019). There is emerging evidence that vitamin D has a role in reducing the risk of pre-term birth (PTB) however the results have been conflicting and the mechanisms behind this association remain unclear (Qin et al., 2016). A case-cohort study of 3453 pregnant women found risk of PTB was higher in those with vitamin D levels below 50nmol/L (Bodnar, Platt, & Simhan, 2015). These findings were similar to a study of 192 pregnant women where mothers who delivered pre-term were found to have lower levels of vitamin D than those delivering at term (Thota et al., 2014). In a meta-analysis of 11 observational studies, pregnant women with vitamin D levels below 50nmol/L had a significantly increased risk of PTB (Qin et al., 2016). Furthermore, a meta-analysis of 26 randomized controlled trials and observational studies identified a significant association between PTB risk and vitamin D deficiency (Zhou, Tao, Huang, Zhu, & Tao, 2017).

Interventional studies that have trialled supplementation with vitamin D to reduce the risk or incidence of PTB however, have found less significant results (Agarwal et al., 2018; Palacios et al., 2019). Despite the inconclusiveness, PTB is a significant public health concern and further research is required to understand the association between vitamin D and PTB.

2.7.3.4 Small for Gestational Age

Neonates born SGA have higher rates of morbidity and mortality. In the year 2017, 2.9% of all live-births in New Zealand were SGA (Ministry of Health, 2019). Vitamin D deficiency is thought to be associated with risk of SGA secondary to predisposing poor bone mineralisation (Khalessi, Kalani, Araghi, & Farahani, 2015). A 2017 meta-analysis of 13 prospective cohort studies found a significant association between maternal vitamin D levels below 50nmol/L and increased risk of SGA infants (Chen, Zhu, Wu, Li, & Tao, 2017). Similarly, a 2018 meta-analysis of 12 observational studies found that pregnant women with vitamin D levels below 50nmol/L exhibited greater risk of birthing an infant who is SGA. Evidence from interventional trials further support this association; a 2018 meta-analysis of 24 randomized, controlled trials found a significantly lower risk of birthing an SGA infant in the mothers prescribed a vitamin D supplement (Bi et al., 2018). Although limited, evidence from the New Zealand population does not support this association. In a 2016 prospective cohort study, 9.9% of the 1710 pregnant women gave birth to an SGA infant. This study found no significant association between lower maternal levels of vitamin D and this pregnancy outcome.

2.8 Vitamin D in Infancy

The prevalence of vitamin D deficiency amongst New Zealand infants has previously been discussed in this literature review (Camargo et al., 2010; Grant et al., 2009; Houghton et al., 2010). Additional risk factors for deficiency in this population group are maternal deficiency and preterm birth given the infant's dependence on maternal stores during pregnancy as previously discussed; preterm birth is therefore a risk factor as a shorter length of gestation interrupts fetal accretion of vitamin D (Rigo & Senterre, 2006; Wheeler et al., 2018). Furthermore, exclusive breastfeeding and inadequate sun exposure may contribute to suboptimal vitamin D status (Ministry of Health, 2013a).

Research suggests that the barrier function of infant skin is immature for up to the first two years of life and that sunburn during infancy carries greater risk of developing skin cancer (Shafie Pour et al., 2015). For this reason, the Companion Statement to the New Zealand Consensus Statement on Vitamin D recommends that until independently mobile, infants should not be deliberately exposed direct sunlight. During this period, infants who receive minimal sun exposure as per these guidelines are largely dependent on dietary vitamin D; dependency increasing when the infant is dark-skinned, lives at high latitude, or during the winter months as these factors further contribute to reduced cutaneous vitamin D production (Ministry of Health, 2013a).

Breast milk, potentially a sole food source for up to the first six months of life, contains very little vitamin D (Wheeler et al., 2015). In 2018, Plunket reported that 22% of New Zealand infants in their database were exclusively breastfed for the first six months of life, 47% for three months and 53% for six weeks (Plunket, 2020).

The Ministry of Health recommends exclusive breastfeeding until around the age of six months (Ministry of Health, 2008a); this guideline should continue to be emphasized and strategies to manage the vitamin D status of an infant must complement this without contradicting sun exposure guidelines for the infant population. Maternal supplementation with vitamin D has been associated with improving the vitamin D concentration in breastmilk to the point of superseding requirements for sun exposure (Dawodu & Tsang, 2012). A RCT by Hollis et al. reported that a daily vitamin D supplement of 6400 international units (IU) per day safely increased the vitamin D content of breastmilk to a level that was sufficient for meeting the infant's vitamin D requirements (Hollis et al., 2015). This regime is much higher than the monthly 50,000IU dose currently subsidised by PHARMAC (Ministry of Health, 2013a).

A New Zealand based study however, reported that maternal dietary vitamin D intake, maternal supplement use and maternal sun exposure were not independently associated with exclusively breastfed infants' serum vitamin D concentration, thus supporting that exclusive breastfeeding is a risk factor for deficiency (Lovell et al., 2016). Median daily dietary intake was estimated as 158IU; the vitamin D content of supplements ranged between 100IU and 800IU (Lovell et al., 2016). Given that maternal supplementation for this purpose is not currently included in New Zealand guidelines, exclusive breastfeeding remains as a recognised risk factor for deficiency (Ministry of Health, 2013a).

2.8.1 Supplementation with Vitamin D During Infancy

The Companion Statement to the 2012 New Zealand Consensus Statement on Vitamin D recommends that full-term, exclusively or partially breastfed infants who have one or more risk factors for deficiency receive a vitamin D supplement. At the time of publication, Vitadol-C, a vitamin A-, C- and D-containing supplement, was the only infant-specific preparation available under the PHARMAC schedule. Since this time, PHARMAC has opted to fund a liquid-form cholecalciferol supplement beginning in 2019 (PHARMAC, 2018). A 2015 prospective surveillance study conducted in New Zealand found that four of the 58 children diagnosed with nutritional rickets had received a vitamin D supplement during infancy. Of these children, 93% were exclusively breastfed as an infant and 81% had intermediate to dark skin tones (Wheeler et al., 2015). This study identified that despite these children presenting with risk factors for deficiency prior to diagnosis of rickets, only a small number received supplementation from their health care practitioner as per the guidelines.

At present, the Companion Statement to the 2012 New Zealand Consensus Statement on Vitamin D discusses vitamin D supplementation with regards to bone health. Outside of the skeletal system however, vitamin D deficiency has more recently been associated with several conditions that are common in childhood including asthma, respiratory infections, eczema and food allergies (Saggese et al., 2015). The mechanism by which vitamin D is thought to influence the aetiology these conditions is immunomodulation (Saggese et al., 2015). In context of the New Zealand population, no large-scale interventional trials have been conducted however a study of 1329 children between the ages of two and five found no association between vitamin D levels and eczema, asthma or allergic rhinoconjunctivitis (Cairncross et al., 2016).

2.8.2 Extra-Skeletal Adverse Infant Health Outcomes of Vitamin D Deficiency

2.8.2.1 Respiratory Tract Infections and Asthma

The immunomodulatory role of vitamin D was alluded to when researchers found a high prevalence of respiratory tract infections amongst rachitic children (Yakoob et al., 2016). Following this, a large number of studies have looked into this association however the results have been conflicting; the evidence appears much stronger in developing countries. Despite the conflict, this is a relevant outcome in context of the New Zealand population given the country has a higher rate of hospitalisation for acute respiratory tract infections (ARTI) in children compared to other developed countries (Simpson et al., 2013). In a RCT involving 173 New Zealand-based pregnant women and their infants receiving a high or low dose vitamin D supplement, a smaller number of infants from the high dose group made health care visits for an ARTI compared to the placebo group. This suggests vitamin D may have had a protective role against contracting an ARTI. This finding was not statistically significant, however (Grant et al., 2015). A secondary analysis of a RCT was conducted with 960 children under the age of 30 months from Delhi, India. The risk of ARTI was found to be significantly higher in participants with vitamin D levels below 25nmol/L (Chowdhury et al., 2017). Similarly, in a study of 922 new-borns, cord-blood vitamin D level had a significant, inverse association with ARTI risk. A 2015 systematic review of seven RCTs however found no significant association between vitamin D supplementation and prevention of childhood ARTI (Xiao et al., 2015). Additionally, a 2016 Cochrane Review found no significant impact of vitamin D supplementation in children with respiratory tract infections (Yakoob et al., 2016).

Evidence is also growing in support of vitamin D functioning to reduce incidence of asthma exacerbation. This finding has been supported by a meta-analysis of 8 RCTs, one of which reported significantly lower rates of emergency department visitation in children receiving a vitamin D supplement (Cassim et al., 2015). Similarly, a systematic review of 23 studies found risk of asthma exacerbation was lower in children with higher vitamin D levels (Riverin, Maguire, & Li, 2015). Without reaching statistical significance, a RCT involving 581 pregnant women found a 25% reduction in risk of developing asthma between the ages of zero to three years in infants birthed by mothers who received a vitamin D supplement during pregnancy (Wolsk et al., 2017). This finding, although not currently supported in the New Zealand population (Cairncross et al., 2016), is of importance given the rate of childhood asthma within this population is amongst the highest internationally (Cairncross et al., 2016). A 2016 Cochrane Review of vitamin D supplementation for asthma management found a statistically significant reduction in risk of asthma exacerbations that require emergency room attendance or hospitalisation (Martineau et al., 2016). This review included a larger proportion of adult opposed to paediatric cases therefore results must be interpreted with caution when generalising to the paediatric population alone.

2.8.2.2 Eczema

An international meta-analysis of 34 observational studies identified the association between vitamin D deficiency and risk of childhood eczema as being stronger in higher latitudes (Pacheco-González, García-Marcos, & Morales, 2018). This finding may be of interest to the New Zealand population given that the international Study of Asthma and Allergies in Childhood found a high prevalence of eczema amongst New Zealand children (Clayton et al., 2013). The most current New Zealand-based observational research however, did not identify a significant association between vitamin D status and childhood eczema (Cairncross et al., 2016).

Internationally, both maternal and neonatal vitamin D status has been associated with statistically significant risk of childhood eczema. A meta-analysis of six prospective cohort studies found a significant association between poor maternal vitamin D status and risk of childhood eczema (Wei, Zhang, & Yu, 2016).

Furthermore, a meta-analysis of 11 studies including seven observational and four clinical trials, identified significantly lower vitamin D levels in children with eczema compared to those without (Kim, Kim, Lee, Choe, & Ahn, 2016).

2.8.2.3 Food Allergies

Meta-analysis and systematic reviews specifically looking at the relationship between vitamin D status and food allergies are yet to be conducted. Results from cohort studies, however, suggest an association exists; the direction of which is conflicting. In a large, Australian cohort study, infants born to parents of Australian origin with vitamin D levels below 50nmol/L were more likely to have allergies to egg and peanuts. Furthermore, these infants were more likely to have multiple food allergies (Allen et al., 2013). Similarly, a report based on data from the Longitudinal Study in Australian Children has identified a latitudinal gradient in food allergy and eczema rates with populations at higher latitudes exhibiting greater incidence. The report suggested that this pattern highlights an association between vitamin D status and the disease states (Osborne, Ukoumunne, Wake, & Allen, 2012). A key finding from a German cohort study of 378 mothers and their infants, however, was that higher levels of vitamin D in mothers during pregnancy increased the risk of food allergy in their infants. Further RCTs and subsequent meta-analyses may be useful in developing a better understanding of this potential deficiency outcome.

2.9 Vitamin D and the Health Practitioner

Health professionals help to educate the population about vitamin D and its associated health benefits. Furthermore, health professionals can identify those who are at risk of deficiency and provide strategies to manage vitamin D status. In order to do so effectively, health professionals must have both sufficient and evidence-based knowledge about the topic (Dix et al., 2017).

The 2012 New Zealand Consensus Statement on Vitamin D is a key piece of literature available to health professionals in New Zealand (Ministry of Health and Cancer Society of New Zealand, 2012). This document states the guidelines for management of vitamin D status in the general population. For pregnant women and infants, evidence-based guidelines are documented in the Companion Statement to the 2012 New Zealand Consensus Statement on Vitamin D (Ministry of Health, 2013a). Released in 2012 and 2013 respectively, no further documents have since been published. Given the change in research availability since this time, health professionals' knowledge of vitamin D may be varied. Exploring this knowledge may provide some direction in bettering the guidelines available to health professionals and thus in providing better health outcomes for populations. Both national and international research is available that focuses on health professionals' knowledge and current practices regarding certain aspects of vitamin D management (Bonevski et al., 2012; Dix et al., 2017; Oberhelman et al., 2018; Reeder et al., 2012; Reeder et al., 2013). These are reviewed in the following section.

2.9.1 Knowledge of Deficiency Risk Factors

Knowledge of certain deficiency risk factors appears varied by profession. An Australian cross-sectional study used a survey to assess the knowledge of 500 general medical practitioners (GP). Poor recognition of dark skin as a deficiency risk factor was identified (Bonevski et al., 2012). Similarly, awareness of dark skin as a risk factor was moderate in a study of 1089 New Zealand-based GPs where 55% of the study population correctly selected this answer (Reeder et al., 2013). An updated version of the survey developed by Bonevski et al. was completed by 134 Australian Dietitians. Greater recognition of dark skin as a deficiency risk factor was seen in this population (Dix et al., 2017). The small population size and low response rate of 3% however, means the results are unlikely to be an accurate representation of differences in knowledge between professions (Dix et al., 2017).

Furthermore, both studies involving GPs were conducted prior to release of their respective national guidelines, thus potentially giving the dietetic sample population, who were investigated following the release of an Australian and New Zealand Bone Mineral Society position statement on vitamin D and sun exposure, an advantage. Across all three studies, nearly all participants identified inadequate sun exposure and concealing clothing as risk factors for deficiency (Bonevski et al., 2012; Dix et al., 2017; Reeder et al., 2013). In a 2015 study of 158 health care physicians working in Saudi Arabia, awareness of dark skin and concealing clothing as factors that impact vitamin D status was reported as poor (Al-Amri, Gad, Al-Habib, & Ibrahim, 2017).

The three studies by Bonevski et al., Reeder et al., and Dix et al. shared similar limitations as all had low response rates, 32% being the highest which was achieved by the New Zealand study (Reeder et al., 2013), suggesting the population samples were unrepresentative. Furthermore, in both studies evaluating knowledge of GPs, comparisons between the sample populations and source populations identified overrepresentation of females and part-time employment (Bonevski et al., 2012; Reeder et al., 2012). With regards to survey design, each of the three studies have used several different risk factor response options. Response options may have influenced response patterns and thus inaccurately represented knowledge between the professions (Reeder et al., 2013). A limitation of the work by Dix et al., and Al-Amri et al. is the small sample population of 134 and 158 respectively.

2.9.2 Knowledge and Attitudes Toward Sun Exposure Guidelines

Using surveys, Bonevski et al., Reeder et al. and Dix et al. explored health professionals' knowledge of sun exposure guidelines for vitamin D synthesis. Across all three studies, there was confusion surrounding the amount of UVR exposure that is required for cutaneous vitamin D synthesis during winter (Bonevski et al., 2012; Dix et al., 2017; Reeder et al., 2012).

In the New Zealand study, majority of GPs correctly recommended use of sun protection methods during peak UVR times in summer months (Reeder et al., 2012). The study identified however, that many GPs continue to recommend sun avoidance during peak UVR hours into the winter months which may contribute to insufficient cutaneous vitamin D synthesis (Reeder et al., 2012). These findings were similar in the Australian study of GPs were under 20% of participants reported advising use of less sun protection in winter (Bonevski et al., 2012). Within the sample population of Australian Dietitians, it was reported that under half of the participants correctly identified UVR exposure recommendations that promote vitamin D adequacy during winter (Dix et al., 2017). In this study, a quarter of the participants recommended direct sun exposure during peak UVR hours in summer for fair skinned individuals however (Dix et al., 2017). Furthermore, nearly a quarter of the Australian GPs perceived thirty minutes of direct sun exposure during peak UVR hours in summer as the length of time required for adequate cutaneous vitamin D synthesis (Bonevski et al., 2012). Although not available when the latter study was conducted, Australian guidelines recommend direct sun exposure for five to nine minutes, depending on location, at 10am or 2pm during summer months (Nowson et al., 2012). These findings suggest there is also confusion around the amount of UVR exposure that is required for vitamin D synthesis whilst being conscious of skin cancer risk. New Zealand GPs believed that a mean time of 15 minutes of direct sun exposure before 11am was sufficient in fair skinned individuals for cutaneous vitamin D synthesis whilst preventing sun damage (Reeder et al., 2012). At the time in which this study was conducted, guidelines available from the Cancer Society of New Zealand recommended "a few minutes" of direct sun exposure either side of the peak UVR hours in the summer months for this skin type (Cancer Society of New Zealand, 2007). The lack of specificity in this guideline means the accuracy of sun exposure recommendations made by the New Zealand GPs cannot be commented on as they were in the Australian GPs and Dietitians.

A key limitation of these studies is that the results are now irrelevant in relation to current guidelines in New Zealand, thus an indication of health professionals' knowledge of safe sun exposure for vitamin D adequacy is unavailable. This is because sun exposure guidelines in relation to vitamin D have moved away from recommending specific amounts of time to be spent in the sun. Recommendations from the 2012 New Zealand Consensus Statement on Vitamin D have previously been outlined in this literature review.

Similar to Bonevski et al., Reeder et al., and Dix et al., a study conducted in Israeli doctors, dermatologists and endocrinologists reported lack of agreement amongst professionals relating to the amount of time required in the sun to synthesis vitamin D (Abu-Abed, Azbarga, & Peleg, 2018). Key limitations of this study, however, are the small sample size of 121 participants and the greater potential for social desirability bias, given the survey was conducted in personal interviews and thus lacked anonymity (Abu-Abed et al., 2018).

2.9.3 Vitamin D in Pregnancy and Infancy

The previously discussed studies by Bonevski et al., Reeder et al., and Dix et al. have looked at health professionals' knowledge of vitamin D for the general population (Bonevski et al., 2012; Dix et al., 2017; Reeder et al., 2012; Reeder et al., 2013). In a sample of 6822 pregnant women enrolled in the Growing Up in New Zealand longitudinal cohort study, 98% of women engaged with a healthcare provider during pregnancy (Bartholomew et al., 2015). This suggests evaluation of health professionals' knowledge of vitamin D for this population group and their infants is appropriate.

At present however, this literature appears limited. Furthermore, current literature focuses largely on doctors' knowledge. Research extending to Dietitians, Midwives and Paediatric Nurses may be beneficial for developing a more representative understanding of health care professionals' knowledge of vitamin D for pregnancy and infancy.

The research currently available focuses on health professionals' awareness of supplementation guidelines (Oberhelman et al., 2018). In the three studies previously outlined, supplementation was the preferred method for treatment of deficiency indicated by the majority of participants (Bonevski et al., 2012; Dix et al., 2017; Reeder et al., 2013). Vitamin D supplementation is recommended prophylactically however, for at-risk pregnant women and infants (Ministry of Health, 2013a). A key limitation of these findings, therefore, is that they do not indicate whether health professionals are aware of supplement guidelines that aim to prevent deficiency. Nor does it allude to health professionals' supplementation practices in infants and pregnant women.

Guidelines for supplementing infants with vitamin D have been devised both nationally and internationally given these infants are at high risk of deficiency (Ministry of Health, 2013a; Oberhelman et al., 2018). In an American study of 56 physicians and nurse practitioners, 92% of the sample population were able to identify the correct, breastfed-infant-specific vitamin D supplement dose as per national paediatric guidelines. Furthermore, participants reported recommending vitamin D supplementation for breastfed infants 70% of the time (Oberhelman et al., 2018). These results suggest good knowledge of vitamin D supplementation for infants however the small sample size and lack of geographic spread, means these results are likely to be unrepresentative. Furthermore, given American guidelines were used, these results cannot be generalised to the New Zealand population (Oberhelman et al., 2018). DelGiudice et al., explored physicians' and nurse practitioners' awareness of vitamin D supplementation guidelines for patients ages 18 years or younger in America. The study reported good awareness of risk factors for vitamin D deficiency amongst participants but a lack of certainty relating to prescribing vitamin D supplements (DelGiudice et al., 2018). This finding suggests some health professionals may be unaware of supplementation guidelines. A key limitation of this study, however, was the small sample size of 34 participants (DelGiudice et al., 2018).

A study by AlBishi et al. explored doctors' and Well Baby nurses' awareness of supplementation guidelines for infants and pregnant women in Saudi Arabia (AlBishi et al., 2018). This study reported that 84% of the 100 participants were aware of the association between breastfeeding and vitamin D deficiency in infants. Furthermore, 77% reported prescribing vitamin D supplements to exclusively breastfed infants as per APA guidelines (AlBishi et al., 2018). These findings suggest health professionals in Saudi Arabia may have good awareness of supplementation guidelines. Similar to previous studies discussed in this section, limitations were the small sample size and use of differing national guidelines (AlBishi et al., 2018). A study by Jain et al. assessed knowledge of vitamin D supplement guidelines in midwives, health visitors and GPs in the United Kingdom (Jain et al., 2011). The study reported that majority of participants were uncertain about supplementation guidelines for infants, pregnant and breastfeeding women, particularly in relation to patients who are high risk for deficiency (Jain et al., 2011). Advice regarding supplementation was given to breastfeeding women by 45% of health visitors and 14% of GPs in this study, suggesting GPs in particular may lack knowledge of supplementation guidelines (Jain et al., 2011). A limitation of this study is the small sample size of 77 health professionals.

The results of these studies are conflicting, highlighting that further research is needed to develop an understanding of health professionals' knowledge of vitamin D for pregnancy and infancy. Furthermore, the research has been conducted internationally and thus is unrepresentative of the New Zealand population of health professionals. New Zealand based studies are therefore needed.

Chapter 3. Research Study Manuscript

3.1 Abstract

Background: Vitamin D is now recognised as having a role in in immune system functioning and in protection against several complications of pregnancy and common diseases of childhood. In 2012, a Consensus Statement was released by the New Zealand Ministry of Health that described the populations who are at risk of deficiency, how to manage vitamin D status whilst being conscious of the harsher ultraviolet environment in New Zealand and outlined who may benefit from vitamin D supplementation. Furthermore in 2013, a Companion Statement was released which provided additional information about vitamin D specific to the pregnant, lactating and infant populations. These documents were designed primarily for use by health professionals. There is limited literature available that explores health professionals' knowledge of vitamin D in New Zealand. International literature is conflicting with some studies reporting good knowledge of vitamin D deficiency risk factors, sun exposure guidelines and supplement guidelines while others report limited knowledge in these areas. International studies have reported on health professionals' knowledge of vitamin D supplement guidelines for infants with conflicting results. Identifying areas where knowledge is lacking will help to identify where New Zealand health professionals require further education.

Aims: The aim of this study is to explore health professionals' knowledge, attitudes and current practices toward vitamin D for the general population, pregnancy and infancy. Furthermore, this study aims to explore whether knowledge and attitudes have changed between 2010 and 2019.

Methods: In this ecological study, an anonymous online questionnaire was used to collect data from health professionals working in a profession recognised by the Health Practitioners Competence Assurance Act. Professionals working with pregnant women, infants and their caregivers were sought after in particular. This questionnaire was conducted in 2010 and in 2019 with different sample populations. Questions were developed in 2010 and in line with available New Zealand guidelines that detailed management of vitamin D status. These were the Food and Nutrition Guidelines for Healthy Infants and Toddlers and for Healthy Pregnant and Breastfeeding Women, and the Cancer Society Position Statement on the Risks and Benefits of Sun Exposure. Question types were a combination of multiple response sets and true or false and yes or no response options. Knowledge questions were forced response to avoid missing data whereas participant characteristic questions were request response to respect privacy. Descriptive statistics were used to analyse the results.

Results: A total of 283 HPCAA-recognised health professionals completed this questionnaire (2010 n=193; 2019 n=90). Health professionals have good knowledge of vitamin D sources, functions and risk factors for deficiency. There appears to be confusion surrounding the vitamin D content of breastmilk (44.4% in 2010 and 31.5% in 2019 selected breastmilk as a good dietary source of vitamin D) and exclusive breastfeeding as a risk factor for deficiency (selected by 14.6% in 2010 and 32.9% in 2019). Knowledge of sun exposure guidelines was challenging to ascertain but results indicated a lack of awareness of safe sun exposure guidelines, primarily for infants. Furthermore, participants from both years were largely unsure about vitamin D supplement availability. Majority of participants did not feel there was enough information available to health professionals regarding vitamin D (81.2% in 2010; 74.4% 2019).

Conclusion: Whilst health professionals had good knowledge of deficiency risk factors, functions and sources of vitamin D, the study identified some knowledge deficits. Interventions to improve knowledge are likely to be well received as majority of participants believe there is not enough information available to health professionals about vitamin D. Areas where health professionals need further education are the vitamin D content of breastmilk, recognition of exclusive breastfeeding as a deficiency risk factor in infants, supplement availability and sun exposure guidelines.

Further studies that explore where health professionals' source their information from regarding vitamin D may provide insight as to why these gaps in knowledge have occurred and how to best rectify them. Future studies should include larger population sizes and greater population diversity.

3.2 Introduction

Traditionally, vitamin D has been recognised for its role in bone health (Pike & Christakos, 2017). The vitamin functions to maintain serum concentrations of calcium and phosphate by upregulating intestinal absorption and renal reabsorption of the two minerals (Pike & Christakos, 2017). Vitamin D may also stimulate resorption of these minerals from bone if necessary, as bone is a large mineral reservoir (Pike & Christakos, 2017). When vitamin D status is poor, and calcium and phosphate concentrations are low, PTH will stimulate remodelling of bone to increase serum concentration of the minerals (Pike & Christakos, 2017). Chronic vitamin D deficiency is therefore associated with weakened bone structure and more severely, bone diseases such as rickets in children and osteoporosis or osteomalacia in adults (Theodoratou et al., 2014).

Tissues in the body that utilise vitamin D express VDR (Jablonski & Chaplin, 2018). Identification of VDR in tissues other than those involved in the skeletal system and calcium and phosphate homeostasis, has led to development of a large body of research surrounding extra-skeletal functions of this vitamin (Wei & Christakos, 2015). Much of this research has suggested that vitamin D may have a role in immune system functioning, and that implications of vitamin D deficiency may extend to risk of infectious diseases, autoimmune conditions and certain cancers (Wei & Christakos, 2015).

New Zealand guidelines define vitamin D deficiency as serum 25(OH)D at 24nmol/L or below and define insufficiency as 49nmol/L or below (Ministry of Health and Cancer Society of New Zealand, 2012). Clinical manifestations of deficiency include delayed growth, delayed standing and walking and frequent falling in children (Bordelon et al., 2009; Thacher & Clarke, 2011; van Schoor & Lips, 2018). In adults, it may present as bone pain, fractures and muscle weakness (Bordelon et al., 2009; Thacher & Clarke, 2011; van Schoor & Lips, 2018). Several New Zealand-based studies have reported on vitamin D insufficiency and deficiency in infants and toddlers. Camargo et al. reported 25(OH)D levels below 25nmol/L in one out of every five of the 925 new-borns (Camargo et al., 2010). Houghton et al. identified 25(OH)D levels below 50nmol/L in 57% of the 12 to 22 month olds sampled in winter (n=55) (Houghton et al., 2010). Grant et al. reported that 25(OH)D levels below 27.5nmol/L were identified in 46 of the 353 six to 23 month olds (Grant et al., 2009). New Zealand-based studies have also assessed vitamin D levels in the pregnant population. Wheeler et al. reported that 25(OH)D levels below 50nmol/L were present in 65% of the 80 participants (Wheeler et al., 2018). Furthermore, Ekeroma et al. identified 25(OH)D levels below 50nmol/L in 109 of the 259 participants (Ekeroma et al., 2015). In a population of 2800 pregnant women from Australia and New Zealand, 25(OH)D levels below 50nmol/L were identified in 772 of the participants (Wilson et al., 2018).

Risk factors for deficiency are largely related to sun exposure and ability to cutaneously synthesise vitamin D, given that UVR is the primary source (Nowson et al., 2012). Comparatively, New Zealand inhabitants are exposed to higher amounts of UVR secondary to ozone depletion and minimal air pollution (Pondicherry et al., 2018). Because of this, New Zealand has one of the highest rates of skin cancer internationally (Pondicherry et al., 2018). As a result, there is growing concern that strict sun protection messages double as a risk factor for vitamin D deficiency (Youl et al., 2009). Additional risk factors are ethnicity and darker skin colour, living at high latitude, season of weather and concealing clothing, typically those worn for cultural, religious or sun protection purposes (Ministry of Health and Cancer Society of New Zealand, 2012; Nowson et al., 2012). Lastly, those who are housebound, institutionalised or regularly spend large amounts of daylight hours inside are at greater risk of deficiency (Nowson et al., 2012).

Pregnant women are at greater risk of vitamin D deficiency as maternal stores are relied on by the fetus for bone growth and development (Pludowski et al., 2013). Research has identified a possible association between maternal vitamin D deficiency and several complications of pregnancy including pre-eclampsia, GDM, PTB and birthing an infant who is SGA (Palacios et al., 2019).

Infants born preterm or to mothers with low vitamin D status are themselves likely to be deficient (Rigo & Senterre, 2006). Sun exposure guidelines for infants suggest no intentional, direct sun exposure at any time of the day as the immaturity of infant skin carries increased risk of skin cancer (Ministry of Health, 2013a; Shafie Pour et al., 2015). Dietary vitamin D is therefore the primary source for infants. Exclusively breastfed infants who receive minimal amounts of sun exposure are at greater risk of deficiency however, as breastmilk contains minimal amounts of vitamin D (Wheeler et al., 2015). Hollis et al. reported that maternal supplementation with a daily dose of 6400IU of vitamin D safely increased the vitamin D status of the breastfed infant, suggesting that the vitamin D content of breastmilk can be improved to a level that is sufficient for meeting the infant's vitamin D requirements (Hollis et al., 2015). Research is conflicting however as a New Zealand study reported that maternal vitamin D supplementation and dietary intake and sun exposure was not independently associated with breastfed infants vitamin D status (Lovell et al., 2016). Additionally, maternal supplementation for the purpose of increasing vitamin D content of breastmilk is not currently included in New Zealand guidelines (Ministry of Health, 2013a; Ministry of Health and Cancer Society of New Zealand, 2012). Breastmilk should therefore continue to be recognised as a poor source of vitamin D. Deficiency in infancy has been associated with several conditions common in childhood. These include asthma, respiratory tract infections, eczema and food allergies (Saggese et al., 2015).

For infants and pregnant women who are at risk of deficiency, current guidelines recommend administering vitamin D supplements prophylactically as testing of vitamin D status is very expensive. These recommendations are outlined in 2012 New Zealand Consensus Statement on Vitamin D and in the Companion Statement that relates specifically to pregnant and lactating women and infants (Ministry of Health, 2013a; Ministry of Health and Cancer Society of New Zealand, 2012). These guidelines were developed for health professionals with the intention of providing background on the management of vitamin D status. As health professionals play a key role in educating the population about vitamin D, as well as identifying those who are at risk of deficiency and devising suitable management plans (Dix et al., 2017), continuing to develop an understanding of health professionals' knowledge of vitamin D is justified.

Current literature pertaining to health professionals' knowledge is limited, particularly in the New Zealand population (Reeder et al., 2012; Reeder et al., 2013). A New Zealand-based study, which assessed knowledge of GPs only, was conducted prior to the release of the Consensus statement. The study reported moderate knowledge of deficiency risk factors and confusion around sun exposure guidelines. This study is limited by the fact it is now outdated, given new guidelines have since been released. Furthermore, this study did not assess knowledge of vitamin D relating to pregnancy and infancy. To the authors knowledge, no New Zealand-based studies have been conducted that explore health professionals' knowledge of vitamin D for pregnancy and infancy. Additionally, there appears to be no New Zealand-based studies that assess health professionals' knowledge following release of the Consensus and Companion Statements. In Australia, knowledge of vitamin D in GPs and Dietitians has been explored (Bonevski et al., 2012; Dix et al., 2017). The studies reported similar results in that health professionals appear to lack knowledge of sun exposure guidelines to achieve vitamin D adequacy in the wintertime (Bonevski et al., 2012; Dix et al., 2017). Furthermore, both studies reported that some health professionals were advising unsafe sun exposure practices in summer (Bonevski et al., 2012; Dix et al., 2017).

Health professionals' knowledge of vitamin D for infancy has been explored internationally, with several studies assessing awareness of vitamin D supplementation guidelines. American, Saudi Arabian and British studies unanimously report confusion amongst health professionals in relation to vitamin D supplement guidelines (AlBishi et al., 2018; DelGiudice et al., 2018; Jain et al., 2011).

Results have been conflicting however, as an American study reported good awareness of their relevant national guidelines (Oberhelman et al., 2018). Research related to health professionals' knowledge of vitamin D for pregnancy does not appear to be available.

This study aims to build on current literature that explores health professionals' knowledge and attitudes toward vitamin D for pregnancy and infancy. Data may be used to identify gaps in knowledge and thus can be used to identify where health professionals require further educating.

3.3 Methods

3.3.1 Ethical Approval

Request for ethical approval of this study was sent to the Massey University Human Ethics Committee. This study received a low risk notification.

3.3.2 Questionnaire Design

In this ecological study, an online questionnaire was used to collect data via SurveyMonkey, an online questionnaire development software, from New Zealand health professionals. This questionnaire was conducted in both 2010 and 2019 with different sample populations of New Zealand health professionals so that change in knowledge could be observed. The questionnaire was composed of 41 questions and took approximately nine minutes to complete according to SurveyMonkey analytics.

The questionnaire was composed of six sections. Aspects of vitamin D knowledge and status management were categorised into the following; general knowledge of vitamin D, awareness of current recommendations, knowledge of vitamin D and sun exposure in the New Zealand context, and current practices regarding management of vitamin D status. Questions were developed in 2010. These were based on comprehensive literature search, the Cancer Society of New Zealand's Position Statement on the Risks and Benefits of Sun Exposure in New Zealand (Cancer Society of New Zealand, 2007) and on Food and Nutrition Guidelines for both Healthy Infants and Toddlers (Ministry of Health, 2008a) and Healthy Pregnant and Breastfeeding Women (Ministry of Health, 2006a). The same questionnaire was administered to the 2010 and 2019 sample populations. This allowed exact comparison of questionnaire responses between the two time points. Furthermore, this gave a better representation of knowledge improvement following release of the Consensus Statement.

Questions were forced response to avoid missing data (Albaum, Roster, Wiley, Rossiter, & Smith, 2010) however those pertaining to participant characteristics were request response to respect privacy. The response set within forced response questions typically gave participants the option to select unsure. Question types were a combination of multiple response sets and true or false and yes or no response options.

The questionnaire was pilot tested in a group of health professionals to assess readability, understanding, and relevance of content.

3.3.3 Recruitment

Participants in the 2010 cohort were recruited via invitation distributed to health professionals listed in Massey University's contact database. Primary researchers in 2010 forwarded invitations to complete the questionnaire to personal contacts in the healthcare workforce.

Invitations to participate (appendix C.1) in the 2019 study were sent to several relevant organisations including Dietitians New Zealand, New Zealand Nurses Organisation, Plunket and New Zealand College of Midwives.

Furthermore, invitations were sent to health professionals listed in Massey University's contact database. Dietitians New Zealand and New Zealand Nurses Organisation permitted the questionnaire to be posted on their closed Facebook groups with memberships of 718 and approximately 8200 respectively. Plunket's Population Health Advisor distributed the online questionnaire invitation via email to their database of registered nurses whom they employ. The governance group from New Zealand College of Midwives were unable to review and distribute the questionnaire invitation within a suitable timeframe for this study. Invitations were sent to Silverdale medical centre, Apollo medical centre, Massey University Health Centre and Alliance Health PHO.

Upon completion of the questionnaire, participants were provided with the questionnaire access weblink which they were encouraged to forward to colleagues. Response rate was not able to be calculated given the anonymity and varying routes of distribution, particularly where access to databases were not provided to the primary researcher.

The information sheet was provided in the preface of the questionnaire. Completion of the questionnaire indicated consent for data to be used for the purpose of this study. Participants remained anonymous however had the opportunity to provide contact details should they want to receive a summary of the study findings. Participants were not incentivised to complete this questionnaire.

3.3.1 Participants

In line with the aim of the study, questionnaire respondents were excluded if they did not indicate employment and/or holding an approved qualification required to practice as a health professional. Health professions included in this study were limited to those recognised by the Health Practitioners Competence Assurance Act (HPCAA) (Ministry of Health, 2020) as this provides a practical channel for delivering interventions to improve knowledge level. Plunket Nurse was offered as an additional employment response to Nurse. Specifying this profession allowed more in-depth statistical analysis of knowledge in professionals who are likely to be interacting with the pregnant and infant population.

Aside from incomplete questionnaire response, no further inclusion or exclusion criteria were defined. Specific criteria such as age, spoken language, location within New Zealand and years of practice were not deemed necessary for improving research quality as a diverse sample population may help to improve representativeness. Ethnicity was prioritised as per Ministry of Health guidelines (Ministry of Health, 2008b). A filter was set in SurveyMonkey that removed participants without a 75% completion rate. Completion rate was calculated manually for hard-copy data.

The sample size of the 2010 population was determined by the number of survey responses that met inclusion criteria. For the 2019 population, sample size was restricted by limited recruitment time due to a strict timeframe for competition of the project.

3.3.5 Data Handling and Statistical Analysis

Additional, hard-copy data were collected from the 2010 study population and uploaded to SurveyMonkey. Data collected in 2019 were solely electronic. Data from both sample populations were exported into Microsoft Excel for cleaning.

Cleaned data were uploaded to IBM SPSS Statistics software package for Windows (version 24). Response proportions were presented as percentages. Where data were missing in single response sets, valid percentage was presented as this value did not include missing cases. Where this has occurred, response n is not equal to sample size n in some instances, as missing cases were not included. Multiple response sets were presented as percentage of cases thus totals do not add up to 100%. Years of experience data were tested for normality using Kolmogorov-Smirnov and Shapiro-

Wilk tests with significance set at 0.05 or below. Abnormal data were log transformed and re-tested for normality. Abnormal data following re-test were presented as median (25^{th}, 75^{th} percentile).

3.4 Results

3.4.1 Participant Characteristics

Responses from 283 health professionals were used in this study. From the year 2010, 193 participants met the inclusion criteria and from the year 2019, 90 participants were suitable for inclusion. A total of 31 participants were excluded from the study due to unsuitable or lack of occupation selected; 19 in the year 2019 and 12 in the year 2010.

Within both cohorts, the majority of the participants were female (95.9% in 2010 and 98.9% in 2019) and of New Zealand European ethnicity (75.3% in 2010 and 2019). In 2010, nurse was the most common occupation (51.3%) whereas dietitian (28.9%) was more common in 2019. Midwives were the least represented occupation in 2010 (5.2%) whereas GPs were the least represented in 2019 (2.2%). Median (25^{th}, 75^{th} percentile) years of experience decreased between the two populations; in 2010 it was 15 (5, 27.5) compared to 8 (4, 16.7) in 2019. Participant characteristics data is summarised in table 3.1.

Table 3.1 Participant Characteristics

	2010 n=193	**2019 n=90**
	n (%)	**n (%)**
Gender		
Female	185 (95.9)	88 (98.9)
Male	8 (4.1)	1 (1.1)
Ethnicity		
NZ European	143 (75.3)	67 (75.3)
Māori	21 (11.1)	7 (7.9)
Pacific Islander	6 (3.2)	0
Chinese	3 (1.6)	1 (1.1)
Indian	4 (2.1)	2 (2.2)
Other	13 (6.8)	12 (13.5)
Occupation		
Dietitian	28 (14.5)	26 (28.9)
Midwife	10 (5.2)	22 (24.4)
General Medical Practitioner	15 (7.8)	2 (2.2)
Nurse	99 (51.3)	10 (11.1)
Plunket Nurse	32 (16.6)	23 (25.6)
Other	9 (4.7)	7 (7.8)
Type of work establishment +		
Hospital based	21 (13.8)	25 (30.1)
Community based	46 (30.3)	31 (37.3)
Plunket clinic	35 (23.0)	18 (21.7)
Medical centre	49 (32.2)	2 (2.4)
Private practice	15 (9.9)	7 (8.4)

+Multiple response set, participants able to select more than one answer.

3.4.2 Knowledge of Vitamin D Sources and Functions

In both populations, 94% of participants selected manufactured in the skin as the most important source of vitamin D. Of the food source response options, the most commonly selected by 2010 participants were infant or toddler formula (68.6%), oily fish (67%), and fortified cow's milk (53.5%). In 2019, the most commonly selected were slightly different and included oily fish (79.8%), eggs (61.8%) and fortified cow's milk (61.8%). In both populations, over one third of participants selected breast milk as a good dietary source (44.3% and 31.5% in 2010 and 2019 respectively). These results are summarised in table 3.2.

Table 3.2 Knowledge of Vitamin D Sources

	2010 n (%)	**2019 n (%)**
What do you think is the single most important source of vitamin D for average New Zealanders?		
Manufactured in the skin	183 (94.8)	85 (94.4)
Natural food sources	5 (2.6)	4 (4.4)
Fortified food products	2 (1.0)	0
Other	2 (1.0)	1 (1.1)
Don't know	1 (0.5)	0
Which of the following are good dietary sources of vitamin D? +		
Grapes	13 (7.0)	1 (1.1
Oily fish e.g. canned tuna, sardines or salmon	124 (67.0)	71 (79.8)
Cow's milk (unfortified)	37 (20.0)	19 (21.3)
Eggs	82 (44.3)	55 (61.8)
Infant or toddler formula	127 (68.6)	48 (53.9)
Red meat	29 (15.7)	6 (6.7)
Bread	15 (8.1)	0
Fish oil	89 (48.1)	39 (43.8)
Breast milk	82 (44.3)	28 (31.5)
Fortified cow's milk	99 (53.5)	55 (61.8)
Liver	53 (28.6)	34 (38.2)

+ Multiple response set, participants able to select more than one answer.

Table 3.3 provides a summary of the health professionals' knowledge of vitamin D functions. In both populations, almost all selected aiding with the absorption of calcium (82.9% and 90% in 2010 and 2019 respectively) and needed for bone development and mineralisation (80.3% and 94.4% in 2010 and 2019 respectively) when asked to select the functions of vitamin D. The proportion of those who selected aiding with immune system function increased between 2010 (38.3%) and 2019 (72.2%). Furthermore, in both populations almost all selected rickets (86.3% and 84.4% in 2010 and 2019 respectively) and osteoporosis (82.1% and 85.6% in 2010 and 2019 respectively) as diseases associated with low levels of vitamin D.

Table 3.3 Knowledge of Vitamin D Function

	2010 n (%)	2019 n (%)
What are the roles of Vitamin D in the body? +		
Aids with the absorption of calcium	160 (82.9)	81 (90)
Vitamin D is an antioxidant	44 (22.8)	18 (20)
Vitamin D is needed for bone development and mineralisation	155 (80.3)	85 (94.4)
Vitamin D aids with immune system function	74 (38.3)	65 (72.2)
Vitamin D is needed for blood clotting	20 (10.4)	13 (14.4)
Which of the disease states listed below are associated with low levels of vitamin D? +		
Breast Cancer	26 (13.7)	15 (16.7)
Prostate Cancer	18 (9.5)	13 (14.4)
Skin Cancer	21 (11.1)	12 (13.3)
Type 1 Diabetes	14 (7.4)	17 (18.9)
Inflammatory Bowel Disease	26 (13.7)	18 (20.0)
Multiple Sclerosis	29 (15.3)	21 (23.3)
Rheumatoid Arthritis	33 (17.4)	22 (24.2)
Depression	99 (52.1)	66 (73.3)
Renal Disease	22 (11.6)	11 (12.2)
Gallstones	7 (3.7)	5 (5.6)
Heart Disease	19 (10.0)	13 (14.4)
Rickets	164 (86.3)	76 (84.4)
Osteoporosis	156 (82.1)	77 (85.6)

+ Multiple response set, participants able to select more than one answer.

3.4.3 Knowledge and Attitudes Toward Sun Exposure

A large proportion of the 2010 (78.5%) and the 2019 (73.3%) participants believed that skin cancer messages make it difficult to get messages about vitamin D across. When asked to identify the correct time period in which time should be spent in the sun during summer, the 2010 participants more commonly selected before 11am and after 4pm (64.8%) whereas the 2019 participants more commonly selected before 10am and after 2pm (68.9%). The proportion of participants who selected before 12pm and after 5pm increased from 1.1% in 2010 to 20% in 2019. A larger proportion of the 2019 participants (78.9%) believed people with dark skin need to spend longer in the sun to synthesis adequate vitamin D compared to the 2010 participants (53.9%). With regards to sunlight exposure through a window, similar proportions of the 2010 and 2019 participants believed this was not safer than outdoor sun exposure (60.1% and 612.2% respectively). Furthermore, similar proportions indicated this method was not as effective as outdoor sun exposure in relation to vitamin D synthesis (47.2% and 52.2% in 2010 and 2019 respectively).

In 2019, a larger proportion of participants believed that people living in the South Island of New Zealand were at more risk of deficiency in 2019 (72.2%) compared to 2010 (46.1%). In 2010, 73% of participants believed season affects the amount of time required in the sun to synthesise vitamin D. A further 81.3% believed that vitamin D status may drop below adequate levels in winter. The results were similar in the 2019 population with 87.8% believing the effect of season and a further 91.1% believing vitamin D status may drop during winter. Table 3.4 summarises these findings.

Table 3.4 Knowledge and Attitudes Toward Sun Exposure Guidelines

	2010 n (%)	2019 n (%)
Skin cancer messages make it difficult to get messages about vitamin D across		
True	150 (78.5)	66 (73.3)
False	28 (14.7)	14 (15.6)
Unsure	13 (6.8)	10 (11.1)
During which times in summer should time be spent in the sun to allow synthesis of vitamin D?		
Before 11am and after 4pm	118 (64.8)	4 (4.4)
Before 10am and after 2pm	44 (24.2)	62 (68.9)
Before 12pm and after 5pm	2 (1.1)	18 (20.0)
Unsure	18 (9.9)	6 (6.7)
People with dark skin e.g. Māori and Pacific Island people need to spend longer in the sun to synthesise adequate vitamin D		
True	104 (53.9)	71 (78.9)
False	50 (25.9)	11 (12.2)
Unsure	39 (20.2)	8 (8.9)
Exposure to sunlight through a window is safer than outdoor sun exposure		
True	37 (19.2)	15 (16.7)
False	116 (60.1)	56 (62.2)
Unsure	40 (20.7)	19 (21.1)
Exposure to sunlight through a window is just as effective as outdoor sun exposure in relation to vitamin D synthesis		
True	52 (26.9)	11 (12.2)
False	91 (47.2)	47 (52.2)
Unsure	50 (25.9)	32 (35.6)
People living in the South Island of New Zealand are more at risk of vitamin D deficiency		
True	89 (46.1)	65 (72.2)
False	64 (33.2)	7 (7.8)
Unsure	40 (20.7)	18 (20.0)
Season affects the amount of time needed in the sun to synthesise adequate vitamin D		
True	142 (73.6)	79 (87.8)
False	27 (14.0)	6 (6.7)
Unsure	24 (12.4)	5 (5.6)
During winter vitamin D status may drop below adequate levels		
True	157 (81.3)	82 (91.1)
False	12 (6.2)	1 (1.1)
Unsure	24 (12.4)	7 (7.8)

3.4.4 Pregnancy and Infancy

The most common advice that health professionals in this study indicated should be given to parents when discussing sun exposure for infants and toddlers varied by year. In 2010, 85.5% selected sun protection measures should be followed between 11am and 4pm followed by 64.8% selecting excessive sun exposure can lead to increased risk of skin cancer. In 2019, 51.2% selected the former and 84.4% selected the latter.

When asked about sun exposure guidelines for infants and their mothers, 57.8% of the 2010 population and 46.5% of the 2019 population believed parents are recommended to expose baby's face and arms for five to ten minutes, dependent on skin colour, of direct sunlight per day before 11am and after 4pm during summer. With regards to sun exposure for infants during winter and spring, 86% of the 2010 population and 88.9% of the 2019 population believed this was necessary to maintain adequate vitamin D levels.

Similar proportions of health professionals in this study believed that pregnant and lactating women are recommended to expose their face and arms to 20 minutes of sunshine per day between October and March with 55.4% selecting true in 2010 and 52.2% selecting true in 2019. Similar proportions believed that deliberate sun exposure during peak UV time was not recommended for pregnant and lactating women (75.6% and 73.3% in 2010 and 2019 respectively). Lastly, similar proportions believed that most pregnant women will achieve adequate vitamin D status in summer through incidental sun exposure outside of peak UV times (53.4% in 2010 and 55.6% in 2019). When asked whether there is enough information about vitamin D available to parents, majority of the participants selected no (95.2% and 94.4% in 2010 and 2019 respectively). A summary of these findings can be found in table 3.5.

When asked about supplement availability in New Zealand, 41.6% of the 2010 population indicated awareness of supplements for infants and toddlers compared to 55.6% of the 2019 population. With regards to supplements available specifically for pregnant women, 37.8% of the 2010 population believed there were supplements available that contained vitamin D compared to 40% of the 2019 population. The most commonly selected recommendation regarding indication for vitamin D supplementation in infants and toddlers for both populations was only infants and toddlers at risk of deficiency require supplementation (57.1% and 80% in 2010 and 2019 respectively). In 2010, 29.8% of participants indicated they were unsure about the recommendation compared to 8.9% in the 2019 population. Table 3.6 provides a summary of these results.

The most commonly selected risk factors for vitamin D deficiency in pregnancy and lactation were being housebound in both 2010 (80.2%) and in 2019 (94.3%). This was followed by covering the skin for cultural or religious reasons in both 2010 (88.8%) and in 2019 (94.3%). Dark skin was selected by 49.2% in 2010 and by 89.9% in 2019. The proportion who selected living in the South Island of New Zealand increased from 33.2% in 2010 to 78.4% in 2019. For infants, the most commonly selected risk factor was irregular sunlight exposure in both 2010 (89.2%) and 2019 (97.8). Exclusive breastfeeding was selected by 14.6% in 2010 and 32.9% in 2019. Covering the skin was selected by 72.4% of the 2010 population and by 86.5% of the 2019 population. Prematurity and maternal deficiency were selected by 45.4% and 65.4% respectively in 2010; in 2019, the proportions increased to 64% and 70.8% respectively.

Table 3.5 Awareness of Guidelines for Infants and Pregnant Women

	2010 n (%)	2019 n (%)
What advice should be given to a parent when discussing sun exposure for infants and toddlers in relation to vitamin D? +		
Sun protection measures (e.g. wearing a hat, wearing sun block, seeking shade) should be followed between 11am and 4pm	165 (85.5)	86 (51.2)
Only expose your baby through a window	8 (4.1)	5 (5.6)
Only expose your baby to sun while he/she is being exclusively breast fed	5 (2.6)	1 (1.1)
Excessive sun exposure can lead to increased risk of skin cancer	125 (64.8)	76 (84.4)
None of the above	16 (8.3)	0
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		
True	111 (57.8)	41 (46.5)
False	24 (12.5)	10 (11.1)
Unsure	57 (29.7)	39 (43.3)
During winter and spring, infant and toddlers should spend time outside in the sun to maintain adequate vitamin D levels		
True	166 (86.0)	80 (88.9)
False	6 (3.1)	2 (2.2)
Unsure	21 (10.9)	8 (8.9)
Between October and March pregnant and lactating women are recommended to expose their face and arms to 5-20 minutes of sunshine per day		
True	107 (55.4)	47 (52.2)
False	21 (10.9)	7 (7.8)
Unsure	65 (33.7)	36 (40.0)
Deliberate sun exposure during peak UV times is recommended for pregnant and lactating women		
True	17 (8.8)	5 (5.6)
False	146 (75.6)	66 (73.3)
Unsure	30 (15.5)	19 (21.2)
Most pregnant women will achieve adequate vitamin D status in summer through incidental sun exposure outside peak UV times		
True	103 (53.4)	50 (55.6)
False	41 (21.2)	19 (21.1)
Unsure	49 (25.4)	21 (23.3)
Is there enough information about vitamin D available for parents?		
Yes	9 (4.8)	5 (5.6)
No	179 (95.2)	84 (94.4)

+ Multiple response set, participants able to select more than one answer.

Table 3.6 Awareness of Supplements for Infants and Pregnant Women

	2010 n (%)	**2019 n (%)**
Are you aware of any Vitamin D supplements for infant and toddlers available in New Zealand?		
Yes	79 (41.6)	50 (55.6)
No	111 (58.4)	40 (44.4)
Do any of the multiple vitamin and mineral supplements designed for women to take during pregnancy contain vitamin D?		
Yes	73 (37.8)	36 (40.0)
No	8 (4.1)	2 (2.2)
Unsure	112 (58.0)	52 (57.8)
What is the current recommendation regarding vitamin D supplementation in infants and toddlers? +		
All exclusively breastfed infants require vitamin D supplementation	11 (5.8)	10 (11.1)
All formula fed infants require vitamin D supplementation	20 (10.5)	3 (3.3)
Only infants and toddlers at risk of deficiency may require vitamin D supplementation	109 (57.1)	72 (80.0)
No New Zealand infants or toddlers require vitamin D supplementation	11 (5.8)	3 (3.3)
Unsure	57 (29.8)	8 (8.9)

+ Multiple response set, participants able to select more than one answer.

Table 3.7 Knowledge of Risk Factors for Deficiency During Pregnancy and Infancy

	2010 n (%)	2019 n (%)
Which of the following are risk factors for vitamin D deficiency during pregnancy and lactation?		
Exclusion of dairy products	74 (39.6)	42 (47.7)
Dark skin	92 (49.2)	79 (89.8)
Being housebound	150 (80.2)	83 (94.3)
Having multiple pregnancies	51 (27.3)	43 (48.9)
Living in the South Island of New Zealand	62 (33.2)	69 (78.4)
Covering the skin for cultural or religious regions	166 (88.8)	63 (94.3)
Which of the following are risk factors for vitamin D deficiency during infancy and childhood?		
Dark skin	100 (54.1)	75 (84.3)
Covering the skin	134 (72.4)	77 (86.5)
Being born prematurely	84 (45.4)	57 (64.0)
Gender	11 (5.9)	8 (9.0)
Having a mother who is vitamin D deficient	121 (65.4)	63 (70.8)
Not being regularly exposed to sunlight	165 (89.2)	87 (97.8)
Exclusive breastfeeding	27 (14.6)	29 (32.9)
Formula feeding	5 (2.7)	11 (12.4)
Born high birthweight	4 (2.2)	9 (10.1)

+ Multiple response set, participants able to select more than one answer.

3.5.4 Current Practices

The most common advice that health professionals in the 2019 population indicated they would give if concerned about vitamin D deficiency in a pregnant woman, was to increase sun exposure (67.9%). In the 2010 population, the most commonly selected response to this question was I do not give advice on vitamin D deficiency (67.9%) followed by increased sun exposure (51.1%). In 2019, 21.8% reported not giving advice to pregnant women.

The results for advice relating to vitamin D deficiency in an infant or toddler mirrored the results for in pregnant women. In 2010, the most common response was I do not give advice (52.5%) followed by increased sun exposure (51.4%). In 2019, the most common answer was increased sun exposure (62.4%). The proportion of participants who selected take a vitamin D supplement in response to this question increased between 2010 and 2019 for both pregnant women (18.9% and 61.5% in 2010 and 2019 respectively) and infants and toddlers (9.3% and 38.8% in 2010 and 2019 respectively).

Participants did not appear confident in recognising the signs of deficiency in infants and children as 84.5% of the 2010 population selected no I do not feel confident followed by 85.6% of the 2019 population.

In 2010, 68.2% of participants were concerned that some of their patients may be vitamin D deficient; in the 2019 population, this proportion was slightly greater at 73.3%. When asked about the number of suspected cases, the most common response was zero in both populations (61.2% and 55.6% in 2010 and 2019 respectively). In 2010, 12.2% of participants reported encountering over five cases compared to 17.8% in 2019. Number of cases was not significantly associated with profession. In 2010, 5.2% of these cases were self-managed by the health professional compared to 17.2% referring on to a specialist or hospital. In 2019, 26.3% were self-managed compared to 55.3% being referred to a specialist.

Information available to health professionals was deemed to be not enough by 81.2% of the 2010 population and 74.4% of the 2019 population. These findings have been summarised in table 3.8.

Table 3.8 Current Practices

	2010 n (%)	2019 n (%)
If you were concerned about vitamin D deficiency in a pregnant woman what advice would you give? +		
I don't give advice on vitamin D deficiency	129 (67.9)	17 (21.8)
Take a vitamin D supplement	36 (18.9)	48 (61.5)
Increased intake of foods which are good sources of vitamin D	86 (45.3)	47 (60.3)
Increased sun exposure	97 (51.1)	53 (67.9)
To take cod liver oil capsules	17 (8.9)	7 (9.0)
Refer to a specialist	64 (33.7)	21 (26.9)
Don't know	18 (9.5)	6 (7.7)
If you were concerned about vitamin D deficiency in a baby/child what advice would you give? +		
I don't give advice on vitamin D deficiency	96 (52.5)	18 (21.2)
Take a vitamin D supplement	17 (9.3)	33 (38.8)
Increased intake of foods which are good sources of vitamin D	89 (48.6)	40 (47.1)
Increased sun exposure	94 (51.4)	53 (62.4)
To take cod liver oil capsules	16 (8.7)	10 (11.8)
Refer to a specialist	74 (40.4)	30 (35.3)
Don't know	20 (10.9)	7 (8.2)
Do you feel confident that you would recognise the signs and symptoms of vitamin D deficiency in infants and toddlers?		
Yes	30 (15.5)	13 (14.4)
No	163 (84.5)	77 (85.6)
Are you concerned that some of your clients/patients may be vitamin D deficient?		
Yes	131 (68.2)	66 (73.3)
No	44 (22.9)	12 (13.3)
Not relevant	17 (12.4)	12 (13.3)
How many suspected or actual cases of vitamin D deficiency have you encountered over the past 5 years?		
None	115 (61.2)	50 (55.6)
1-2	36 (19.1)	18 (20.0)
3-5	14 (7.4)	6 (6.7)
>5	23 (12.2)	16 (17.8)
How were these cases managed?		
Not applicable	112 (58.3)	11 (14.5)
Provided all the management myself	10 (5.2)	20 (26.3)
Referred to specialist/hospital	33 (17.2)	42 (55.3)
Other	37 (19.3)	3 (3.9)
Do you think there is enough information about vitamin D available for health professionals?		
Yes	36 (18.8)	23 (25.6)
No	155 (81.2)	67 (74.4)

+ Multiple response set, participants able to select more than one answer.

3.5 Discussion

This study explores health professionals' knowledge and attitudes toward vitamin D for pregnancy and infancy in 2010 and 2019. The results indicate a varying level of understanding relating to vitamin D general knowledge, current recommendations for infants and pregnant women, and sun exposure guidelines. Although there appears to be an improvement in knowledge since 2010, there are still some important gaps, especially regarding the vitamin D contribution of breast milk, supplements, and sun exposure recommendations for infants. In both year groups, majority of participants were in agreement that there is insufficient information about vitamin D available to health professionals and parents.

3.5.1 Participant Characteristics

Females were largely overrepresented in both year groups. This finding is similar to that of an Australian study conducted by Dix et al. addressing knowledge of vitamin D in dietitians (Dix et al., 2017). An explanation for this overrepresentation in the latter study, is that the Australian dietetic workforce is largely female-dominated (Brown, Capra, & Williams, 2006). Additionally, New Zealand European ethnicity was overrepresented in both year groups, a finding similar to that of a New Zealand-based study conducted by Reeder et al. of health professionals' knowledge (Reeder et al., 2013). The limited representation of Māori and Pacific in the present study is similar to findings presented in a report by The New Zealand Health Workforce Advisory Committee. Māori and Pacific practitioners were reported to make up five and 1.7% of the professional health workforce respectively (Health Workforce Advisory Committee, 2010).

3.5.2 Knowledge of Vitamin D Sources and Functions

Similar proportions of participants in 2010 (94.8%) and 2019 (94.4%) correctly identified the primary source of vitamin D as being manufactured in the skin. This finding is similar to the New Zealand-based knowledge study where 91% of participants identified sun exposure outdoors as the main source of vitamin D (Reeder et al., 2013).

Selection of good dietary sources of vitamin D varied between year group with infant or toddler formula being the most frequently selected in 2010 (68.6%) and oily fish being more frequently selected in 2019 (79.8%). Both items are suitable food sources of vitamin D, relevant to different populations (Ministry of Health, 2013a; Ministry of Health and Cancer Society of New Zealand, 2012). Knowledge of food sources was assessed by Dix et al.; the results of this study were similar to data from the 2019 participants with oily fish being selected by 85% of participants (Dix et al., 2017). A concerning finding however, was that breastmilk was selected as a good dietary source of vitamin D in both year groups (44.3% and 31.5% in 2010 and 2019 respectively). Frequency of selection decreased between population however suggesting that awareness of the low vitamin D concentration of breastmilk, may have improved over time with release of the Consensus and Companion Statements. Breastmilk is the preferred food source for infants as per Ministry of Health guidelines (Ministry of Health, 2008a); it is possible that public health messages pertaining to the nutritional completeness of breastmilk, have led to confusion about vitamin D content. Furthermore, evidence is available that suggests maternal supplementation with vitamin D increases the vitamin D concentration of breastmilk to an acceptable level (Dawodu & Tsang, 2012). In a 2006 pilot RCT, Hollis et al. demonstrated that a daily 6400IU vitamin D supplement taken by lactating women was effective in raising serum vitamin D concentration in their breastfeeding infant (Wagner, Hulsey, Fanning, Ebeling, & Hollis, 2006). Infants in the study whose mothers did not receive a vitamin D-containing supplement, themselves received a 300IU daily vitamin D supplement (Wagner et al., 2006). The rise in serum vitamin D in infants of supplemented mothers was equivalent to the rise in serum vitamin D observed in the infants who received a 300IU supplement (Wagner et al., 2006). A limitation of this study was the small sample size of 19 women.

A more recent 2015 RCT conducted by Hollis et al. with a sample size of 334 mother-infant pairs, reported that a daily vitamin D supplement of 6400IU taken by the mother increased the vitamin D content of their breastmilk to meet the vitamin D requirements of the infants without harmful side effects (Hollis et al., 2015). Similar to the pilot RCT, maternal vitamin D supplementation of 6400IU per day raised the breastfed infants' vitamin D level equivalent to infant vitamin D supplementation of 400IU per day (Hollis et al., 2015). These findings highlight that breastmilk has the potential to be a good dietary source of vitamin D, when the lactating mother is replete. Awareness of this research may have contributed to professionals' selection of this response. it is important that New Zealand health professionals remain aware of the limited contribution breastmilk makes to the infants' vitamin D status given that the vitamin D concentration of breastmilk is improved when mothers are supplemented in much larger doses than the monthly 50,000IU currently subsidised in New Zealand. Maternal supplementation and subsequent changes in breastmilk vitamin D concentration have been explored in the New Zealand population. Lovell et al. reported that the serum vitamin D concentration in exclusively breastfed infants was independent of maternal supplementation, dietary intake and sun exposure (Lovell et al., 2016). Additionally, a study by Hougton et al. of 193 infants and toddlers reported that breastfeeding was independently associated with lower infant and toddler 25(OH)D levels (Houghton et al., 2010). A study by Grant et al. of 353 infants and toddlers reported that duration of breastfeeding was not associated with risk of vitamin D deficiency in the infant or toddler, however risk was increased in those who had never received milk formula (Grant et al., 2009). These findings further support that New Zealand health professionals must remain aware of the typically low vitamin D concentration of breastmilk. With the exception of breastmilk, health professionals in both year groups appeared to have good knowledge of vitamin D food sources as all appropriate answers were selected.

Majority of participants from both year groups correctly selected the functions of vitamin D as aiding in the absorption of calcium (82.9% and 90% in 2010 and 2019 respectively) and needed for bone development and mineralisation (80.3% and 94.4% in 2010 and 2019 respectively). This result was similar to those identified by Dix et al. where 95% selected calcium absorption and 95% selected bone development and mineralisation (Dix et al., 2017). In the present study, a much larger proportion of participants in 2019 selected aiding with immune system functioning (72.2% in 2019 compared to 38.3% in 2010). The increased frequency of selection in 2019 may be a result of vitamin D's role in immunity receiving greater research attention over the past decade. Dix et al. reported that immune system functioning was selected by 58% of participants (Dix et al., 2017). Majority of participants from both year groups correctly and most frequently selected rickets (86.3% and 84.4% in 2010 and 2019 respectively) and osteoporosis (82.1% and 85.6% in 2010 and 2019 respectively) as diseases associated with low levels of vitamin D. Similar results were observed by Dix et al. where 96% selected osteoporosis and 80% selected rickets (Dix et al., 2017).

3.5.3 Knowledge and Attitudes Toward Sun Exposure

Across the year groups, participants shared a similar attitude toward sun exposure messages making it difficult to get messages about vitamin D across. Both cohorts reported that public health messages about skin cancer risk made it difficult to communicate the important of vitamin D (78.5% in 2010 and 73.3% in 2019). Bonevski et al. reported similar results with 67.7% of participants agreeing that skin cancer prevention messages contribute to development of vitamin D deficiency (Bonevski et al., 2012). Reeder et al. reported that patient request for information regarding the use of sun protection and its impact on vitamin D was reported as one of the most vitamin D-related patient enquiries.

Knowledge of appropriate times in summer when time should be spent in the sun varied by year group. In 2010, the most frequently selected option was before 11am and after 4pm. Based on sun guidelines available at the time, this timeframe was correct (Cancer Society of New Zealand, 2007).

In 2019, the most frequently selected option was before 10am and after 2pm. Again, depending on guideline used, this timeframe is now correct. According to the Australian and New Zealand Bone Mineral Society Position Statement on Vitamin D in Health in Adults, before 10am and after 2pm are safe times for direct sun exposure to ensure adequate synthesis of vitamin D. The 2012 New Zealand Consensus Statement on Vitamin D states that direct sun exposure before 10am and after 4pm is safer; the questionnaire did not offer this timeframe, however. Overall, knowledge of suitable timeframes for sun exposure appeared good. Furthermore, knowledge appeared to shift with release of new guidelines. Concerning however, is that the proportion of participants who selected before 12pm and after 5pm increased between 2010 (1.15) and 2019 (20%) despite release of new guidelines. This is concerning as UVR becomes potentially damaging from 10am onwards (National Institute of Water and Atmospheric Rsearch, 2020). Reeder et al. reported that 35% of participants recommended daily sun exposure during peak UVR times of the day as a method for preventing vitamin D deficiency, without reference to season (Reeder et al., 2013). It is possible that the findings of Reeder et al. support the present study in that there is some confusion amongst health professionals relating to sun exposure guidelines.

A larger number of participants in 2019 (78.9%) compared to 2010 (53.9%), believed that people with dark skin such as Māori and Pacifica needed to spend longer amounts of time in the sun to synthesise adequate vitamin D. This finding suggests that awareness of skin colour and its impact on vitamin D status has improved. However, different guidelines state different recommendations. The Consensus Statement acknowledges dark skin as a deficiency risk factor but does not advocate for longer periods of sun exposure for this skin type. A similar guideline was presented in the outdated Cancer Society Position Statement. The Australian New Zealand Bone Mineral Society Position Statement suggests that individuals with dark skin may need to spend six to seven times longer in the sun to synthesis adequate vitamin D compared to their fairer skinned counterparts. Given the sun protective nature of melanin, darker skinned individuals are likely to need longer in the sun to synthesise adequate vitamin D (Webb et al., 2018). Ethnicity is typically used to associate skin tone in past and current New Zealand guidelines (Cancer Society of New Zealand, 2007; Ministry of Health and Cancer Society of New Zealand, 2012). New Zealand-based research, however, has identified disassociation between ethnicity and skin colour following migration and inter-ethnic marriage (Callister et al., 2011). As a result, advocating for longer periods of sun exposure for certain ethnicities may pose an increased risk of skin cancer development if appropriate timeframes in which sun exposure is safer, are not identified (Callister et al., 2011). Dix et al. reported similar results with 83% of participants agreeing that dark-skinned individuals needed to spend longer in the sun to synthesis vitamin D (Dix et al., 2017). Furthermore, Reeder et al. presented similar results, with participants reporting a longer mean number of minutes of sun exposure required for those with darker skin compared to lighter skin (Reeder et al., 2012). Neither the present study nor Dix et al. defined the UV period in which greater amounts of sun exposure are suitable for darker-skinned individuals. It cannot be concluded therefore, whether health professionals have good knowledge of safe sun exposure practices for darker-skinned individuals. It can be concluded however, that health professionals' awareness of skin colour and its implication for cutaneous vitamin D synthesis has improved from 2010 to 2019.

Health professionals in both cohorts appear confused as to whether sun exposure is safer through a window (see table 3.4). Similarly, health professionals appear confused about the efficacy of sun exposure through a window (see table 3.4). In an Australian survey of 114 mothers, 40% indicated sunning their baby on advice of a health practitioner to treat jaundice. Furthermore, 18.8% of these women indicated sunning their baby through a window (Harrison & Buettner, 1999). A further Australian study of 285 nurses reported that 20.5% of participants recommended sun exposure through a window for treatment of jaundice (Harrison, Hutton, & Nowak, 2002).

It is possible that a common belief about sun exposure through a window for treatment of jaundice has created confusion surrounding the safety and efficacy of sun exposure through a window in general.

Awareness of living in the South Island of New Zealand as a risk factor for vitamin D deficiency greatly improved between 2010 and 2019 with 46.1% correctly selecting true in 2010 compared to 72.2% in 2019. The proportion of those who selected unsure remained similar, however, with 20% selecting this response option in both year groups. Both the Cancer Society Position Statement on Sun Exposure and the Consensus Statement highlight that individuals living in more southern regions of New Zealand are less likely to synthesise adequate vitamin D cutaneously. A possible reason for the increased awareness in 2019, may follow the 2018 release of a highly publicised research article by Wheeler et al. that highlighted prevalent vitamin D deficiency in southern New Zealand (Wheeler et al., 2018). This article received media coverage by the New Zealand Herald in 2018 (Author not listed, 2018). Dix et al. reported similar findings to the 2019 population with 76% of participants selecting latitude of residence as a risk factor for deficiency.

Knowledge of the effects of season on vitamin D status appeared good in both year groups. In 2010, 73.6% believed season affected the length of sun exposure needed to synthesise adequate vitamin D. A further 81.3% believed that vitamin D levels may fall below adequate during winter. In 2019, proportions were similar (87.8% and 91.1% respectively). Dix et al. found similar results with 95% of participants agreeing that season affects the amount of UVR exposure needed to synthesise adequate vitamin D (Dix et al., 2017). Reeder et al. reported that 47% of participants selected supplements as a primary source of vitamin D in winter, a greater proportion than those who selected sunlight, suggesting that health professionals in this study were also aware of seasonal impact. Furthermore, Reeder et al. reported that 48% of participants selected relaxation of sun protection in winter as a preventative measure against vitamin D deficiency (Reeder et al., 2013). Bonevski et al. reported however, that 33.1% of participants recommended their patients used sun protection measures at all times during winter. This suggests there was confusion around the impact of season of vitamin D synthesis. Associations between season and vitamin D deficiency have been documented in the New Zealand population. Lucas et al. reported that 25(OH)D levels below 50nmol/L were identified in 56-74% of the 1606 post-menopausal participants during winter, which was an increase from the proportion of participants identified as having suboptimal 25(OH)D levels in summer (28-58%) (Lucas et al., 2005). Wheeler et al. reported that season had an effect on risk of vitamin D deficiency, in combination with latitude, in a prospective surveillance study of New Zealand children (Wheeler et al., 2015). Additionally, findings from the 2008/09 New Zealand Adult Nutrition Survey highlight that vitamin D deficiency is more likely to occur in the cooler months of August to October (Ministry of Health, 2012). It is important therefore, that health professionals are aware of the seasonal impact on vitamin D status.

3.5.4 Awareness of Sun Exposure Guidelines for Infants and Pregnant Women

Both year groups in the present study had opposing strengths and weaknesses regarding advice about sun exposure in relation to vitamin D for infants and toddlers, as neither population were able to unanimously identify the two key advice points in the response set. In 2010, the more frequently selected response was sun protection measures should be followed between 11am and 4pm (85.5%). This was selected by 51.2% of participants in the 2019 population however, with the more frequent selection being excessive sun exposure can lead to increased risk of skin cancer (84.4%). This option was selected by 64.8% in the 2010 population. It is concerning that near half of the 2019 population may not advise use of sun protection measures when discussing sun exposure in relation to vitamin D. More so, it is concerning that this pattern has been observed despite the increase in sun exposure guideline availability following 2010.

This finding is supported by Bonevski et al. who concluded that participants appeared more concerned about vitamin D status than risk of skin cancer (Bonevski et al., 2012). New Zealand has one of the highest rates of skin cancer internationally, secondary to a comparably harsher UVR environment (McKenzie, 2017). Sun exposure in relation to vitamin D adequacy therefore, must not compromise on sun safety behaviours, particularly in the infant population whose skin is more susceptible to UVR-induced damage (Shafie Pour et al., 2015).

Around half of the 2010 (57.8%) and 2019 (46.5%) populations believed that parents should expose infants to five to twenty minutes of direct sun exposure outside of the hours of 11am and 4pm, during summer. Sun exposure recommendations for the infant population vary, depending on the guideline looked at. Five to twenty minutes of direct sun exposure outside of peak UVR hours during summer is recommended in the Food and Nutrition Guidelines for Healthy Infants and Toddlers (Ministry of Health, 2008a). The current Companion Statement however, advises against direct sun exposure for infants at any time of the day, regardless of season (Ministry of Health, 2013a). It appears that knowledge of sun exposure guidelines did not improve in the 2019 cohort, with the release of the new guideline. A much larger proportion of the 2019 participants were unsure about the sun exposure guideline for infants, however. This uncertainty may be due to the conflicting guidelines in the Companion Statement and Food and Nutrition Guidelines for Healthy Infants and Toddlers (Ministry of Health, 2008a; Ministry of Health and Cancer Society of New Zealand, 2012). Internationally, health professionals have been identified as an influential source of information pertaining to sun protective behaviours (Lin, Eder, & Weinmann, 2011). Health professionals must therefore be advocating safe sun exposure practices. In order to do so, guidelines available to health professionals must be consistent.

Similar proportions of participants in both year groups agreed that infants and toddlers should spend time outside in the sun during winter to maintain adequate vitamin D levels (86% and 88.9% in 2010 and 2019 respectively). For toddlers who are independently mobile, sun exposure guidelines for the general population are suitable and sun exposure in winter is recommended (Ministry of Health, 2013a; Ministry of Health and Cancer Society of New Zealand, 2012). Despite season, direct sun exposure is not recommended for infants, however (Ministry of Health, 2013a). The specificity in current guidelines poses a challenge when using this question to comment on knowledge of safe sun exposure practices in the 2019 population. In the 2010 population, awareness of sun exposure guidelines was good as response mirrored the available recommendations in the Food and Nutrition Guidelines (Ministry of Health, 2008a). Comparison between year group relating to knowledge of safe sun exposure practices cannot be commented on, however, given that practices that constitute safe sun exposure have changed. What can be concluded however, is that these findings support those of a previous question from section 3.5.3, in that health professionals appear to have good knowledge of the influence of season on vitamin D synthesis.

Just over half of health professionals in 2010 (55.4%) and in 2019 (52.2%) believed that between October and March, pregnant women are recommended to expose their face and arms to five to twenty minutes of sunshine per day. Guidelines for the general population are suitable for pregnant and lactating women (Ministry of Health, 2013a). For 2010 participants, it could be argued that the five to twenty-minute time period is in line with the Cancer Society Position statement which recommends a few minutes to longer, depending on skin tone, of sun exposure either side of peak UVR times (Cancer Society of New Zealand, 2007). Similarly, for 2019 participants it could be argued that the five to twenty minutes is in line with the Consensus Statement's recommendation to partake in daily outdoor physical activity, the time of day at which depending on season. Furthermore, this recommendation is provided by the Food and Nutrition Guidelines for Healthy Pregnant and Breastfeeding Women.

This would suggest that an underwhelming proportion of health professionals had good knowledge of vitamin D and sun exposure guidelines. In 2010, 33.7% selected unsure in response to this recommendation compared to 40% in 2019. Uncertainty may be due to the lack of specificity regarding the time of day at which sun exposure is recommended. This question may therefore be an unfair representation of knowledge of safe sun exposure practices. In the following question, similar proportions of participants in 2010 (75.6%) and in 2019 (73.3%) disagreed that deliberate sun exposure during peak UVR times is recommended for pregnant and lactating women, suggesting that health professionals are aware of safe sun exposure practices for achieving vitamin D adequacy.

Similar proportions of health professionals in both year groups believed that pregnant women would achieve adequate vitamin D status in summer through incidental sun exposure outside of peak UV hours. This proportion was close to half (53.4% in 2010 and 55.6% in 2019) suggesting that health professionals in this study may be uncertain about the length of time required to synthesise adequate vitamin D. The Food and Nutrition Guidelines highlight that incidental sun exposure in summer is sufficient (Ministry of Health, 2006a) suggesting that health professionals in the 2010 population were largely unaware of their current guidelines. The Companion Statement however does not report this, therefore uncertainty related to this statement in the 2019 population is reasonable. Given that there are many factors which impact cutaneous synthesis of vitamin D, such as skin colour, level of clothing and latitude, this statement may not be appropriate for achieving adequate vitamin D levels in pregnant women. This finding therefore appears to support results from section 3.5.3, which suggest health professionals have good knowledge of factors influencing cutaneous vitamin D synthesis and thus of risk factors for deficiency.

In both year groups, participants near unanimously agreed that there was not enough information available to parents about vitamin D (95.2% and 94.4%). In 2013, fact sheets were published for parents and pregnant women by The Ministry of Health in several different languages that detailed sources of vitamin D, risk factors for deficiency and indicators for supplementation (Ministry of Health, 2013b, 2013c). It is possible that health professionals in 2019 are unaware of this or do not believe it is adequate. As health professionals themselves are a source of information to parents, it is interesting that the belief of insufficient information being available to parents was so unanimous. To follow this up, health professionals were asked whether they felt there was enough information available to them regarding vitamin D. In 2010, 81.2% selected no and in 2019, 74.4% selected no. The slight decrease may reflect better publicity surrounding release of the new guidelines in 2012 (Ministry of Health and Cancer Society of New Zealand, 2012) however it is troubling that despite these specific guidelines, such a large proportion of health professionals in 2019 believed there is insufficient information available to them. Furthermore, this finding highlights that it is unreasonable to expect health professionals to provide adequate information to parents, if sufficient information is not available to the professionals themselves. This warrants further research into understanding how current clinical guidelines may not be meeting the needs of health professionals. These findings are supported by those of Bonevski et al. and Reeder at al. where majority of their participants reported that they would highly value clear guidelines pertaining to management of vitamin D status (Bonevski et al., 2012; Reeder et al., 2012). Furthermore, Bonevski et al. reported that clinical guidelines were a source of information for less than one third of the population (Bonevski et al., 2012). Both studies were conducted prior to the release of the Consensus Statement, however.

3.5.5 Awareness of Supplements for Infants and Pregnant Women

Many health professionals lacked awareness of vitamin D supplements available for infants. In 2010, 58.4% reported being unaware and in 2019, 44.4% reported being unaware. Although awareness appears to have improved, it is of concern that the improvement was so slight given that PHARMAC opted to fund a vitamin D-only supplement for infants beginning in January of 2019 (PHARMAC, 2018).

Prior to this, Vitadol-C, a vitamin D-containing multivitamin, was available to infants as per the PHARMAC schedule (PHARMAC, 2018). Similarly, when questioned about vitamin D-containing supplements for pregnant women, majority of participants in 2010 (58%) and 2019 (57.8%) were unsure. Given that there is no vitamin D supplement designed specifically for pregnant women as there is for infants, and that pregnant women are advised to seek information from their health professional regarding supplements, it is pertinent that health professionals are aware of the options. Overall, health professionals appear to lack knowledge of vitamin D supplement availability for infants and pregnant women. The Companion Statement outlines the suitability of Vitadol C for the infant population as this was the funded supplement at time of publication (Ministry of Health, 2013a). An update is warranted given this will be discontinued and replaced with Puria (PHARMAC, 2018). Multivitamin and mineral supplements designed for pregnancy are not discussed in the Companion Statement (Ministry of Health, 2013a) which may be a potential flaw given that health professionals in the present study appear to lack awareness of their vitamin D content. The document does however highlight that the vitamin D preparation used in the New Zealand general population is suitable for use in pregnancy (Ministry of Health, 2013a).

With different levels of detail, supplementation guidelines available to the 2010 and 2019 populations suggest that only infants at risk of deficiency may require vitamin D supplementation. In 2010 and in 2019, health professionals appeared to have good knowledge of the supplementation guidelines as the aforementioned recommendation was the most frequently selected response when asked about vitamin D supplementation guidelines for infants (57.1% and 80% in 2010 and 2019 respectively). A smaller proportion of participants in 2019 (8.9%) were unsure about the guideline compared to 2010 (29.8%) suggesting that awareness of this guideline improved over time.

3.5.6 Knowledge of Risk Factors for Deficiency During Pregnancy and Infancy

Overall, health professionals in 2010 and in 2019 appeared to have relatively good knowledge of risk factors for deficiency in pregnancy, key improvements being in acknowledgement of dark skin and southern locality. In 2010, the most frequently selected risk factor was covering the skin (88.8%) whereas in 2019, it was being housebound (94.3%). Risk factors for deficiency in pregnant women as per the Consensus Statement include having dark skin, being housebound, living in the South Island and covering the skin for cultural or religious purposes. In 2019, each of these responses were selected by more than 80% of participants suggesting a good level of knowledge. Furthermore, selection of dark skin increased from 49.2% in 2010 to 89.8% and selection of living in the South Island increased from 33.2% in 2010 to 78.4% suggesting that awareness of risk factors improved over the intervening decade.

Over one third of participants selected exclusion of dairy as a risk factor (39.6% and 47.7% in 2010 and 2019 respectively). Dairy is a source of naturally occurring vitamin D however provision of adequate vitamin D required to meet dietary requirements is largely dependent on food fortification (Itkonen et al., 2018), a practice that is voluntary in New Zealand (Food Standards Australia New Zealand, 2017). When sun exposure is adequate, exclusion of dairy products will not impact vitamin D status negatively (Ministry of Health and Cancer Society of New Zealand, 2012). It is important that health professionals are aware of this as to not place undue emphasis on the vitamin D content of dairy products before other interventions.

Health professionals appeared less aware of risk factors for deficiency in the infant population. As with previous sections, health professionals had better knowledge of dark skin as a risk factor in 2019 (84.3%) compared to 2010 (54.1%). In both year groups, participants appeared to have good knowledge of covering the skin (72.4% in 2010 and 86.5% in 2019) and irregular sun exposure as risk factors (89.2% in 2010 and 97.8% in 2019).

Participants appeared to be less aware of maternal deficiency and prematurity however frequency of selection increased between 2010 and 2019 suggesting an improvement in knowledge. Maternal deficiency is outlined as a risk factor in all available guidelines (Cancer Society of New Zealand, 2007; Ministry of Health, 2008a, 2013a). Prematurity, however, is outlined in the Companion Statement only, which may account for the increased awareness between 2010 and 2019.

The proportion of participants who selected exclusive breastfeeding as a risk factor was fairly small in both year groups, however, did improve between 2010 (14.6%) and 2019 (32.9%). The Food and Nutrition guidelines state that prolonged exclusive breastfeeding is a risk factor; the Cancer Society Position Statement and the Companion Statement, however, specify exclusive breastfeeding without a timeframe. Similar findings have been observed internationally where misperception of the vitamin D content of breast milk led practitioners to decide against initiation of supplementation in their exclusively breastfed infant patients (Oberhelman et al., 2018; Sherman & Svec, 2009). While routine supplementation of breastfed babies is not supported by New Zealand guidelines, supplementation is recommended for babies who are breastfed with one or more risk factors present. Health professionals, therefore, must be aware of breastfeeding as a deficiency risk factor. Under-supplementation has been observed in the New Zealand infant population despite presentation with risk factors for deficiency (Wheeler et al., 2015).

3.5.6 Current Practices

To explore current practices, participants were asked what advice they would give to infant or pregnant patients if they were concerned about vitamin D deficiency. The proportion of participants who indicated they did not give advice about vitamin D decreased in 2019, suggesting that health professionals are more active in managing vitamin D status in 2019 compared to 2010.

The proportion of participants who reported they would suggest a supplement to pregnant women (18.9% in 2010 and 61.5% in 2019) and to infants (9.3 in 2010 to 38.8% in 2019) increased over the decade, suggesting increased confidence in using this treatment. These findings also highlight that participants may be more likely to suggest supplementation for pregnant women opposed to infants. This may be due to participants being unaware of supplements available for infants (table 3.6). Furthermore, this supports findings from the New Zealand infant population where supplementation has not been initiated despite presentation with risk factors for deficiency (Wheeler et al., 2015). Internationally, health professionals have shown greater likelihood of initiating supplementation when indicated in infancy (Oberhelman et al., 2018). Despite availability of New Zealand guidelines pertaining to supplementation with vitamin D in infants (Cancer Society of New Zealand, 2007; Ministry of Health, 2008a; Ministry of Health and Cancer Society of New Zealand, 2012), knowledge of this practice appears limited. It is not recommended that infants are exposed to direct sunlight and increasing food sources of the vitamin may not be appropriate depending on age and feeding mode. Health professionals, therefore, must be confident in prescribing supplements to the infant population when indicated. Nurses and Plunket Nurses make up 67.9% of the 2010 population and 36.7% of the 2019 population. Given these professions do not typically have prescribing rights, bias may have been introduced to questions pertaining to supplements.

The proportion of health professionals who indicated they would recommend increasing sun exposure for a pregnant woman increased from 51.1% in 2010 to 67.9% in 2019. It is not concerning that a large proportion may recommend increased sun exposure, as previous results indicate health professionals will advocate for this safely in pregnant women. Furthermore, this recommendation is in line with Best Practice Advocacy Centre New Zealand's guideline (Best Practice Advocacy Centre New Zealand, 2011). It could therefore be argued, that an insufficient proportion of health professionals selected this response. Similar proportions of participants in 2010 (51.4%) and in 2019 (62.4%) reported they would advise increased sun exposure for infants.

The proportion of participants increased between 2010 and 2019, despite release of guidelines advocating against direct sun exposure for infants. For independently mobile children however, sun exposure guidelines for the general population apply. Increasing sun exposure may therefore be a suitable measure. The specificity of current guidelines poses a challenge in commenting on health professionals' knowledge of safe sun exposure practices for children.

In both year groups, similar proportions of participants indicated they did not feel confident in their ability to recognise the signs and symptoms of vitamin D deficiency (84.5% in 2010 and 85.6% in 2019). Similar findings have been identified in existing literature. Reeder et al. reported that 43% of participants were not at all confident in their knowledge of vitamin D (Reeder et al., 2012). Furthermore, Dix et al. concluded that their results highlighted a lack of confidence amongst participants with regards to managing vitamin D status (Dix et al., 2017). Bonevski et al. however, reported that 77.3% of participants were somewhat confident in their knowledge of vitamin D. Bias may have been introduced into the latter study however as 43% of participants reported receiving a greater than usual amount of information about vitamin D in the last 12 months (Bonevski et al., 2012). Health professionals are at the forefront of recognising vitamin D deficiency in the general population. Public health becomes endangered when health professionals do not feel confident in their ability to recognise health conditions. Responsibility falls on both health professionals and government organisations to ensure members of the healthcare workforce are sufficiently equipped to manage health conditions. Signs and symptoms of vitamin D deficiency are outlined in the Consensus and Companion Statements under indications for vitamin D testing (Ministry of Health, 2013a; Ministry of Health and Cancer Society of New Zealand, 2012). Current New Zealand guidelines for the management of vitamin D status focus largely on prevention opposed to treatment however, as vitamin D supplementation is recommended for asymptomatic at-risk individuals. Given the limited focus on treatment of symptomatic deficiency, it is reasonable that health professionals do not feel confident in recognising the signs. Health professionals must be aware of the symptoms however, particularly to support the health of individuals who do not fall into the at-risk categories. Lack of confidence may further be explained by the number of actual or suspected cases of vitamin D deficiency that health professionals have been exposed to. In both year groups, over half of the participants reported they had encountered none over the last five years (61.2% in 2010 and 55.6% in 2019). Of the 44.4% of the 2019 participants who had encountered or suspected vitamin D deficiency in a patient, 55.3% reported these cases were referred on to specialists or hospital. It cannot be concluded whether this is due to a lack of confidence as current guidelines advise referral to a specialist if metabolic bone disease is identified (Ministry of Health, 2013a). Dix et al. reported that participants more commonly had seen zero to five cases of vitamin D deficiency (34%) in the last year however 25% reported seeing 31 or more cases. Participants who had encountered over 31 cases were more likely to be working in private practice (Dix et al., 2017). Private practice employees were largely underrepresented in the present study which may account for some of the dissimilarity between present findings and those of Dix et al.

Similar proportions of participants from both year groups expressed concern that some of their patients may be vitamin D deficient (68.2% in 2010 and 73.3% in 2019). Dix et al. reported similar results with 86% of participants indicating they were concerned that their patients were deficient in vitamin D (Dix et al., 2017). Further, Bonevski et al. reported that 83.3% of participants indicated they were concerned their patients may lack sufficient vitamin D (Bonevski et al., 2012). Reeder et al. had similar findings with 87% of participants indicating they were concerned their patients were not getting enough vitamin D (Reeder et al., 2012). Findings from the present study appear to build on existing literature in that concern about vitamin D deficiency is widespread amongst health professionals. This concern highlights that the present study was justified. Vitamin D deficiency is a relevant condition for the health professionals included in the present and existing studies (Bonevski et al., 2012; Dix et al., 2017; Reeder et al., 2012).

Assessing knowledge provides insight as to the care which may be provided to affected individuals, thus highlighting whether current clinical guidelines have been adopted into practice.

3.6 Strengths and Limitations

A key strength of this study is that it is the first, to the authors knowledge, to assess knowledge in a variety of health professions working with mothers and children. Existing literature focused largely on knowledge of GPs thus the present study had the potential to be more representative of the healthcare workforce compared to previous studies. Sample numbers and uneven distribution between health professions in the present study however, reduced representativeness. This is one of the first New Zealand-based studies, to the authors knowledge, which addresses health professionals' knowledge after the release of the Consensus and Companion Statements, thus providing a more relevant assessment of knowledge. Participants were not asked whether they had seen the Consensus and Companion Statements; this is a key limitation in using this data to assess whether health professionals have incorporated the guidelines into practice. Furthermore, it reduces the reliability of recommendations for future practice as causation for gaps in knowledge was not addressed. Exploring sources of information utilised by health professionals may have alluded to the reason why knowledge deficits occurred. Additionally, questions developed in line with outdated guidelines may have confused participants in the 2019 population as recommendations differ in current guidelines, thus providing an inaccurate measure of knowledge.

3.7 Conclusion

Findings from the present study were largely consistent with existing literature where available. This study builds on existing literature suggesting that health professionals have good knowledge of vitamin D sources, functions and risk factors for deficiency (Bonevski et al., 2012; Dix et al., 2017; Reeder et al., 2012). Knowledge of sun exposure guidelines are more varied however, with some practices considered unsafe in line with current guidelines (Bonevski et al., 2012; Dix et al., 2017; Reeder et al., 2012). Gaps in knowledge appear related to the vitamin D content of breastmilk and the availability of vitamin D supplements for infants, despite clarification in current guidelines and recent release of a vitamin D-only infant supplement (Ministry of Health, 2013a; PHARMAC, 2018). Confusion around recommendations for sun exposure is more reasonable given the inconsistencies between available guidelines, particularly relating to direct sun exposure for infants (Ministry of Health, 2008a, 2013a). Overall, knowledge appeared to improve from 2010 to 2019. Further research is necessary to investigate how health professionals have responded to the Consensus and Companion Statement and to identify effective interventions to improve knowledge in this sector of the health workforce. The current findings provide useful insight as to areas where further education for health professionals is needed.

Chapter 4. Conclusion and Recommendations

4.1 Overview

The aim of this study was to assess health professionals' knowledge and attitudes toward vitamin D for the general population, pregnancy and infancy. This was achieved by conducting a questionnaire that addressed knowledge of vitamin D status management. Additionally, this study aimed to assess change in knowledge, which was achieved by conducting the questionnaire in 2010 and again in 2019, without alteration to questions. The objectives of this study were to assess knowledge of vitamin D sources, functions and risk factors for deficiency, knowledge and attitudes toward sun exposure in relation to vitamin D adequacy, awareness of vitamin D supplements, and exploration of current practices regarding management of vitamin D. These objectives were achieved by development of the questionnaire in line with New Zealand guidelines regarding vitamin D.

Health professionals in both year groups appeared to have good knowledge of vitamin D sources, including cutaneous synthesis as the primary source for humans and of which foods that are higher in vitamin D. Functions of vitamin D appeared well-known. An appropriate increase in the proportion of participants who believed vitamin D was involved in immune system functioning was observed from 2010 to 2019, mirroring the increase in research available that recognises this extra-skeletal function. Knowledge of deficiency risk factors appeared to improve between the first and second questionnaire, particularly with regards to latitude and dark skin. In both year groups, the impact of season on vitamin D appeared well-known. With regards to infant risk factors, majority of participants in both cohorts failed to identify exclusive breastfeeding as a risk factor. Furthermore, a large proportion of participants from both year groups identified breastmilk as a good dietary source of vitamin D. Evidence is available that suggests breastmilk can be a good source of vitamin D if the lactating mother is supplemented (Hollis et al., 2015). However, health professionals should continue to identify exclusive breastfeeding as a risk factor for deficiency as per current New Zealand guidelines as breastmilk is not a naturally occurring vitamin D-rich food source (Ministry of Health, 2013a). Additionally, there is research available to suggest maternal vitamin D supplementation is not independently associated with infant 25(OH)D levels in breastfed infants (Lovell et al., 2016).

Participants in 2019 appeared more aware of the impact of latitude and darker skin tone on cutaneous vitamin D synthesis, compared to 2010. Knowledge of the safety and efficacy of sunlight exposure through a window was poor in both year groups, however. Despite release of guidelines highlighting sunlight exposure through a window as unsafe and ineffective, knowledge did not change between the year groups. For infants and pregnant women, previous New Zealand guidelines discussed sun exposure requirements for achieving vitamin D adequacy with reference to the number of minutes needed to be spent in direct sunlight. The 2010 population appeared to lack knowledge of this guideline. Uncertainty relating to these guidelines increased in 2019, which may have been due to the inconsistency between recommendations outlined in the newer Consensus and Companion Statements (Ministry of Health, 2013a; Ministry of Health and Cancer Society of New Zealand, 2012) and older Food and Nutrition Guidelines (Ministry of Health, 2006a, 2008a). Newer guidelines detail sun exposure requirements for vitamin D adequacy with reference to participating in outdoor physical activity, opposed to a prescriptive number of minutes (Ministry of Health, 2006a, 2008a). Health professionals' in both year groups appeared to have better knowledge of safe sun exposure practices for pregnant women opposed to infants. This may be due less inconsistency in sun exposure guidelines for pregnant women (Ministry of Health, 2006a; Ministry of Health and Cancer Society of New Zealand, 2012).

Participants appeared to have greater knowledge of the supplementation guideline for infants in 2019 compared to 2010. Awareness of supplements available for infants however, remained poor in both year groups. Despite advertisement of the funded vitamin D-containing multivitamin in the Companion Statement (Ministry of Health, 2013a) and recent decision by PHARMAC to fund a vitamin D-only supplement for infants (PHARMAC, 2018), an increased awareness of infant supplement availability in the 2019 population was not observed. With regards to current practices in both year groups, a larger proportion indicated they would advise pregnant women to take a vitamin D supplement compared to infants, suggesting participants may lack confidence in prescribing supplements to infants. Participants in both year groups were largely unaware of the vitamin D content of supplements designed specifically for pregnant women.

Current practices were addressed through selecting hypothetical advice for management of vitamin D deficiency in an infant or child and pregnant woman. A lesser proportion of participants indicated they would not give advice in 2019 compared to 2010, suggesting participants from the 2019 group may be more confident in managing vitamin D status. Participants in 2019 appeared to have good knowledge of appropriate advice for pregnant women, including increase sun exposure, increase intake of vitamin D food sources and to take a supplement. Health professionals in the 2019 group appear to have a better understanding of vitamin D management for pregnant women than for infants. A similar pattern was observed in the 2010 group.

This study has made a valuable contribution to existing literature detailing health professionals' knowledge of vitamin D. Health professionals appear to have good knowledge of vitamin D sources, functions and risk factors for deficiency, and this knowledge has improved over time. It appears that health professionals lack knowledge of safe sun exposure practices for infants, however inconsistencies in sun exposure guidelines for achieving vitamin D adequacy may have contributed to this. Overall, management of vitamin D status in infants may be an area where health professionals need more support, given the lack of knowledge indicated by the present study pertaining to exclusive breastfeeding as a risk factor for deficiency, safe sun exposure and supplement availability. Further research looking at sources of information utilised by health professionals may be useful in understanding why these gaps in knowledge have occurred.

4.2 Strengths

4.2.1 Questionnaire Design

A key strength of this study is that, to the authors knowledge, this is the first New Zealand study to health professionals' knowledge of vitamin D following an update in guidelines. Additionally, this is the first study, that the author is aware of, which covers such a broad scope of vitamin D knowledge. Previous studies focused largely on sun exposure or supplementation for infants specifically, thus the broad scope of this study is a major strength as overall knowledge of vitamin D can be assessed. A key result of this being that avenues for future research have been identified. In similar studies, knowledge level has been scored (AlBishi et al., 2018). The absence of a scoring system in the present study was a strength as this provided more specific details about health professionals' knowledge.

Another strength of this study was the use of national guidelines to devise questionnaire items. This provided a more objective measure of knowledge and was able to provide some insight as to whether health professionals are familiar with the guidelines.

4.2.2 Recruitment

A major strength of this study was that health professionals from a range of professions, particularly those who are likely to work with infants and pregnant women, were recruited. To the authors knowledge, this is the first study in New Zealand that assesses knowledge of vitamin D in professions other than GPs.

Use of governing bodies for questionnaire distribution is strength of this study as it increases the questionnaire reach and thus may increase the geographical diversity of the sample population. However, the two cohorts were self-selected and therefore not representative of health professionals in New Zealand.

4.3 Limitations

4.3.1 Questionnaire Design

A strength of this study was the use of the same questionnaire by the two cohorts. This allowed for accurate comparison of knowledge. A limitation of this, however, was that certain sun exposure questions did not align with more recent guidelines. Sun exposure questions should have been edited for the 2019 cohort to ensure they were in line with recommendations from the Consensus and Companion Statements.

4.3.2 Population Characteristics

The sample size of this study was relatively small, particularly in comparison to existing studies of health professionals' knowledge of vitamin D, therefore may not be representative of knowledge in the wider population of health professionals in New Zealand. Furthermore, the sample size of the 2019 year group was notably smaller than that of the 2010 year group, thus unlikely to accurately reflect change in knowledge. Additionally, response rate was unable to be calculated. This statistic may have given insight as to the sample population's representatives of the source population.

Both sample populations lacked diversity given that majority of participants were female and of New Zealand European ethnicity. Additionally, the 2010 year group lacked diversity between professions, with nurses comprising 67.9% of this year group. For both year groups, diversity amongst professions may have been improved if additional contact databases were used such as the Medical Council of New Zealand's register of Doctors and the New Zealand College of Midwives database. GPs were largely underrepresented in this study; greater involvement from this profession would have improved diversity and therefore generalisability. It has been noted in existing literature that this profession are particularly challenging to engage (Bonevski et al., 2012).

4.4 Final Recommendations

4.4.1 Key Messages from this Study

Knowledge deficits amongst health professionals have been identified in this study. Causation for these deficits must be identified to strengthen interventions that focus on improving knowledge. Interventions to improve knowledge are likely to be well received by health professionals as near three quarters of all participants in both cohorts believe there is not enough information about vitamin D available to health professionals. Furthermore, approximately two thirds of all participants reported they were concerned that some of their patients may be deficient in vitamin D. Only 15% of all participants, however, reported they felt confident they would recognise the signs and symptoms of vitamin D deficiency. Areas where health professionals need further education as identified by the present study are:

- The limited vitamin D content of breastmilk and recognition of exclusive breastfeeding as a risk factor for vitamin D deficiency.
- Vitamin D supplements that are available to the infant population.
- Sun exposure guidelines for infants.
- The lack of safety and efficacy of sun exposure through a window for stimulating cutaneous vitamin D synthesis.
- Recognition of the signs and symptoms of vitamin D deficiency.

4.4.2 Future research

Continuing to develop the literature regarding knowledge of vitamin D is necessary, given the severity of deficiency complications. Future research will be beneficial to population health as findings may guide development of public health initiatives. Useful avenues for future research are:

- Assessment of where health professionals' source their information from regarding vitamin D, as this may provide some understanding as to why the gaps in knowledge have occurred.
- How best to educate health professionals, so that interventions to improve knowledge are successful.
- Larger sample sizes and greater sample population diversity is needed in future studies to strengthen generalisability.
- Additionally, in-depth qualitative studies are needed to better understand knowledge and current practices. This may highlight gaps in knowledge that cannot be identified in quantitative questionnaires.

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Appendices

Appendix A. Supplementary Results

Table A.1 Supplementary Results

	2010 n (%)	2019 n (%)
In New Zealand we are seeing a re-emergence of rickets		
True	131 (68.2)	62 (68.9)
False	15 (7.8)	3 (3.3)
Unsure	46 (24.0)	25 (27.8)
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		
True	112 (58.0)	73 (81.1)
False	42 (21.8)	9 (10.1)
Unsure	39 (20.2)	8 (8.9)
If yes, will pregnancy women meet their requirements for vitamin D from supplements alone? *(In following from: Do any of the multiple vitamin and mineral supplements designed for women to take during pregnancy contain vitamin D?)*		
Yes	13 (6.8)	4 (4.9)
No	82 (42.7)	39 (47.6)
Unsure	97 (50.5)	39 (47.6)
Which of the following treatments would you use as a first line treatment for rickets? +		
Vitamin D supplements	121 (70.3)	64 (86.5)
Calcium supplements	66 (38.4)	33 (44.6)
Dietary change to include more calcium	77 (44.8)	35 (47.3)
Dietary change to include more vitamin D	101 (58.7)	43 (58.1)
Increased sun exposure	124 (72.1)	47 (63.5)
Don't know	9 (5.2)	0
Do you ever recommend that your client/patient has a blood test to measure their vitamin D status?		
Yes	59 (30.6)	55 (61.1)
No	116 (60.1)	35 (38.9)
Not relevant	18 (9.3)	0
Years of experience (median (25th, 75th percentile))		
2010 (n=182)	**2019 (n=86)**	
15.0 (5.0, 27.5)	8.0 (4.0, 16.75)	

+ Multiple response set, participants able to select more than one answer.

Appendix B. Research Approval

B.1 Massey University Human Ethics Committee Low Risk Standing

Date: 02 July 2019

Dear Alexandra Thomson

Re: Ethics Notification - **4000021370** - **New Zealand Health Professional's beliefs and knowledge of Vitamin D in pregnancy and infancy.**

Thank you for your notification which you have assessed as Low Risk.

Your project has been recorded in our system which is reported in the Annual Report of the Massey University Human Ethics Committee.

The low risk notification for this project is valid for a maximum of three years.

If situations subsequently occur which cause you to reconsider your ethical analysis, please contact a Research Ethics Administrator.

Please note that travel undertaken by students must be approved by the supervisor and the relevant Pro Vice-Chancellor and be in accordance with the Policy and Procedures for Course-Related Student Travel Overseas. In addition, the supervisor must advise the University's Insurance Officer.

A reminder to include the following statement on all public documents:
"This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named in this document are responsible for the ethical conduct of this research.

If you have any concerns about the conduct of this research that you want to raise with someone other than the researcher(s), please contact Professor Craig Johnson, Director - Ethics, telephone 06 3569099 ext 85271, email humanethics@massey.ac.nz."

Please note, if a sponsoring organisation, funding authority or a journal in which you wish to publish requires evidence of committee approval (with an approval number), you will have to complete the application form again, answering "yes" to the publication question to provide more information for one of the University's Human Ethics Committees. You should also note that such an approval can only be provided prior to the commencement of the research.

Yours sincerely

Research Ethics Office, Research and Enterprise
Massey University, Private Bag 11 222, Palmerston North, 4442, New Zealand **T** 06 350 5573; 06 350 5575 **F** 06 355 7973
E humanethics@massey.ac.nz **W** http://humanethics.massey.ac.nz

Human Ethics Low Risk notification

Professor Craig Johnson
Chair. Human Ethics Chairs' Committee and Director (Research Ethics)

Research Ethics Office, Research and Enterprise
Massey University, Private Bag 11 222, Palmerston North, 4442, New Zealand **T** 06 350 5573; 06 350 5575 **F** 06 355 7973
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B.2 Royal New Zealand Plunket Trust Application for Research & Evaluation Review

ROYAL NEW ZEALAND PLUNKET TRUST
APPLICATION FOR RESEARCH & EVALUATION REVIEW

This form is for external or internal researchers seeking Plunket support for their study by way of advertisement, recruitment or participation. All details must be completed in full. Please note, no research or evaluation funding can be allocated by the reviewers of this form.

Contact Details

Principal investigator: Alex Thomson _____

Organisation: Massey University _____

Role in organisation: Student Dietitian _____

Email: a.thomson1@massey.ac.nz _____ Phone: 0211623600 _____

Address: Massey University Oteha Rohe Campus, The Station Crescent, Albany, Auckland 0632 _____

Contact for this application if different from above:

Name: _____ Position: _____

Email: _____ Phone:

_____

Address: _____

Research Details

Title: New Zealand-based Health Professionals' Attitudes and Knowledge of Vitamin D During Pregnancy and Infancy _____

Proposed start date: 1st May 2019 _____

Proposed end date: December 31st 2019 _____

What support are you seeking from Plunket?

I want Plunket to advertise my research/evaluation ☐

I want to observe, survey or interview Plunket People ☐

I want to observe, survey or interview Plunket Clients ☐

I want Plunket to help recruit participants for my research/evaluation ☐

Other ☐

Please explain _____

1. Research/ Evaluation Summary

Summary of purpose and objectives of the research (please use simple language, including why, who, what and where):

The purpose of this study is to explore what New Zealand-based health professionals are currently recommending about vitamin D during pregnancy and infancy. Furthermore, the purpose of this study is to explore whether health professionals' knowledge of vitamin D during pregnancy and infancy has changed within the last decade. Involvement in this study will require competition of a questionnaire that explores knowledge of vitamin D sources and functions in the body, risk factors for deficiency and supplement availability. Current practices regarding deficiency prevention and treatment as well as experience with cases of deficiency will also be explored.

Vitamin D deficiency is becoming increasingly prevalent amongst infants and pregnant women within New Zealand. Deficiency is associated with complications of pregnancy, bone deformities and poor immune system functions. It is essential that prevention of vitamin D deficiency becomes a public health initiative. Health professionals are at the forefront of providing education to this population group about vitamin D and its importance for health. These findings will provide useful insight as to what information is being provided to pregnant women and the primary caregivers of infants in New Zealand. Research such as this is important for shaping development of public health policy that supports the health of our pregnant and paediatric populations.

2. Risk Profile

a) Is the Research / Evaluation testing methods, actions or advice contrary to current best practice guidelines?

b) If yes, how will participants be protected?

c) Does your research involve vulnerable participants? Yes / No

d) If yes, how will participants be protected?

3. Local Involvement

a) Does your research require the involvement of a local or regional Plunket team? _ Yes / No

b) If yes, where? An invitation to complete this questionnaire extends to health care staff from all Plunket teams nation-wide _____

c) Is the local or regional Plunket team aware of your research?_____ Yes / No

d) If yes, who have you been in contact with? _____

4. Reporting of results

a) What are the expected outputs of the research? Please include proposed publications.

The results will be presented in a thesis as required by the Master of Science Nutrition and Dietetics program at Massey University, Auckland. This research is being conducted by student Dietitian Alex Thomson (a.thomson1@massey.ac.nz) under the supervision of Dr Pam von Hurst (p.r.vonhurst@massey.ac.nz) and Dr Cath Conlon (c.conlon@massey.ac.nz). This concludes the research team. The findings may be written up for publication in an academic journal if appropriate.

b) Will the results be provided to participants?

Yes. Questionnaire respondents are given the option of listing their email address if they would like to receive an analysis of the results.

5. Ethics

a) Do you have ethics approval from a HDEC accredited New Zealand ethics committee? Yes / No

b) If no, will you be seeking ethics approval from an HDEC accredited ethics committee? Yes / No

c) If no, please explain

6. Funding

How will the research be funded? No funding is required for this study.

Are the proposed sources of funding likely to introduce any conflicts of interest for Plunket? (If unsure please put yes) Yes / No

If yes, please explain potential conflicts and how these may be mitigated.

7. Accompanying documents

Please attach the following to this application:

- Your research proposal

  AND/OR

- A copy of the consent form.
- A copy of the information to be given to participants.
- A copy of any questions participants will be asked (questionnaires, interview or focus group questions).
-

  AND

- A copy of your ethics approval (if applicable)

8. Signature

All the information included above and in the attached documents is true and correct.

Signature, Principal Investigator: 

Date: 10/10/2019

Appendix C. Additional Documents

C.1 Email and Facebook Group Invitation Template

Hi there,

I am a student Dietitian at Massey University in Auckland.

I am currently completing my thesis which looks into what New Zealand-based Health Professionals are recommending about Vitamin D during pregnancy and infancy.

I would be extremely grateful to have input from (insert relevant health profession/organisation/Facebook group).

If you would like to be involved in this exciting research project, please follow this link and complete the 5-10 minute questionnaire: https://www.surveymonkey.com/r/M89VZTQ

Please feel free to forward this invitation to any of your colleagues. I would love to hear from Health Professionals all around the country!

If you are experiencing any difficulties with accessing this link, or have any questions about this research, please send your enquiries to me at a.thomson1@massey.ac.nz.

Thank you in advance for any input you are able to provide - I know you will all be rushed off your feet with very busy schedules.

Warm regards,

Alex Thomson

C.2 Participant Information Sheet in Questionnaire Preface

In this questionnaire we would like to find out about health care professionals' knowledge of Vitamin D and what they are recommending to mothers and their infants and pregnant women.

The questionnaire may take up to 10 minutes to complete. Try to be as honest as possible, all responses are confidential and anonymous. No personal details are collected which can identify you. We do ask about your profession and general area of work i.e. hospital, community or private practice but you are not required to answer these questions if you feel they could identify you or are uncomfortable answering them. The overall results of the questionnaire are going to presented in a thesis as required by the Master of Science Nutrition and Dietetics program at Massey University, Auckland. The findings may be written up for publication if appropriate.

If you would like any further details prior to completing the questionnaire please contact either Dr Cath Conlon (c.conlon@massey.ac.nz), Dr Pam von Hurst (p.r.vonhurst@massey.ac.nz) or Student Dietitian Alex Thomson (a.thomson1@massey.ac.nz) from Massey University, New Zealand.

Please note: This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named in this document are responsible for the ethical conduct of this research. If you have any concerns about the conduct of this research that you want to raise with someone other than the researcher(s), please contact Professor Craig Johnson, Director - Ethics, telephone 06 3569099 ext 85271, email humanethics@massey.ac.nz.

C.3 Blank Questionnaire

1. Knowledge about Vitamin D

In this survey we would like to find out about health care professionals' knowledge of Vitamin D and what they are recommending to mothers and their infants and pregnant women.

The survey may take up to 15 minutes to complete. Try to be as honest as possible, all responses are confidential and anonymous. No personal details are collected which can identify you. We do ask about your profession and general area of work i.e. hospital, community or private practice but you are not required to answer these questions if you feel they could identify you or are uncomfortable answering them. The overall results of the survey are going to presented in a thesis as required by the Master of Science Nutrition and Dietetics program at Massey University, Auckland. The findings may be written up for publication if appropriate.

If you would like any further details prior to completing the questionnaire please contact either Dr Cath Conlon (c.conlon@massey.ac.nz), Dr Pam von Hurst (p.r.vonhurst@massey.ac.nz) or Student Dietitian Alex Thomson (a.thomson1@massey.ac.nz) from Massey University, New Zealand.

Please note: This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named in this document are responsible for the ethical conduct of this research. If you have any concerns about the conduct of this research that you want to raise with someone other than the researcher(s), please contact Professor Craig Johnson, Director - Ethics, telephone 06 3569099 ext 85271, email humanethics@massey.ac.nz.

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

- ◯ Manufactured in the skin from sunshine
- ◯ Natural food sources
- ◯ Fortified food products
- ◯ Supplements
- ◯ Other (please specify)

* 2. What are the roles of vitamin D in the body? (Please tick as many as apply)

- [ ] Vitamin D aids with the absorption of Calcium
- [ ] Vitamin D is an antioxidant
- [ ] Vitamin D is needed for bone development and mineralisation
- [ ] Vitamin D aids with immune system function
- [ ] Vitamin D is needed for blood clotting
- [ ] Other (please specify)

* 3. Which of the disease states listed below are associated with low levels of vitamin D (Please tick as many as you know apply)

- [ ] Breast Cancer
- [ ] Prostate Cancer
- [ ] Skin Cancer
- [ ] Type 1 diabetes
- [ ] Inflammatory bowel disease
- [ ] Multiple Sclerosis
- [ ] Rheumatoid arthritis
- [ ] Depression
- [ ] Renal Disease
- [ ] Gallstones
- [ ] Heart disease
- [ ] Rickets
- [ ] Osteoporosis
- [ ] Other (please specify)

* 4. Which of the following are good dietary sources of vitamin D? (Please tick all that apply)

- [ ] Grapes
- [ ] Oily fish e.g. canned tuna sardines or salmon
- [ ] Cow's milk (unfortified)
- [ ] Eggs
- [ ] Infant or toddler formula
- [ ] Red meat
- [ ] Bread
- [ ] Fish oil
- [ ] Breast milk
- [ ] Fortified cow's milk
- [ ] Liver
- [ ] Other (please specify)

* 5. Which of the following are risk factors for vitamin D deficiency? (Please tick all that apply for each group)

	During Pregnancy/Lactation	During Infancy/Childhood
Exclusion of dairy products	☐	☐
Dark skin	☐	☐
Being housebound	☐	☐
Having multiple pregnancies	☐	☐
Living in the South Island of New Zealand	☐	☐
Covering the skin for cultural or religious reasons	☐	☐
Being born prematurely	☐	☐
Gender	☐	☐
Having a mother who is vitamin D deficient	☐	☐
Not being reguarly exposed to sunlight	☐	☐
Exclusive breast feeding	☐	☐
Formula feeding	☐	☐
Being born with a high birth weight	☐	☐
None of the above	☐	☐
Don't know	☐	☐

Other (please specify)

* 6. Do you think that there is enough information about vitamin D available for:

	Yes	No
Health professionals	☐	☐
Clients	☐	☐
Parents	☐	☐

please comment if appropriate

2. Current recommendations for Vitamin D

* 1. Which of the following is recommended to help prevent vitamin D deficiency in infants and young children? (Please tick all that apply)

- [ ] Mother spending time in the sun each day during pregnancy
- [ ] Infant spending time in the sun
- [ ] Taking a vitamin D supplement
- [ ] Don't know

* 2. During which times in summer should time be spent in the sun to allow synthesis of vitamin D? (Please tick.)

- ○ Before 12pm and after 5pm
- ○ Before 11am and after 4pm
- ○ Before 10am and after 2pm
- ○ Unsure

* 3. What other advice should be given to parents when discussing sun exposure for infants and toddlers in relation to vitamin D? (Please tick all that apply.)

- [ ] Sun protection measures (e.g. wearing a hat, wearing sun block, seeking shade) should be followed between 11am and 4pm.
- [ ] Only expose your baby to sunlight through a window.
- [ ] Only expose your baby to sun while he/she is being exclusively breast fed.
- [ ] Excessive sun exposure can lead to increased risk of skin cancer.
- [ ] None of the above

* 4. What is the current recommendation regarding vitamin D supplementation in infants and toddlers? (Please tick.)

- [ ] All exclusively breast fed infants require vitamin D supplementation
- [ ] All formula fed infants require vitamin D supplementation
- [ ] Only infants and toddlers at increased risk of deficiency may require vitamin D supplementation
- [ ] No New Zealand infants or toddlers require vitamin D supplementation
- [ ] Unsure

* 5. Are you aware of any vitamin D supplements for infants and toddlers available in New Zealand?

- ◯ Yes
- ◯ No

If yes, can you name the supplement

* 6. Do any of the multiple vitamin and mineral supplements designed for women to take during pregnancy contain vitamin D?

- ☐ Yes
- ☐ No
- ☐ Don't know

7. If yes, will pregnant women meet their requirements for vitamin D from supplements alone?

- ☐ Yes
- ☐ No
- ☐ Don't know

3. In New Zealand

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

* 1. Skin cancer prevention messages make it difficult to get messages about vitamin D across

- ◯ True
- ◯ False
- ◯ Unsure

* 2. People living in the South Island are more at risk of vitamin D deficiency than those living in the North Island

- ◯ True
- ◯ False
- ◯ Unsure

* 3. In New Zealand we are seeing a re-emergence of rickets in children

- ◯ True
- ◯ False
- ◯ Unsure

* 4. People with dark skin e.g. Maori and Pacific Island people need to spend longer in the sun to synthesise adequate vitamin D.

- ◯ True
- ◯ False
- ◯ Unsure

* 5. Exposure to sunlight through a window is just as effective as outdoor sun exposure in relation to vitamin D synthesis.

- ◯ True
- ◯ False
- ◯ Unsure

* 6. Exposure to sunlight through a window is safer than outdoor sun exposure.

- ◯ True
- ◯ False
- ◯ Unsure

* 7. 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.

- ◯ True
- ◯ False
- ◯ Unsure

* 8. Season affects the amount of time needed in the sun to synthesise adequate vitamin D.

- ◯ True
- ◯ False
- ◯ Unsure

* 9. 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.

- ◯ True
- ◯ False
- ◯ Unsure

* 10. During winter and spring infants and toddlers should spend some time outside in the sun to maintain vitamin D levels.

- ◯ True
- ◯ False
- ◯ Unsure

* 11. Most pregnant women will achieve an adequate vitamin D status in summer through incidental sun exposure outside peak UV times.

- ◯ True
- ◯ False
- ◯ Unsure

* 12. Between October and March pregnant and lactating women are recommended to expose their face and arms to 5-20 minutes of sunshine per day.

- ◯ True
- ◯ False
- ◯ Unsure

* 13. Deliberate sun exposure during peak UV times is recommended for pregnant and lactating women.

- ◯ True
- ◯ False
- ◯ Unsure

* 14. During winter vitamin D status may drop below adequate levels

- ◯ True
- ◯ False
- ◯ Unsure

4. Your current practice

* 1. Are you concerned that some of your clients/patients may be vitamin D deficient?

- ◯ Yes
- ◯ No
- ◯ Not relevant

* 2. If you were concerned about vitamin D deficiency in a pregnant women or a baby/child what advice would you give? (Please tick all that apply)

	Pregnant women	Baby or child
I don't give advice on vitamin D deficiency	☐	☐
Take a vitamin D supplement	☐	☐
Increased intake of foods which are good sources of vitamin D	☐	☐
Increased sun exposure	☐	☐
To have a blood test to measure vitamin D status	☐	☐
To take cod liver oil capsules	☐	☐
Refer to a specialist	☐	☐
Don't know	☐	☐

Other (please specify)

* 3. Do you feel confident that you would recognize the signs and symptoms of vitamin D deficiency in infants and toddlers?

◯ Yes ◯ No

* 4. How many actual or suspected cases of vitamin D deficiency have you encountered over the past 5 years?

☐ None ☐ 1-2 cases ☐ 3-5 cases

☐ More than 5 cases

5. How were these cases managed?

- ○ Provided all management of the case myself
- ○ Referred patient to specialist/hospital
- ○ Not applicable – haven't seen any such cases.
- ○ Other (please describe)

6. Which of the following treatments would you use as a first-line treatment for rickets? (Please tick all that apply)

- ☐ Vitamin D supplements
- ☐ Calcium supplements
- ☐ Dietary change to include more calcium
- ☐ Dietary change to include more vitamin D
- ☐ Increased sun exposure
- ☐ Other (please specify)

5. Please tell us about yourself

1. Gender: (Please tick)

◯ Male ◯ Female

2. Ethnicity: (You may tick more than one)

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

Other (please specify)

3. What is your current occupation?

- ☐ Dietitian
- ☐ Midwife
- ☐ Practice nurse
- ☐ Plunket nurse
- ☐ Karitane nurse
- ☐ Clinical nurse
- ☐ Nurse educator
- ☐ Nurse manager
- ☐ Medical practitioner
- ☐ General medical practitioner
- ☐ Other (please specify)

4. What kind of establishment are your currently working in? (for example paediatric ward at a hospital, practice nurse at a medical centre, community dietitian, GP at a medical practice)

- [ ] Hospital based
- [ ] Coummnity based
- [ ] Plunket clinic
- [ ] Medical centre
- [ ] Private practice
- [ ] Other (please specify)

5. How many years experience do you have?

6. Please state your formal qualifications and any field of speciality

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

8. If you would like to receive an analysis of these survey results, please provide your email address

6. Thank you

We appreciate your help.
Please pass this link onto any other Health Care Professionals who you think would be willing to help us.
https://www.surveymonkey.com/r/M89VZTQ