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Knowledge, attitudes and practices of US-based registered dietitians regarding Vitamin D as a key nutrient in public health

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Abstract

The purpose of this study was to determine the knowledge, attitude and behavior influences of Registered Dietitians (RDNs) regarding Vitamin D (VD). An electronic questionnaire served as the data collection tool developed using previously validated questions and supplemented with behavior construct questions. Content and face validity was assessed by an expert panel; internal consistency was assessed using Cronbach's Alpha. Scores were assessed for knowledge to determine dietitian awareness and competency about VD, attitudes of RDNs regarding importance and practices around VD, and influences on RDN behavior including by other healthcare providers (HCP). Relationships between scales for knowledge, attitude and behavior were examined including the impact of demographic factors on scores. Data was collected from 541 subjects providing informed consent. RDNs were predominantly female, 92%, with good general knowledge of VD (M=84.89, SD=6.71). Regression analysis indicated that increases in age, education and certification inversely impacted behavior scores. Younger RDNs were more influenced in VD behaviors than older RDNs; 42% of RDNs defer to other HCP and 46% defer to lead physician. Dietitians holding Bachelor or Master degrees were more likely to be influenced by others regarding VD practices than dietitians with terminal degrees of PhD or DCN. The results reveal knowledge gaps for the role of VD beyond bone health consistent with high reliance on professional guidelines using evidenced based recommendations from bone health research.

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Introduction

Registered Dietitian Nutritionists (RDNs) are the specialists in nutrition responsible for evaluation of nutritional status, recommendations for medical nutrition therapy and development of nutritional program interventions. The ability to comprehend nutrient metabolism and critical pathways, stay abreast of current research and apply appropriate evidence-based practice through relevant translation for public laypersons, physicians, or other healthcare professionals are paramount to core competencies for the RDN. Basic knowledge of genetics, growth, metabolism, and immune health as it relates to nutrient status and population health are applications RDNs implement routinely. Educating other health professionals on appropriate nutritional screening is an important contribution of the dietitian on the health care team. Consistent with this is the ability to advocate for screening practices, nutritional supplementation, and nutrition therapies to improve patient outcomes. Early screening and recognition of nutritional deficiencies are needed to change progression of the health trajectory, yet as it relates to Vitamin D (VD) status, assessment is not routinely conducted and remains controversial. Guidelines for serum levels vary between leading medical organizations with recommended daily intakes based on calcium homeostasis and bone health and without guidelines for specific medical conditions such as pregnancy or critical illness. Therefore, this study is proposed to explore RDN knowledge, attitudes and practices related to emerging roles of VD as a valuable tool in prevention and support of prominent public health crises affecting the United States today.

Chapter 1: Literature Review

Critical role of Vitamin D

Vitamin D is well recognized for its role in calcium homeostasis and as a necessary nutrient to prevent rickets. Identification of rickets dates back as early as 1645, with anti-rachitic therapies of cod liver oil identified in 1824 and sunlight exposure in 1919.[1]Recommendations for daily intake of VD are based on studies to support bone health, eliminate rickets and reduce falls attributed to bone demineralization. Reference VD status, established by the Institute of Medicine, is identified by serum levels of 25(OH)D at 20ng/ml to "protect 97.5% of the healthy populations from skeletal disorders such as osteoporosis and osteomalacia".[2,3] With the virtual disappearance of rickets and osteomalacia supported by the US fortification of milk dating back to 1930's, urgency in assessing intake adequacy for Vitamin D garners limited interest for risk screening from most health professionals. Under ideal circumstances this fat-soluble vitamin functions as a prohormone which can be synthesized in the body in adequate amounts to meet needs. This is a plausible explanation for the lack of concern over dietary intake and risk screening of the general population by healthcare providers. The ability to synthesize this steroid hormone also muddies its classification as an authentic Vitamin.

Vitamin D (VD) is a term encompassing a group of chemically related compounds which function as hormones for the body. Utility of VD beyond skeletal health is gaining relevance as its role in genetic signaling, immune function, modulation of cell growth, insulin metabolism, inflammation and lung function is elucidated and studied with increased significance.[4,5] Furthermore, identification of α-1 hydroxylase in cells other than kidney, including skin

epithelial, lung, breast, intestine, prostate, endocrine glands, pancreatic islets, thyroid, testes, ovary, placenta, macrophages, T&B lymphocytes, dendric cells, osteoblasts, chondrocytes and a variety of tumors point to roles for vitamin D beyond calcium homeostasis and bone health. [6]

Table 1. Vitamin D Complexes[a]

Vitamin D	Cholecalciferol	Either D2 or D3
Vitamin D_2	Ergocalciferol	Plant sources
Vitamin D_3	Cholecalciferol	Animal sources
25 hydroxy Vitamin D	Calcidiol, Calcifediol	25(OH)D
1,25 dihydroxy Vitamin D	Calcitriol	$1,25(OH)_2D$
Vitamin D Binding Protein	DBP	Transport protein
Vitamin D Receptor	VDR	Transcription factor
CYPs	Cytochrome P 450s	Oxidases
CYP27A1/CYP2R1	25-hydroxylase	25^{th} carbon
CYP27B1	1-α hydroxylase	1^{st} carbon
CYP24A1	24 & 25 hydroxylase	Catabolic enzyme for $1,25(OH)_2D$

[a] Terminology obtained from Bikle[7] and Vitamin D and Bone Health[8]

Under ideal circumstances the body endogenously produces VD when skin is directly exposed to ultraviolet B-light (UVB). With UVB light, 7-dehydrocholesterol is synthesized in the skin which undergoes hydroxylation by 25α-hydroxylase in the liver resulting in 25-hydroxyvitamin D (25(OH)D), or calcidiol. Another hydroxylation occurs in the kidney by α 1-hydroxylase resulting in 1,25 dihydroxycholecalciferol ($1,25(OH)_2D$. This form, also known as calcitriol, is the active form of Vitamin D. This active form has high affinity for VD Binding Protein (DBP) which is expressed in target tissues. DBP is the transport constituent for hydrophobic VD needed to circulate the vitamin in blood. In addition to endogenous production, VD can be obtained through dietary intake, however, prevalence in common foods is low. Plants, supplements or irradiated food provide the form D2, called ergocalciferol, while animal sources provide D3, or cholecalciferol.[4,9] D3 is three-fold more potent than D2 [10] and is the preferred form for vitamin supplements. D2 differs from D3 in the location of the double bond between C22 and C23 and the presence of the methyl groups on the C24 side chain.[6] As a result, D2 has lower ability to bind with DBP, is cleared faster from circulation lowering its hydroxylation to 25(OH)D and thus rendering it less desirable for supplementation.[6] Foods which contribute VD to the diet include fatty fish (such as salmon, mackerel, cod), egg yolk, irradiated mushrooms, and fortified milk. However, fortification with VD is voluntary in the United States. With roughly 70% of dietary VD is absorbed from the lumen,[11] and limited dietary options, reaching recommended intake with the aforementioned assortment of dietary sources proves difficult. According to NHANES data for 2011-2014, median intake of VD in the United States was 3.5µg (140IU); mean intake 4.9µg (196IU). [12] Skin pigmentation plays a role in the ability of skin to

produce VD as melanin can decrease VD synthesis.[13] However, optimal intake or ideal serum levels for VD are not established for ethnic groups.

Assessment of VD status is by serum measurement of 25(OH)D which is the most abundant circulating form of VD and the most stable with a half- life of 2-3 weeks. Unlike VD itself, 25(OH)D is found almost primarily in the blood.[6] Alternatively, 1,25 $(OH)_2D$ has a half-life of 4-6 hours; this form can become sequestered in fat cells making serum tests inaccurate. The active form may be elevated or normal when Parathyroid hormone (PTH) is mobilized in VD deficiency, triggered by a decrease in intestinal calcium absorption. During the increase in PTH, stimulation of the kidney produces increased 1,25$(OH)_2D$ which may be normal while 25(OH)D is insufficient.[14] 25(OH)D is a summation of dietary and endogenous VD accounting for D2 and D3. Various methods are used to assess serum levels; primarily radioimmunoassay, chemiluminescence and the gold standard liquid chromatography tandem mass spectrometry (LC-MS/MS). The first method uses a chemistry platform based on antibody methods; the second can allow for separate estimation of D2 and D3. LC-MS/MS provides specificity, reproducibility, and high sensitivity.[13] This method is not readily available and is used by large clinical or commercial laboratories.[6] Laboratory variation may be high between methods. Reported measures for VD are nanograms per milliliter (ng/mL) or nanomoles per liter (nmol/L). Thus, a call for standardization is important when using research to determine evidence-based decisions to guide practice or when setting serum target levels in population health. It is important to note that VD status may be impacted by several factors. These are skin color, season of blood draw, smoking, use of sunscreen, age, dietary intake, geography/latitude, length of day, smog and cultural dress. [1,15,16]

Goal VD levels are a topic of much discussion and variation among organizations providing guidelines for VD status. The Institute of Medicine (IOM) recommends a circulating level of 20ng/mL as appropriate for individuals whereas the Endocrine Society (ES) recommends 30ng/mL.[14,17,18] Scientific Advisory Committee on Nutrition (SACN) identifies serum levels below 25nmol/L as deficient and European Calcified Tissue Society (ECTS) identifies deficiency below 50nmol/L with severe deficiency below 30nmol/L.[13] (See Table 2) These differences may be attributed to the types of research criteria included in reviews from which levels are determined. IOM focused on a base of skeletal integrity data, whereas ES included observational data inclusive of VD in capacities beyond bone health.[18] Pilz and colleagues[19] note that use of conventional data and meta-analyses supporting IOM target 25(OH)D levels are based on causality in establishing an Estimated Average Requirement (EAR) which targets 50% of population and Recommended Daily Allowance (RDA) which covers 97% of the population targets, may underestimate daily intake needed to obtain goal serum levels. These scientists advise more advanced statistical methods based on individual data are necessary. Another school of thought to determine optimal status proposes evaluating healthy subjects exposed to ideal sunlight conditions such as lifeguards, outdoor/field workers and sunbathers when establishing optimal levels.[20] This group has reported 150nmol/L serum levels for VD based on these healthy subjects with adequate sunlight exposure. Wagner proposes to attain this level would necessitate a daily intake of 4,000-6,000IU compared to current guidelines.[18]

Table 2. Laboratory Assessment of Vitamin D Status[a]

Organization	Deficiency	Insufficiency	Optimal
Endocrine Society (ES)	≤20ng/mL	21-30 ng/mL	>30ng/mL
Institute of Medicine (IOM)	<12ng/mL	12-20ng/mL	>20ng/mL
Mayo Clinic	<10ng/mL	10-24ng/mL	25-80ng/mL
American Assoc. Clin Endocrinologists (AACE)	<30ng/mL		30-50ng/mL
Nat'l. Academies of Sciences, Eng., and Med/Food Nutrition Board	<12ng/mL	12-20ng/mL	>20ng/mL
Euro Calc. Tissue Soc. (ECTS)	<10ng/mL	10-20ng/mL	20-30ng/mL
European Food Safety Authority (EFSA)	<20ng/mL		20-30ng/mL
Scientific Advisory Committee on Nutrition (SCAN)	<10ng/mL		

[a]Measurements taken from AACE[21] and Lips, et al.[13]
Conversion: 25-HydroxyD Total: 1ng/mL=2.496nmol/L

This in stark contrast to the current RDA 600IU for most adults which includes pregnant women.

Wagner [18] further notes viewing current recommendations per kilogram dosage, infants are receiving 133 IU/kg and pregnant women are receiving 10 IU/kg. It is important to note that excessive sun exposure would not continue to produce VD in excess due to the heat sensitivity of the chemical structure and its breakdown equalizing that of production after prolonged exposure to sunlight. These varying viewpoints regarding optimal VD levels will require further

investigation and discussion as no guidelines have been established to specifically address skin color, genetic variations or altered needs in pregnancy or COVID-19.

Vitamin D and Adverse Pregnancy Outcomes

A keen area of interest is the role of VD during pregnancy. Expression of DBP has been identified in the yolk sac and in fetal serum during the third trimester.[11] It has been established that exposure to estrogens increases DBP. VD metabolism is enhanced during gestation commencing with conception and fluctuating by trimester. The pregnant mother requires a carefully orchestrated adaption to adequately support immune health to carry the fetus who has half of its DNA contributed by the father. Placental development is a critical step in pregnancy and a poorly formed placenta will lay the foundation for adverse pregnancy outcomes including hypertension, pre-eclampsia (PE), vasculitis and altered liver function necessitating early delivery.[20] Placental tissue and decidua contain VDRs and synthesize 2 forms of Vitamin D: $1,25(OH)_2D$ and $24,25(OH)_2D$.[22] The former molecule impacts transcription of two genes impacting immune modulation, CYP27B1 (codes for 1-α hydroxylase) and CYP24A1(codes for 24-hydroxylase), while the latter accumulates in bone to potentially impact fetal bone calcification [22] $1,25(OH)_2D$ impacts cytokines by decreasing T helper 1 (Th1) and increasing Th2. Th2 plays a role in implantation of the trophoblast in early pregnancy. $1,25(OH)_2D$ also functions in transition of endothelial cells into decidua, supports fetal growth via calcium transport, secretion of placental hormones and control of inflammatory cytokines.[23] Placental dysfunction and poor spiral artery development potentially lead to inflammatory response, poor placental perfusion, preeclampsia, intrauterine growth failure (IUGF) and spontaneous preterm birth (SPB).

A review was conducted by the author on clinical research for VD in critical pregnancy outcomes of pre-eclampsia (PE), preterm birth (PTB)and birth weight (BW). Findings from research published in January 2016 to Oct 2020 included original articles which report data for serum levels of VD (25(OH)D, documentation of PE, PTB and or BW were reviewed. An expansive search was conducted in CINHAL using broad search terms for VD and pregnancy narrowed to research on human subjects. Observational, case control, cross-sectional and RCT studies were eligible for inclusion.

Two of three RCTs reviewed indicated a role for VD in development of preeclampsia. One study providing 4 levels of supplementation focused on mild and severe VD deficiency found no PE in women with VD levels >30ng/mL.[24] Rates of PE by VD status following supplementation were 1.3% in those with VD >20ng/mL, 16% in moderate deficiency (10-20ng/mL) and 38.5% in severe (<10ng/mL). In this study, only 2.7% of supplemented women were able to obtain serum 25(OH)D levels >30ng/mL. Following supplementation, risk of PTB decreased 30% in moderately deficient and 67% in severely deficient subjects.[24] It is important to clarify supplementation was initiated in the first trimester. A second supporting trial noted VD status of ≥30ng/mL maintained in early and late pregnancy was a predictor for decreased risk of PE. Researchers reported adequate VD status (≥30ng/mL) in early pregnancy maintained into the later third trimester resulted in lower incidence of PE compared to subjects with poor VD status (<30ng/mL).[25] In this study using intent to treat analysis of supplemented subjects with basic and moderate level supplementation, no differences to PE outcomes were observed between the supplemented groups. Intent to treat analysis often results with inaccurate outcomes weakening evidence analysis due to inclusion of non-compliance and dropout subjects. An important benefit

of this study was early assessment of maternal serum VD starting at 10 weeks allowing subjects to enroll up to 18 weeks of gestation. The third trial examined birth weight outcomes after VD supplementation and was included in this review as it met criteria for maternal serum VD levels and birth outcomes including infant weight and preterm birth.[26] In this study, no significant differences were noted in outcomes for SGA or PTB. Researchers also used intent to treat, started supplementation later in pregnancy (17-24 weeks gestation) and did not adjust for confounders.

The largest percentage of VD data for prenatal outcomes is based on observational studies; a type of research considered lesser in strength when evaluating research for evidence-based practice protocols. However, when studying nutrients, the typically "strong" RCTs are poorly suited to provide assessment of nutrient interventions. True VD supplementation evaluations ideally would require all subjects to be VD deficient at the start of the study with the control remaining without supplementation in order to have a true comparison to the supplemented group outcomes.[18] Subjects would need to be kept indoors to prevent exposure to VD stimulating production of sunlight and would require control or accounting of other influencing variables mentioned earlier. When considering trials providing supplementation, the change to the nutrient status must be reported in study outcomes. Rostami's RCT cited previously identified only 2.7% of supplemented pregnant females were able to reach the 30nmol/L still considered deficient by ES and SCAN, uncertain IOM, but substantially below the AACE goal which defines 75-125nmol/L as sufficient. [13,21] As a result, it seems reasonable that we continually conduct observational studies to test the association of VD in pregnancy outcomes. Although there is diversity in study methods which further complicate comparison of

outcomes, a summarizing view from observational studies has identified a theme for VD status with adverse pregnancy outcomes of PE and BW.

Seto and colleagues [27] considered race and maternal characteristics on VD and SGA, identifying infant racial differences in VD status with black infants significantly higher rates of VD deficiency (VDD) than whites. Black infants with VDD were found to have 2.4 greater odds of SGA; however, the relationship of VDD to SGA seen in black infants was not present in whites. Increased odds of VDD were found with maternal BMI in this study and was also found by Monier. [28] These researchers studied a sample of women in their first trimester (10-14 weeks gestation) to investigate an association of VD with PTB and SGA using ES criteria for VD status and secondarily assessed by quartile. Risk for PTB with darker skin and low VD was significant in the lowest quartile; no significant relationship for SGA or preterm birth was found without stratification. Pereira-Santos [29] looked at VD's effect on BW considering social determinants of health including prenatal care. This study demonstrated a direct effect on BW and projected for each maternal 1 nmol increase in VD, BW increased 3.06g. Meng [30]considered a large birth cohort on the relationship of VD and growth restriction. This study determined that in severe or moderate VDD there was a decrease of 79.8g and 49.9g respectively, in infant BW. Risk of SGA increased in severe VDD with a relative risk of 2.24. Hemmingway, et al[31] also considered SGA in functional VDD (defined as VD <30nmol/L) with elevated PTH and found a 16% prevalence of SGA in functional VDD vs control at 6.7% with no effect of functional VDD on PE or gestational hypertension. This was a predominantly white Irish cohort (97.7%) up to 16 weeks' gestation whose results should not be universally applied to dark skinned populations. A Brazilian cohort study found low VD related to BMI and season of serum collection and a

significant correlation of hypovitaminosis D to PE. Subjects included in this study had high prevalence of VD deficiency (43.7%) and (37%) insufficiency, only 19% had normal VD.[32] Of note, this study included women at any stage during pregnancy. Cut offs for VD categories were similar to ES for normal VD status >74.88nmol/L and insufficient VD status 49.92-72.38 nmol/L and deficiency at <49.9 nmol/L. Value categories were noted not to align to appropriate numeric categories; it is difficult to determine if these are attributed to multiple typographical errors or poor study design. A very large study on Chinese pregnant females enrolled mid-late pregnancy (24-38 weeks' gestation) found VD was a high-risk factor for severe PE with an odds ratio of 2.2 which increased to 3.2 when confounding factors were applied.[33] No significant impact of maternal VD on BW was found by this team. High rates of VD deficiency were noted in the Chinese cohort with 78.9% deficient in the second trimester and 94% deficient after 35 weeks. Although diagnosis of PE is made at 20 weeks' gestation by elevated blood pressure readings and protein in the urine, it is tied to early disruption in placental development. Timing of late blood draw may not capture earlier pathological changes and association with VD levels later in pregnancy. This may provide an opportunity for application of the Barker Hypothesis with early development of the placenta impacted by hypovitaminosis D at time of placentation and measurement of VD status after 8-10 weeks as a possible study design error.

Case control studies offer an opportunity to compare vitamin D status and maternal outcomes by comparing data of interest and confounding variables from matched groups. In a study by Powe and colleagues [34] comparing VD in the first trimester by demographic with PTB, no association was found. Evaluation of VD in this study used gold standard LC-MS/MS with confirmatory analysis of VD by ELISA. Samples were obtained early in gestation. This sample

was 66% white and may have impacted application of results to other populations. An important question that arises in considering this study: would data outcomes provide alternative results if we had identifiable requirements for VD by skin color? Shahraki, et al[35] examined VD status of moms through the lens of proposing VD as a possible modifiable risk factor to assess association with term and preterm neonates and secondly to determine if the VD status of mothers was different between moms going to term vs those with preterm birth. This study included maternal serum VD and outcome frequency of PTB vs term. Researchers found differences in the mean levels of VD in mothers and neonate between term and preterm delivery which was determined not to be significant. A significant correlation was found between maternal serum VD and neonatal VD in both delivery groups. A weakness of this study was the small sample size and lack of comparison of VD levels to prevalence of preterm birth. Another approach to evaluate the role of VD in LBW, SGA and PTB looks at cord blood levels of vitamin D from a large sample of Canadian women taken immediately after delivery. [36] Samples were categorized <50nmon/L, 50-75nmol/L, >75nmol/L. Lower categories of VD status (<50nmol/L) were omitted due to the low prevalence (5%) of the sample below 30nmol/L. Based on the lack of subjects in poor VD status as defined by IOM and ES categories, the majority of subjects exhibited sufficient VD status. Results indicated subjects with lower VD <50nmol/L had lower risk for LBW than subjects >75nmol/L. An inverse association was observed across the range of VD levels. No significant difference was found between controls and SGA or PTB. A lifestyle questionnaire was included in this study which allowed the cohort to be identified with low percentage of obesity and high percentage of leisure time physical activity. This study had numerous flaws including lack of poor VD status subjects upon which researchers tested risk. The reported data

for LBW associations was based on only 13 subjects of 83 in the LBW group who exhibited VD below the threshold of 50 nmol/L. IOM recommends above 50nmol/L for sufficiency, but this study lacked specificity to identify deficiencies in the lowest category which may have impacted results. This sample does not seem large enough to draw conclusions as evidenced by the small percentage of subjects in the study with vit D <30nmol/L and the inability to categorize them into a separate group. Although this study did not measure serum maternal VD levels it included using cord blood as a surrogate of maternal status of VD demonstrated to be a suitable marker for maternal status by Motamed.[37]

The above research points to a role for VD in prenatal outcomes, however, viewed by established science of evidence-based medicine, no clear, consistent, reproducible evidence can be identified. This results from varying definitions of VD status criteria, multiple methods for measuring serum levels of VD and the complications of confounding data. Further difficulty in studying VD is the lack of ability to account for endogenous production when supplement interventions are evaluated and a lack of consistent accounting of dietary intake from exogenous sources. It is also important not to discount studies that do not find linear relationships. With nutrients there is an exponential benefit to increasing or improving status, but also a point where additional nutrients do not improve the condition. Saturation causes a plateau or bend in the curve of supplementation levels where no continual benefit of supplementation improves conditions. When comparing responses to supplements, it is impossible to account for individual differences in absorption and metabolism of supplementation. However, it is necessary to account for changes in nutrient status when supplementing VD and to identify time needed to

reach optimal levels before assessing benefit. Without these considerations, results may miss an opportunity to capture benefits and may inaccurately report outcomes.

A significant amount of scientific literature has been written on research regarding VD and the possible association to PE, PTB, IUGF and SGA yet, as noted in the literature review, conclusive evidenced based recommendations have not been established. This may be attributed to lack of reproducible studies emanating from use of different assays, mixed populations, accounting of confounding variables related to pregnancy outcomes or VD status, and lack of agreement on optimal thresholds for VD cutoffs. However, consistent reports of suboptimal status are identified across the literature and risk screening has shown beneficial in identification of VDD. Supplementation has also been shown to improve VD status, but optimal levels of supplementation and time required to achieve those levels remains elusive. In a number of studies, vitamin D supplementation failed to achieve "optimal" levels chosen by study researchers.

A potential solution to study quality in nutrient research is provided by Heaney[38] who has proposed five rules for nutrient effect studies: 1.) Measurement of basal nutrient status as inclusion criteria 2.) Intervention large enough to change nutrient status measured with appropriate methods 3.) Adequate recording of change in nutrient status 4.) Hypothesis must define a change in nutrient status as an effect 5.) Careful optimizing of co-nutrient status to adequately assess nutrient of interest. Many of the studies discussed fail to meet all 5 criteria. RCTs do not achieve true deficient status throughout the study for comparison with healthy levels of VD on outcomes, observational studies do not provide manipulation of VD status to demonstrate cause and effect, and case control studies do not optimally identify matches for true

control status. Crossover studies to test dose response within the same individual would require creation of a deficiency state prior to each treatment arm and would not be acceptable under human subjects research protocol.

Yet, discounting RCT studies based on this concept is not the intention. While the studies may not meet ideal criteria proposed by Heaney[38], they define a theme which lends credit to the role of VD in pregnancy outcomes. The studies highlight the complex factors which make typical evidence-based medicine RCT protocol limiting when evaluating research outcomes to develop practice recommendations for VD.

Despite lack of evidence implicating VD in a causal role aforementioned adverse maternal outcomes, the American College of Obstetricians and Gynecologists (ACOG) may want to reconsider guidelines [39] excluding VD from routine prenatal screening. The American Association of Clinical Endocrinologists (AACE) recommends screening of individuals meeting certain criteria and those criteria particularly pertinent to pregnant females include malnutrition, sedentary lifestyle, limited sun exposure, obesity and dark skin.[21] In communities serving uninsured, underinsured, low income or dark-skinned pregnant females there is a high likelihood prenatal patients will meet one of the screening criteria. In some geographic locations with increased exposure to lead caused by aging municipal infrastructure, water contamination or poorly maintained dwellings built prior to the lead paint ban, decreased VD, increased PTH and loss of calcium from bones can cause increased lead uptake. Lead can accumulate in bones replacing lost calcium and over time will be released into serum. Lead has a long half-life lasting potentially decades. Lead easily crosses the placenta and can result in cognitive or developmental delays during fetal growth.[40]

This review identifies important considerations for healthcare practitioners working with prenatal patients identifying a benefit to evaluating patients at risk for VDD. The effect of BMI, skin color and season including access to sunlight, has been a recurring theme in VD status. Research reviewed here supports a case for screening as an opportunity to modify a risk factor whose function impacts metabolic pathways potentially culminating in PE, PTB and implications in infant weight.

A Role for Vitamin D in COVID-19 Disease Course

The onset of the novel Coronavirus, known as SARS-CoV2, has spread to pandemic proportions resulting in 165.7 million cases of COVID-19 and 3.8 million deaths worldwide according to the WHO COVID-19 dashboard on June 20, 2021.[41] Initial cases were met with no known treatment and rapidly rising acute respiratory distress overwhelming ICUs, splitting ventilators to meet demand, adaptive breathing devices when ventilators were not available and off-label use of antiviral medications, anti-inflammatories, antimalarial and autoimmune medications in a desperate effort to save lives. Rapid spread by the airborne virus led to overwhelmed hospitals, ICU bed shortages and an intense search for practices to slow the severity of adverse outcomes and death. COVID-19 was identified to have severe inflammatory responses resulting in cytokine storms and hypercoagulatory thromboses. For medical professionals aware of the role for VD in innate and adaptive immune responses, along with its affinity to reduce renin and downstream effects of Angiotensin Converting Enzyme-2 (ACE 2), stimulate Interleukin (IL)-4 and IL-10 suppressing hyperinflammatory cytokines and thrombotic

states, plausibility of a role for Vitamin D became an area of intense interest to alter the course of COVID-19.

Low levels of VD have been linked to increased rates of infection and autoimmune diseases including tuberculosis, influenza, diabetes, multiple sclerosis, and respiratory infections.[42] Function of the active VD ($1,25(OH)_2D_3$) is mediated by VDR binding to DNA using cofactor RXR after entering the cell nucleus where it then binds with Vitamin D Response Elements (VDRE). It is at this location modulation of enzymes occurs to impact expression of T-cells affecting development, differentiation and ultimately function.[42] VD further supports immune function by influencing the Rennin Angiotensin System (RAS) via inhibition of renin resulting in increased ACE2. ACE2 functions in degradation of Angiotensin II, a toxic excess of which results in acute respiratory distress syndrome. In this manner VD alteration of ACE2 provides anti-inflammatory, antioxidant and antifibrotic support in immune function.[43]

A review of research has provided some perspective on those at risk for COVID-19 and the course of disease possibly related to VD status. Studies between June 2020 and April 2021 were accessed from the CINHAL database and met criteria for human studies, peer-reviewed, English and full text articles. 35 abstracts were reviewed, 12 articles were included in the review.

Only one RCT was available for inclusion in this review. Entrenas and colleagues[44] supplemented calcifediol initially at .532mg on admission then .266 mcg on day 3 and 7, then 2x per week until discharge or ICU admission. Patients treated with calcifediol had no deaths and were discharged without complaints. The non-supplemented groups had 13 admissions to ICU and 2 deaths with remainder discharged. Authors observed calcifediol significantly decreased the

need for ICU admission. Sulli, et al[45] also reported VD significantly lower in COVID vs age matched non-COVID controls recruited from an outpatient rheumatoid arthritis clinic. VD status was significantly lower in those with COVID-19 vs control, with COVID group having 57% severe deficiency vs control 22%. VD of patients who died during hospitalization was also significantly, lower than those who survived; VD levels reported at 3ng/mL vs 8.4ng/mL respectively. Negative correlations were identified with VD and O2; positive correlations with Partial Pressure of Oxygen (PaO2), Sulfur Dioxide (SO2), Arterial Oxygen Pressure: Inspired Oxygen ratio (PaO2/FiO2).

The remaining 11 studies reviewed were retrospective observational studies generally considered to provide weak evidence, but which are increasingly recognized as reputable in epidemiologic findings. In many of these cases study designs were poor or fair due to observations evaluated during acute care when best practices and care standards were rapidly evolving and had not been universally identified. Unanimously lower VD levels were observed in severe COVID patients versus lesser courses or asymptomatic cases. Luo et al[46] reported patients were 2.7 times more likely to have severe COVID if VDD. Similarly, Maghbooli [47] reported 59% more likely to have severe COVID with VD <30ng/ml, 32% more likely hypoxic and 36% with lymphocyte < 20%. Similar findings were reported in the pediatric population where Bayramoglu [48] evaluated clinical severity and inflammatory markers in COVID subjects ≤ 18yo. Moderate to severe VDD pediatric COVID patients identified with higher fibrinogen and lower lymphocytes compared to insufficient and normal VD status pediatric subjects. This study reported independent predictors of severe clinical course in COVID for VD deficiency, d-dimers and fibrinogen levels. Research by Jain [49] supported an association of VD status with COVID

severity identifying significant differences in VD levels of asymptomatic versus severely ill COVID patients. Furthermore, authors identified significantly higher IL6 (19.6 vs 12.9) and TNF (13.2 vs 11.8) in severe COVID to asymptomatic patients, respectively. Fatalities in VD group were 21% versus 3% in asymptomatic COVID patients. Supporting a role for VD status in COVID outcomes was again identified in research on 30 Greek ICU patients where higher VD status on ICU admission (16.7ng/mL vs 9.4ng/mL) was found in survivors compared to non-survivors. All deaths documented during this study were in the low VD group identified as below 15.2ng/mL. Additional support relating VD to course outcomes for COVID-19, [50] compared SARS-CoV-2 inpatients to outpatients differentiated by O2 saturation with the former needing hospitalization and oxygen support and the latter receiving home care from medical and nursing home visits. Using a cutoff of 12ng/mL, a 6-fold increase in severity of COVID was identified and a 15-fold increase in death. When adjusted to 20ng/mL a significant but weaker association remained.

Contrary evidence of no association of VD on course in COVID outcomes was presented in a study of Austrian hospitalized and outpatient subjects.[51] This evaluated 18 outpatients and 87 inpatients from positive PCR test to 8-week follow up clinical evaluation. Results reported no association of VD and disease severity. This study should be reviewed with careful attention to gaps in design. Patients were considered to have mild disease status if able to be outpatients, moderate if requiring hospitalization and severe if requiring oxygen support during hospitalization. VD parameters were identified in the following manner: less than 30ng/mL as deficient, 30-50ng/mL as insufficient, and over 100ng/mL was sufficient. VD levels at enrollment were compared against 8-week follow up. Results reported no significant difference

found with VD status and disease severity. Additionally, VD status was not related to persistent burden of disease, lung function or ongoing inflammation. However, authors did not have VD levels for subjects at onset of COVID diagnosis due to not routinely assessing VD status on hospital admission and therefore used surrogate VD levels available close to hospital admission. Additionally, it is reported that 10 patients received VD supplementation "not related to disease severity". The aim of this research initiative is identified as analyzing an association of VD status with clinical presentation and course of COVID-19 yet VD samples were not taken upon enrollment in the study or at onset of positive PCR. Survey questions and laboratory values were obtained at 8-week follow up. Authors reported poor VD status in COVID patients and disturbed PTH-VD axis in COVID patients with severe courses of the disease. Poor study design with inconsistent research conclusions makes this outlier report of poor value in contributing to understanding the role of VD in COVID mortality and morbidity.

Provider Practices Regarding Vitamin D

In 2014 serum VD was the 5th most ordered laboratory test for Medicare Part B patients[12] thus suggesting concerns in elderly 65+ and the relationship to bone mineralization and fall risk. Outside of skeletal health and calcium homeostasis, an unveiling of the pathways, associations and implications of VD is emerging. The Academy of Nutrition and Dietetics (AND) practice application follows IOM recommendations reporting approximately 50% of Americans achieve VD adequacy with a serum concentration of 16ng/mL or less.[52] These practice guidelines rely on data rooted in calcium homeostasis and bone health research. As noted earlier, the ACOG [39] does not recommend screening for VDD in routine prenatal labs, also citing lack of evidence to support a role for VD in adverse maternal outcomes. Also, specific targets have not been set to

establish sufficient levels of VD for pregnant females. Currently in the United States, dietary guidelines for pregnant females recommend 600 IU daily which is identical to male and female recommendations in non-pregnant adults. Hence, no alterations are recommended for VD intake when pregnancy is established. Alternatively, the American Academy of Pediatrics (AAP) suggests supplementation of maternal VD during pregnancy with 1000 IU during the prenatal period to raise infant stores to the target 20ng/mL.[53]

Outside of the United States, country after country has identified poor VD status with prevalence at epidemic proportions particularly in Low and Middle Income Countries.[54] In a working group commissioned by the Sackler Institute for Nutrition Sciences and the Bill and Melinda Gates Foundation, recommendations call for increased professional awareness of risk factors and consequences of VDD along with accurate estimates of VDD are needed.[26] This fits with WHO Sustainable Development Goal 3: Good Health and Well Being which includes a reduction in maternal mortality and ending preventable death in children under 5.[55]

The role of VD in pregnancy may also be linked with immunomodulatory functions discussed in COVID-19 research. Similarly, identified in the review was a lack of VD screening in early COVID patients and a significant role for VD in severity of disease progression. In consideration for these substantial pathways involving VD and a detrimental influence on public health, recognition and screening for VD status may provide a reduction in adverse outcomes for both pregnancy and COVID. Recent evidence supports a change in established practices for VD screening and supplementation. Given the rapid advances in VD research, a survey to establish practices of RDNs in knowledge, attitudes and practices concerning VD is critical in elucidating knowledge gaps in medical nutritional therapies. Unfortunately, research to obtain RDN

perspectives on Vitamin D knowledge, attitudes or screening practices is lacking. To better understand practices of similar interest in related healthcare providers, a broader search to include physicians, nurses and other healthcare practitioners was conducted.

A broad literature search was conducted to assess research among providers who care for patients at risk for VD deficiency. The search was conducted in CINAHL, PubMed, and Web of Science. Search terms included physicians, doctors, clinicians, healthcare providers and attitudes, beliefs, knowledge, practices and Vitamin D. Research published January 2016 to December 2020 was included. Thirteen studies related to opinions and practices for VD were reviewed and one study on nursing knowledge of gestational hypertension included for possible link to VD and pregnancy.

The most pertinent study that reviewed assessing practices, knowledge and opinions of OB-GYN providers around VD supplementation was completed by Mohamed and colleagues[56] in 2016. This study is the most current among limited research specific to healthcare providers and VDD. Incidentally, it was published in the same year as the comprehensive updated Cochrane review on Vitamin D supplementation during pregnancy and the relationship to adverse pregnancy outcomes. Overlapping study periods did not allow physicians to benefit from the Cochrane analysis. The Mohamed led study focused on Juniors and Fellows of the ACOG using a qualitative survey administered via an on-line questionnaire. This study had 101 respondents who recognized VD insufficiency as problematic yet had low use of VD screening. Results indicated only 45% read ACOG Opinion 495 concerning VD supplementation during pregnancy and 48 % believe women taking the PNV are at low risk for VDD. The study noted

68% found VD insufficiency to be a problem and 66% believed in a benefit from VD, yet only 6.9% screened for VDD.

Several VD studies assessing practices and supplementation around VD among practitioners have been conducted in pediatric medicine. One survey among 241 Uniformed MD Service members regarding VD supplementation assessed practices in providing supplementation during breastfeeding (BF) and adherence to AAP guidelines. Results indicated 89% of AAP members supplemented VD compared to 63% AAFP (family practitioners) supplementing BF infants.[57] Recommendation of AAP is to supplement all BF infants 400IU daily until weaned to 1L VD fortified milk daily.[58] The most common reason not to supplement VD was the belief that infants had adequate sunlight exposure. The second most common reason supplementation was not provided revealed lack of familiarity with AAP guidelines regarding supplementation. A similar survey conducted on the Swiss Society of Pediatricians (SSP) members found 97% supplemented VD as recommended by the SSP.[59] 88% of responders reported routinely measuring VD in children with poor VD status. Authors advised the self-reporting of practices may not reflect clinical practice. Intentional bias of participating physicians would be expected to be minimal in evidenced based practice data collection particularly in assessing an important vitamin status. In a similar study of Turkish pediatricians, assessment of adherence to VD supplementation used as a prophylaxis to prevent VDD in children reflected physician adherence to program guidelines.[60] The Turkish Health Ministry monitors physician compliance with the prophylaxis program rewarding compliance. Karabulut and colleagues[61] reported 75% following recommended dosing of 400 IU daily in infants,10% provided 800 IU and the remainder provided 600 IU or 1200 IU. This questionnaire consisted of

only 5 questions completed on-line. The most useful data obtained from this study found physicians-initiated VD supplementation later than recommended by the VD Prophylaxis Program due to incorrect beliefs that maternal VD protected infants until 3 mos. of age. Elitok, et al[62] also surveyed Turkish physicians and residents on VD supplementation practices in the pediatric population finding the most frequent dose 400 IU until 2 years of age. Conversely, in a study conducted of pediatricians in Las Vegas, NV to assess practices and experience with rickets and VD supplementation in the sunny location of Las Vegas, only 47% recommended supplementation for exclusively fed BF infants and 42% answered incorrectly on rarity of rickets in the US. Researchers reported Pediatricians who assessed sun exposure were more likely to supplement VD.

This review included 4 quantitative and qualitative surveys among general medicine healthcare providers to assess sampling and research questions regarding practices and beliefs of the sample groups. Three of the four related to VD practices. In the survey conducted with physicians from Pakistan, where VD deficiency is prevalent in 91% of the population, only 9.6% order VD levels in every patient. 85.6% order levels with symptoms or signs and 9% do not order VD levels.[63] In this study more than half treated empirically and the remainder used guidelines. In this same country a study conducted by Juanid[64] surveyed medical students using a scored validated questionnaire and reported 47% had good nutrition knowledge, 54% had good general knowledge yet only 8.8% had good practice knowledge. A theme is developing as noted in the pediatrician surveys that good knowledge regarding VD is not present in all providers despite available practice guidelines. Among providers, in those who have knowledge, it is not always followed through in practices for assessment or supplementation. This is evidenced by

research published by Epling and colleagues[65] who assessed practices and attitudes around diagnosis and management of hypovitaminosis D. Outcomes of this study indicated the primary source for VD testing is patient request and which patients rely on sources of health information from media, radio, magazines and TV.

In a study of Asian and Australian nurses to assess impact of health beliefs on practices, it was found many nurses have false and ungrounded beliefs related to health and nutrition upon which they rely when giving patient advice.[66] This study was qualitative with data collected from a survey of rated beliefs followed by a 1 hour recorded interview asking open-ended questions regarding these beliefs. Regardless of country, authors identified nurse knowledge was not based on scientific information and reasoning for beliefs was similar amongst the nurses.

Further assessing attitudes and beliefs regarding VD from a testing perspective, a study was identified which assessed barriers and facilitators to VD testing. In an opinion by Hofstede [67] regarding excessive VD testing, the author notes the cost of VD testing in the US for 2016 was $350M. It was noted earlier in the introduction that VD tests were the 5th most frequently ordered test in Medicare part B patients. To better assess physician barriers and facilitators to reduce testing, Hofstede, et al [67] utilized semi structured interviews for practitioners and patients participating in the REVERT study. Final sample size included 20 general physicians and 19 patients. Reasons for VD testing were identified as medical or non-medical. Most common reason for GPs to test was high risk patients with very dark skin or clinical report of fatigue or myalgia. Non-medical reasons identified as “good will” creating opportunity for “follow-up” or “conflict avoidance”.

Additional examination of references included in reviewed studies brought two additional research studies. One conducted on 572 Tehrani adults to assess general knowledge, nutrition knowledge, attitudes and behavior by Amiri, et al.[68] This was excluded from the literature search due a selection population of average adults which did not meet the healthcare provider criteria. However, this research provided the D-KAP38 study which was validated using face, content and construct validity. The D-KAP38 was subsequently tested when used in research on medical students. [69] Many of these questions are appropriate for use or potential adaptation for the RDN survey. A second older study completed in 2011 by Bonevski,[70] produced a cross-sectional survey of 500 Australian GPs for practices and attitudes related to VD. The age of this study disqualified it from the literature search but availability of the validated survey warrants consideration in the RDN survey development. Both surveys have been obtained from supplemental study data and served to provide questions for the RDN survey developed as part of this research initiative.

While no research on Registered Dietitians or Nutritionist has been found, a clear theme was identified as a result of the review on VD practices by other healthcare providers indicating a high reliance on practice board recommendations. Supplementation of VD in pediatrics was clearly consistent with supplementation given when indicated by guidelines as noted in the AAP practitioners and Swiss Society of Pediatricians. Overall, knowledge regarding VD was not strong. Amongst non-pediatric practitioners, supplementation may have been driven by conflict avoidance, good will or follow up necessity. The COVID literature review included some discussion of research data among physicians supplementing patients, but beliefs or practices were not described and practice varied between physicians with no defined guidelines. Whether

this applies to RDNs as nutrition specialists and interdisciplinary team advisors has not been researched. A literature review to identify practices or knowledge yielded no peer reviewed studies. A Practice Application printed in Journal of the Academy of Nutrition and Dietetics published in 2019 is the most recent guide for RDNs.[71] This publication discusses the "common clinical practice" for VD supplementation and how "routine" VD testing has become. Accuracy of these pronouncements is lacking. In fact, as noted earlier, routine screening and supplementation is not recommended by professional guidelines. Also discussed in detail is the research behind the evidence-based recommendations using bone health as driver for role and benefits of supplementation. Without evidence to understand current RDN practices this is merely projection and underscores the need to assess RDN knowledge, attitudes and practices related to VD as well as awareness of current roles for VD in prominent health priorities of 2021: poor maternal health outcomes and high US mortality rates and benefits of VD status in COVID 19. Research to evaluate awareness of RDNs about present day endorsements by prominent VD research studies indicating a need for a new thinking on evidence-based VD practice guidelines is needed. This includes an understanding of the application of current definitions of optimal status and its limitations, intent for application of research behind those recommendations and competency in applying current research to traditional guidelines to provide cutting edge nutritional therapy. Research on RDN knowledge, attitudes and practice provides a baseline for establishing competencies, practice applications and education needs. Understanding RDN practice behaviors can illuminate need for increased academic teaching requirements, inform continuing education needs, increase propagation of best practices when guideline updates are lagging and improve dissemination of VD research during interdisciplinary interaction. This

research initiative aimed to address the research gap and establish a springboard for future research and education initiatives.

(Refer to Supplement 1for Literature Review Matrix)

Chapter 2: Theoretical Framework

Implementation research examines the application of evidence-based study outcomes to healthcare practice. It has been reported 30-40% of patients do not receive care according to scientific evidence.[72] This has been illustrated in the current research reviews which discussed greater understanding of VD in maternal health and COVID disease severity but identified lagging changes to guidelines in establishing screening for optimal VD status and supplementation. This study initiative is an effort to understand RDN behavior and application of current research to practice to achieve more effective patient outcomes. To approach this initiative using a methodological comprehensive process, a theory which identifies predictors of modifiable behaviors was used to assess current RDN actions and identify relevant outcomes driving nutritional intervention.

Eccles identifies attributes of theories which meet the ability to explain behaviors particularly as they can relate to healthcare providers, or RDNs in this case. Elements ascribed to a well-chosen theory include: ability to demonstrate an effect in prediction of behavior, explanation of behavior in terms of constructs which are modifiable (knowledge, beliefs, attitudes, constraints) and ability to address non-volitional components whether facilitators or barriers to the desired behavior.[72]

Theoretical framework is needed in research to provide a template or scaffold for study design. It will apply structure and format to approach a problem, creating the methodology based on defined concepts, assumptions supporting those concepts and postulation of beliefs applied to the research hypothesis. Taken a step further, the theoretical framework can identify and explain the relationships between the theory constructs.[73] Utilizing health behavior theory in development of a questionnaire can provide a helpful framework in survey conceptualization driving critical questions related to the theory constructs and applying a method of question format to evaluate perspectives which will relate to the research question or problem. This approach will aid focus to guide data collection and interpretation. Theory application also aids the reader in clarity and understanding. However, less than 10% of researchers apply theory in research protocols.[72]

Human behavior theories, when applied to understand or predict behavior, can be beneficial in providing a context or framework for methods assessing desired behaviors. Evidence-based health behavior theories can serve as a planning tool to support research focused on understanding application of science driven judgements by nutrition clinicians to guide evolving best practices. One commonly used model is the Theory of Planned Behavior from which constructs lend themselves to understanding behavior drivers and providing a formal structured approach to a data collection tool created to assess these influencers.

Theory of Planned Behavior

The Theory of Planned Behavior (TPB) was originally developed as the Theory of Reasoned Action (TRA). The TRA behavioral model was based on cognitive thoughts and

attitudes related to actions which are influenced by knowledge, norms, and intentions. The TRA developed in the 60's was later revised to include a construct termed Perceived Behavior Control to address drivers which account for factors related to control impacting actions. The current model became the TPB in 1985.[74] The TPB was established to describe behaviors over which individuals have control [75] and those constructs which have been identified as leading to specific behaviors. This can practically be applied to assessing RDN beliefs about Vitamin D and attitudes which influence behavior. Suitability of TPB as the framework in this research template is evident with sensible explanation of the constructs. TPB has 6 constructs which drive behavior explanation.[75]

Theory of Planned Behavior Constructs

Attitudes-Referring to an individual's positive or negative view of the specific behavior which considers what is expected or needed; such as the behavior of screening or supplementing VD. It includes the expectancy for outcomes when engaging in measures focused on treatment of VD status. Attitude is a dependent variable which in this instance can be influenced by independent variables of experience or years working as an RDN, employer or facility practices including policies and procedures, and algorithms for best practices. Another dependent variable which may interact with attitude is knowledge. Knowledge is influenced by training, education or years working in the field.

Behavior Intention-Refers to the desire or propensity to practice the desired behavior of screening and supplementing VD. Intention is the largest predictor of behavior, influenced by attitudes and subjective norms. The stronger the intention, the more likely one is to engage in the

desired behavior. Behavior intention can be influenced by the dependent variables of attitude defined above, and knowledge. An RDN will have attitude as a foundation for the motive to perform the desired behavior of addressing VD status. This RDN will also need to possess knowledge to drive the decision informing intent.

Subjective Norm- A behavior or belief held by influential significant others to which the RDN will compare their own behavior. This may positively or negatively influence intention. It includes support from like-minded others and beliefs held by influencers about the specific behavior. This construct addresses the effect of others on the RDN behavior. Such influencers can be facility scope of practice, policies or procedures related to supplementation, laboratory assessment and other healthcare provider actions or attitudes which may support or intimidate a dietitian's behavior.

Social Norm- Collective or shared expectations for what is considered by others to be appropriate, desirable or undesirable behavior. An RDN may be influenced by peer practices or social beliefs such as holistic approaches to supplementation or clinical guidelines. Particularly relevant in this research where “optimal” VD status has various definitions from varying professional organizations.

Perceived Power-Refers to an individual’s expectation or ability to make the desired change or perform the behavior of interest. Perceived power includes elements that may interfere with the ability to execute the desired behavior. An RDN may be influenced negatively if she makes a recommendation to a health care provider (or patient) which is not valued, embraced or

implemented. This may elicit a change in behavior. Conversely, if a dietitian perceives she has the power to improve VD status she is more likely to practice the behavior.

Perceived Behavioral Control- Perceived behavior control (PBC) addresses the perception of how 'easy' or how 'able' one is to engage in the desired behavior. PBC is the differentiating construct from TRA addressing situations that arise which may exist outside of the individual's ability to control the behavior. For example, a situation such as food insecurity may be outside of one's control yet represents a barrier to implementing a desired behavior related to healthy eating, access to VD supplementation or increased consumption of foods high in VD. Overlapping with influencers of behavior, including the influence of subjective and social norms, PBC may prevent the RDN from easily performing the desired VD behaviors.

Theory of Planned Behavior Strengths and Limitations

Strengths of the TPB model include the weighted construct impact of the three main factors: Attitude, Subjective Norm, and Perceived Behavior Control which represent RDNs interest in performing the desired VD behavior, influence of social factors, specifically what others will think of the behavior, and the understanding of factors outside the subject's control which may influence behavior. The desired VD behaviors are supported by the literature reviews and public health data regarding VD as described in detail in chapter 1 which meld well with the theoretical framework of TBP. A significant contextual strength is the applicability to TPB framework in best practices by providing a guide of values which identify steps in the education process to achieve the desired behavior change.

One limitation of the TPB has been addressed in expanding the TRA to TPB by adding the Perceived Behavior Control construct. PBC was identified as a significant barrier to implementing desired behavior and thus accounts for another factor influencing the desired behavior. In spite of recognition of this construct, applying TPB to some behaviors may still be limited by factors not under the control of the individual. Individual control is the cornerstone for the TPB model. For the RDN, an organization's clinical guidelines or best practice algorithms may establish protocol for VD screening or administration. Although they may be outdated and not reflective of recent VD pathway knowledge it may dictate behavior removing it from control of the RDN. Another limitation is intent to implement the desired behavior. One may have intent but may not have ability. Intent should not be confused with ability; lacking tools or finances are barriers to desired behavior not addressed by constructs. A clear example of this may be reimbursement guidelines or requirement for authorized testing by Center for Medicaid and Medicare Services or Health Maintenance Organizations. This can be a barrier to best practice dictated by financial constraints.

Use of TPB also seems to imply recent influences on behavior. The theory does not address the time frame between the intent and the actual performance of the behavior or longevity of continuing to repeat the behavior. The crossroads of intent and opportunity must intersect.

Best Use of Theory of Planned Behavior

Health behavior research has indicated that the most effective nutrition behavior interventions are those which are theory driven and applied specifically to health practices.[76] Use

of TPB is very effective in nutrition education programming which can be applied to dietetics and nutrition education at the university level as well as continuing education for professionals in practice. This theory allows for programs to be developed which address knowledge of base facts such as value of dietary sources of VD and VD supplementation. It can change attitudes where knowledge is identified as mis-informed or uninformed thus creating a desired positive attitude. Collective and personal knowledge combined with social perception can change the acceptability or frequency of the behavior making it easier for individuals to comply with desired behavior. By changing knowledge and attitudes one can expect intention to follow. Intention has the largest influence on behavior. While performance of the intended behavior may be diminished by perceived ability to comply or factors influencing behavior being outside on the individual's control as noted in earlier examples. In order to use this model properly, public health and academic educators need to be well versed in healthcare culture when designing an intervention to assess or address the desired practice. Misunderstanding the reasons VD screening and assessment may be absent may lead to poor ability to change the behavior or target the correct audience. This may not consider economic impact to the decision-making process as in excessive or unwarranted screening for VD or social determinants of health currently facing under-resourced communities who are at higher risk for VDD and lower access to resources to supplement or prevent insufficient status. This model is also noted to be more successful with reinforcement or regular follow-up which is beyond the scope of this research. Design of an appropriate intervention or recommendations to guide RDNs can be a next step to address outcomes of the study. Finally, attitude is a moderate predictor of behavior, but TPB may not weigh other factors appropriately.

Theory of Planned Behavior Application

TPB was applied to a questionnaire to assess dietitian's promotion of whole grains in a study conducted by Chase, et al.[77]. Concepts from constructs were applied to questionnaire development around dietitian's normative beliefs regarding whole grains and base knowledge on health benefits, perceived behavioral control related to ability to have patients follow recommendations, and intent to exhibit the behavior of recommending whole grains in the next 1 month. Results indicated a moderate ability to explain dietitian's ability to perform the desired practice of promoting whole grains (df=3, F=74.5, R^2, p<.001). Dietitians were found to have low levels of knowledge about whole grains and self-efficacy. Recommendations arising from the study results suggest continuing education for dietitians to increase knowledge and improve self-efficacy.

The TPB works well in adult behaviors when there is good personal control. An example may be driving skills, breastfeeding, recommendations for supplementation or other decision making related to health behaviors. It does not work in situations when significant barriers to control are present such as finances needed to engage in desired behavior (i.e., food purchases) or resource limitation (transportation). It will also not work well in those without reasoning or decision-making skills such as infants, very young children or cognitively or mentally impaired individuals. TPB is well suited to surveying beliefs and attitudes regarding an educated, professional study population of RDNs to understand practices around VD and to inform how the constructs impact the research outcome. It can allow for understanding the relationships of the variables to each other and how they impact the constructs and desired behavior.

This research study applied TPB in the development of the questionnaire to gain understanding of *attitudes* which influence decisions regarding VD screening and supplementation. Specifically, items which focus on RDN attitudes focus on beliefs about VD, and general knowledge about VD. To assess the influence of others' attitudes or beliefs regarding VD, questions regarding *subjective norms* assessed influence on RDN as a result of other's beliefs. This included questions which derive information about RDN assessment of VD status and applying questions related to testing recommendations and advice on supplementation. A third goal determined if RDN behavior is influenced by some of the TPB constructs. Not addressed in this research initiative are questions to assess *perceived control* which can allow or prevent the dietitian intent of screening, supplementing based on their intent or lack of control over acting on the intent due to policies or guidelines which require alternative behavior. TPB guided question selection to align constructs with survey items needed to convey information of interest and derived outcomes consistent with study aims. Answers provided were directed at clarifying dietitian behavior according to the principles of the theory as described earlier while providing evidence-based research on knowledge or RDNs and establishing a reference tool for RDN behavior.

Chapter 3 Methodology

The purpose of this research initiative was to understand RDN knowledge, attitudes, and practices regarding VD through evaluation of RDNs perspectives and accuracy of information regarding VD, awareness of emerging evidence regarding expanded role of VD, practices regarding VD and influence of subjective and social influencers regarding VD practices. Three aims were established to inform and assess outcomes of interest. Research methodology included

use of the TPB constructs which serve as scaffolding to assess the behavior and guided by accepted research protocol for sound questionnaire development and data collection.

Aims

This research study focused on 3 aims in exploration of RDN knowledge, attitudes, and practices related to emerging roles of Vitamin D in health. Practices of nutrition professionals can impact clinical excellence in all phases of population health reaching across the lifespan and in all environments from community living to acute care.

Aim #1

The first aim explored the knowledge of RDNs relating to VD. Possessing adequate knowledge is paramount to understanding the importance and influence of VD in population health. This study provided a descriptive exploration of RDN knowledge assessed by a score to address comprehension and awareness of recent VD pathophysiology.

Aim #2

The second aim assessed the presence of a relationship between knowledge and attitude regarding VD. Questions directed at data collection for this goal assessed attitudes of RDNs related to VD screening and supplementation. This aim evaluated a possible association of RDN knowledge to nutrition attitudes related to intervention or lack of intent to directly address VD status and treatment. To address VD status, RDNs would need to screen for inadequate intake or take initiatives to objectively measure VD status via request for laboratory analysis or placing

orders for serum levels. The hypothesis for this aim states: There is no relationship between knowledge regarding VD and attitudes to screen or supplement VD.

Aim #3

The third aim explored the factors which are associated with influences on RDN practice as is related to TPB constructs of social norms and subjective norms. TPB allowed for measurement of influencing factors related to performance of the desired behavior of screening or supplementing VD. For example, it might be feasible the RDN would like to assess VD status for an individual but for other reasons, the RDN may not act on the desired behavior, these include influence of others or conflict with alternative professional recommendations. The hypothesis for this aim: RDNs are not influenced by peers or significant other HCPs regarding VD practices.

Study Design

The study design was a quantitative, cross-sectional study using an electronic administered questionnaire emailed to RDNs.

Study Population

The sample population was US dietitians credentialed by the Commission on Dietetic Registration as RDNs who have active status with the CDR. Active status is defined as those dietitians who have been credentialed by the Commission on Dietetic Registration and maintain continuing education and registration status and are qualified to practice in the field of nutrition under the RDN scope of practice. To be included in the survey, RDNs provided informed

consent as part of the survey tool and had access to email for receipt and completion of the survey. Exclusions for the study were uncredentialed dietitians or nutritionists who are students in dietetics, those without RDN status and those under 18years of age.

The rationale for choosing RDNs for the study population is reflective of the RDN training and education positioning them as nutrition professionals who possess the leadership and expertise to practice skillfully in nutritional science.

Sample Size

Study sample size was calculated at 80% power with an $\alpha = .05\%$. The calculation was performed using the Qualtrics sample size calculator.[78] The population for sample size calculation was based on Bureau of Labor Statistics for Dietitians and Nutritionists employed in 2019 reported at 74,200. (BLS) Sample size was determined to be 383 subjects.

Sampling Method

The sampling method was a purposive, non-probability sampling to meet the necessary sample size and within the ability of the researcher to obtain access to RDN emails for informed consent and survey completion. Active Registered Dietitians were reached by the researcher through work groups, State Dietetic Associations, and professional settings. Recruitment emails approved by the IRB were sent to contacts and professional RDN groups who distributed the survey to membership. Recruitment emails were sent to RDNs over the course of 8 weeks to meet power analysis sample size. At 10 weeks the survey was closed.

Data Collection

Recruitment emails were sent to RDNs over the course of 8 weeks from November 29, 2021 to January 24, 2022. The survey remained open two additional weeks with the goal of allowing late responses until February 2, 2022. On February 2 the questionnaire was closed for response having met the goal for power analysis sample size. RDN professional associations were contacted by email asking administrators to share the RDN questionnaire with membership. This email outreach included state affiliates of the Academy of Nutrition and Dietetics (AND) as well as personal and professional contacts who are RDNs. At 10 weeks the survey was closed.

Survey Development

A literature review was conducted to ascertain previous questionnaires developed to assess VD knowledge, attitudes and practices related to VD. No surveys were conducted specifically on RDNs. Numerous surveys considered practices, attitudes and supplementation in healthcare professionals. These studies are included in Supplement 1Literature Matrix. Bonevski [70] developed and validated a study tool to be used with General Practitioners published in 2012. This tool collected data on demographics, work variables VD testing, practices, knowledge, attitudes and patient inquiries related to VD. [70] Subsequently, Amiri [68] published a questionnaire (D-KAP-38) to assess knowledge, attitude and practice regarding VD in an urban Middle Eastern adult population. This served as a tool utilized by Juanid [69] who administered the D-KAP-38 to 340 Bachelor of Medicine Bachelor of Surgery Students. Portions of this survey are applicable to

the current research initiative, but supplemental data collection questions are required to meet research intent.

A survey questionnaire was developed using a selection of survey questions previously designed and tested by other researchers[79,80] for reliability and validity pertaining to knowledge, attitudes and practices related to VD. Those questions about VD cogently fitting with the TPB theory constructs of attitudes, subjective norm and social norm that were able to cull information stipulated in the aims were selected from validated surveys. Questions which ascertained RDN knowledge comprise section 1 (Knowledge) of the questionnaire, Section 2 of the questionnaire addressed attitudes and practices (Attitudes) of the RDN and Section 3 gathered data related to impact on TPB theory constructs of subjective norms and social norms on RDN behavior (Behavior). This survey did not address additional TPB constructs of Perceived Power and Perceived Behavior Control which fall outside of the aims of this research. Constructs of social and subjective norms which are not addressed in previous validated questionnaires were addressed by new survey questions developed for this research initiative. Primary resources for validated surveys were compiled from Amari, et. al [80] who developed a questionnaire to assess knowledge, attitudes and practices regarding VD in Tehranian adults and Bonevski, et al.[70] who surveyed Australian general practitioners regarding attitudes and practices regarding VD.

Questions were vetted for reliability and validity by the author to complete the research tool. The tool was then evaluated by an expert panel and tested in a pilot group using test and re-test analysis. The survey included demographic data on subjects including age, gender, education, years in practice, practice setting and specialty certifications. All survey data collected was quantitative. A copy of the survey can be found in Appendix A.

Content Validity

Content Validity for all items on the behavior scale was calculated using two methods, Content Validity Index (CVI) and Content Validity Ratio (CVR). Validity was evaluated by 12 experts who focused on the ability of the survey to include necessary and relevant questions needed to ascertain intended information. According to Rodrigues, et al,[81] Content Validity Index (CVI) is the most widely reported measure of content validity in questionnaire development. This evaluation used subject experts to ensure that added survey questions address concepts of subjective norm, social norm ensuring the study aligns questions with TPB constructs and accurately reflect informational responses requested. For newly developed questions related to behavior, experts were asked to evaluate each of 10 questions on a Likert scale: *irrelevant, somewhat relevant, quite relevant* or *extremely relevant.* Seven respondents completed the questionnaire to provide feedback on relevance of behavior questions. Not all respondents answered all questions. CVI was calculated for each question. The top two scales of *quite relevant* and *extremely relevant* were tabulated by question then divided by number of respondents answering the question. Ideal score is 1 indicating questions did not need review. A score .70 or higher were reviewed with consideration and items with values lower than .70 were re-evaluated for possible revision. A total of 4 questions received a score of 1. Two questions fell into the range <1 but >.7. Four questions fell below .7 and were identified for re-evaluation.

Content Validity was also calculated using a Content Validity Ratio (CVR) score to determine essentiality of the items in the Behavior block. Reference CVR score ranges 1 to -1 with a score closer to 1 being optimal.[81] A score higher than 0 indicates 50% agreement.[82] CVR is calculated by (Ne-N/2)÷ (N/2)[81]. Ne= number of panelists noting *Quite Relevant* or *Extremely*

Relevant; N= total number of experts answering the question. Due to the sample size (n=7), the critical value would be 1 representing 100% agreement. After calculating CVR for each behavior survey question, 3 questions resulted in CVR=1, meeting Lawshe's minimum value for acceptability.[82]

Face Validity

Supplemental survey question format and wording from previously validated survey questions were evaluated for face validity to ensure clarity of question and ease of understanding proposed wording. The survey was designed to be easy and quick to complete. Face validity was assessed by the expert panel representative of the study population. Experts were asked to complete the questionnaire noting *Yes, No*, or *I Don't Know* assessing each question on Relevance and Clarity. Questions included an opportunity for reviewers to add comments. All responses were reviewed by the primary investigator. Fifty-three questions had a relevance score of 1; 25 scored <1 but >.70; 5 questions relevance scored <.70. For clarity, 60 questions had a score of 1; 12 scored <1 but >.70 and 10 scored below .70 and were flagged for review. For questions with 2 or more *No* answers, comments were noted and if necessary, wording of questions were slightly adjusted Adjustments included removal of the word religious when describing clothing covering the body. No significant revisions were required to finalize the survey.

Internal Consistency

The questionnaire was piloted on healthcare professionals who were emailed a link to complete the questionnaire. Thirty-six individuals were invited to complete the survey. These

questions were previously reviewed by the expert panel and included final wording for the RDN questionnaire. Completed questionnaires were reviewed after 2 weeks. Block 2 items were devised to assess attitudes related to VD and allowed for this construct to be evaluated for internal consistency using Cronbach's Alpha. The expected minimum standard for Cronbach's Alpha was set at an α of .5-.7. This minimum was targeted to be consistent with recommendations and values used in previous research.[83] Question style primarily excluded reversed phrased questions to avert negatively impacting α which is noted to reduce the sum of covariances and ultimately reducing Cronbach's α.[83] Results yielded Cronbach's α =.80 which suggests good reliability for Attitude block questions. Knowledge questions were not analyzed for internal consistency as these are not subject to consistency values but are scientifically based and not interpretive. Behavior questions were also not rated for consistency as these are directed at actual practices of RDNs also not appropriate for internal consistency assessment.

The pilot questionnaire was sent again to all those responding to the first questionnaire to assess percent agreement with consistency of answering questions. Results by participant were aligned and number of questions answered in agreement with the first pass compared to the second pass was calculated and divided by the number of questions answered. Percent agreement for each respondent was added and divided by number of respondents. Average percent agreement was .70, which was deemed satisfactory.

IRB Approval

Institutional Research Board (IRB) approval was required as data were collected from Human Subjects. Expedited approval from University of North Florida (UNF) IRB was obtained

after submission and review of an exempt application including IRB forms and sample supporting materials from the research study. Expedited approval was granted based on the anonymity of the research survey and use of methods previously approved in IRB survey submissions for similar research studies. Refer to Appendix B for IRB approval.

Data Management

Data were electronically collected in Qualtrics with no identifying personal information. Data was stored in the defined program using two factor authentication. Stored data were available to the principal researcher consistent with electronic password access controlled by UNF technology and data management protocols.

The survey was conducted over 10 weeks. At the end of 10 weeks the survey was closed. A number of questionnaires were not fully completed after informed consent, possibly timing out prior to questionnaire completion. This allowed for some sections to be completed while others were interrupted or stopped prior to completion of each segment. Questionnaire responses were coded in the following manner: *Yes*=3, *I Don't Know*=2, *No*=1, Missing Data=0. Each set of questions was treated as a block to allow for comparison of groups and block score means. Treatment by block allowed each block to be evaluated for the number of questions completed and included or omitted in block scoring criteria.

Data Cleaning

Questionnaires were reviewed for missing data. Each of the three category sections of Knowledge, Attitude, Behavior, required 80% or greater question completion for inclusion in block data analysis. Missing data were coded with zero for identification and removal from SPSS

calculations. This data review process was completed by the primary investigator. Participants needed to answer 80% of questions in the block to be included in data analysis. Scores were compiled for each subject by block and used in group analysis. Block One (Knowledge) question (12_1) of the Qualtrics entry contained a blank entry offering choices but with no question. This item was removed from the analysis to prevent points attributed to the blank question. Two questions in the Attitude/Practice block were incorrectly completed by many respondents who selected *Yes* for more than one category for the questions regarding the number of patients treated in the last 12 months. As a result, questions 25 and 26 were omitted from scoring for all participants in Block 2. This question was not relevant to all subjects particularly those working in non-patient facing job roles.

Statistics

Data analysis was conducted in IBM's SPSS version 27. Questionnaire responses were coded in the following manner: *Yes*=3, *I Don't Know*=2, *No*=1, Missing Data=0. Analysis of each block was conducted according to research aims. Statistical tests performed on each block are noted in Table 3. Statistical analysis included analysis and review of scores by block. To address Aim 1, descriptive analysis of data and scores on question responses for the knowledge block were reviewed. Aim 2 was assessed by Pearson Correlation Coefficient to evaluate a relationship between block scales followed by evaluation using Chi-Square. Aim 3 intended to assess influence on RDN behavior and to determine those variables influencing behavior. This was determined using linear regression.

Table 3. RDN Questionnaire Statistical Testing of Study Aims

Aim	Construct	Section/Questions	Statistical Test	Outcome
1	Knowledge	Section 1-10 Questions	Descriptive/Score	Awareness/Competency
2	Attitude (Practice, screening, supplementation)	Section 2-10 Questions	Pearson Correlation & Chi-Square	Relationship to Knowledge
3	Social Norms, Subjective Norms	Section 3-10 Questions	Linear Regression	Influencing factors on RDN Practices

Analysis for normality was conducted for each block. Knowledge histogram and normal Q-Q plot supported a normal distribution. Attitude scale histogram showed slight skewness but close to normal curve. Normal Q-Q plot for attitude scale was well along adherence to the line plot. The Behavior scale also showed slight skewness to the right with strong results on adherence to the Q-Q plot. Demographic data were reviewed by analysis of frequencies to describe the study population.

Assessment of Aim 1 was completed using descriptive statistics to assess the RDN knowledge by score for general knowledge along with frequencies by question response of *Yes,*

No, I Don't Know to detect patterns in knowledge. Descriptive statistics included assessment by question and knowledge block scale for each participant.

Descriptive statistical analysis conducted on each block provided means for group comparison. Pearson's correlation coefficient, *r*, was used to assess for a relationship between the 3 scales of Knowledge, Attitudes and Behavior. Pearson's *r* was used to assess strength and direction of correlation. This test was selected to assess Aim 2 testing for a relationship between knowledge and attitude. Knowledge and Attitude scores were divided into quartiles used to assess associations between groups of varying knowledge with attitudes/practices. Level of significance was set $\alpha = .05$.

Assessment of Aim 3 focused on identifying predictors and influences on behavior. Linear regression was run to determine contribution of predictors Knowledge and Attitude scales on the dependent variable of Behavior and included other demographic variables (age, education, years in practice, practice setting and certifications) to identify predictors. After identifying predictors, ANOVA was used to compare Behavior scales within categories age, education and certifications to assess the relationship followed by post hoc tests to identify subcategory differences. Tukey served as the post hoc test for chosen comparisons. Finally, frequencies on knowledge and attitude blocks were reviewed to assess trends in RDN knowledge, attitudes and practices.

Chapter 4 Results

The purpose of this study was to assess RDN knowledge, attitudes, practices, and behavior related to VD. Prevalence of VD deficiency has been well documented by NHANES

and in recent research. [12,84] This study was undertaken to provide RDN perspectives related to VD and to identify gaps in knowledge, thus informing about the practices of RDNs who the nutrition experts are. The investigation utilized a questionnaire to examine study aims and establish baseline information about knowledge, practice attitudes and behavior and then to propose areas which may improve knowledge or performance based on results including identifying educational or research needs to support improved public health. Total responses to this questionnaire equaled 541. Of the 541, 3 subjects did not provide consent to participate and were removed from data analysis.

Demographic Data

Study participant demographic data indicated 92% of respondent RDNs are female, 52% work in a clinical inpatient or outpatient setting. Age groups 21-40 and 51-60 were similarly represented with few RDNs over 70yrs of age. Master's degrees were held by 52% of subjects; only 10% have terminal degrees of PhD/DCN. Roughly half of participating RDNs are in the field less than 5 years or over 30 years. Specific demographic data for the study population is pro vided in Table 4.

Table 4. Characteristics of RDNs completing a survey regarding VD

N=538				
	Frequency	**Percentage**	**Valid**	**Missing**
Practice Setting			509	29
Clinical	279	51.90%		
Community/Public Health	68	12.60%		
Wellness/Corporate Health	22	4.10%		
Retail/Business	9	1.70%		
Research/Pharma/Food Sci	10	1.90%		

Education	69	12.80%		
Mgmt./Admin	19	3.50%		
Retired/Vol/Not Working	33	6.10%		
Age			509	29
20-30	106	19.60%		
31-40	114	21.20%		
41-50	74	13.80%		
51-60	112	20.80%		
61-70	78	14.50%		
>70	25	4.60%		
Gender			504	34
Male	10	1.90%		
Female	493	91.60%		
Declined	1	0.20%		
Education			509	29
Bachelor Degree	173	32.20%		
Master Degree	279	51.90%		
PhD/DCN	57	10.60%		
Years in Practice			509	29
0-5	136	25.30%		
6-10	64	11.90%		
11-20	88	16.40%		
21-30	95	17.70%		
>30	126	23.40%		
Additional Certifications			127	411
Certified Nutrition Support Clinician (CNSC)	27	5.00%		
Certified Diabetes Educator (CDE/CDCES)	66	12.30%		
Certified Specialist Gerontology Nutr (CSG)	7	1.30%		
Certified Specialist Sports Dietetics (CSSD)	5	0.90%		
Certified Specialist Pediatric Nutr (CSP)	8	1.50%		
Certified Specialist in Renal Nutrition (CSR)	7	1.30%		
Certified Specialist in Oncology Nutrition (CSO)	7	1.30%		

Data Analysis

A detailed review of block 1 questions to assess knowledge directed at addressing Aim 1 provided a descriptive exploration of RDN knowledge of VD. Data indicated fair overall performance of RDNs on individual knowledge questions. This is evidenced by a mean score for the knowledge scale of 84.89 with SD 6.71 (M =84.89, SD =6.71). Forty-five percent of dietitians scored ≥86% (n=207). Twenty-three dietitians (five percent) scored over 95%. Conversely, 6 (one percent) scored below 67%. Dietitians did well identifying those at risk for VDD. However, calcium supplementation and physical activity were not well recognized as ways to prevent VDD. Exercise was also queried as a source of increasing VD with results indicating lack of knowledge in its association with increasing VD levels. Seventy-two percent of dietitians recognized that 10-30 minutes of sunlight is necessary for adequate synthesis of VD in the general public but that it could depend on other factors. Sixty percent believe that VD more than the recommended daily intake could be harmful. Opinions were split regarding VD deficiency being caused by inappropriate intake with 53% believing VDD does not result from inadequate dietary intake and 41% believing it does result from inadequate intake. Seventy-seven percent of dietitians believe VD intake should differ based on seasons of the year. Sixty-six percent of dietitians believe urbanization prevents sun exposure necessary for adequate levels of VD. Similarly, 62% believe that the high expense and limited dietary sources of foods high in VD are barriers to adequate intake.

To explore Aim 2, correlation was used to assess for a relationship between the 3 scales of Knowledge, Attitudes and Behavior. (See Table 5 for Scales). Pearson's Correlation Coefficient revealed a significant moderate correlation between knowledge and attitude *r (415)*

=.37, p <.001. The null hypothesis for Aim 2 is rejected. No significant relationship was revealed between knowledge and behavior or behavior and attitude. (See Table 6).

Table 5. Descriptive data for Block Scores of RDN questionnaire regarding VD

Block	Mean	SD	Minimum	Maximum	Skew	Kurtosis
Knowledge	84.89	6.71	49	101	-.52	1.75
Attitude	48.45	6.33	25	62	-.64	.59
Behavior	18.78	4.14	10	30	.02	-.52

Table 6. Pearson Correlation between Blocks RDN VD Questionnaire

		Knowledge	Attitude	Behavior
Knowledge	Pearson	1	.365	.077
	N	457	417	409
	p-value		.000	.122
Attitude	Pearson	.365	1	-.051
	N	417	419	411
	p-value	.000		.300
Behavior	Pearson	.077	-.051	1
	N	409	411	411
	p-value	.122	.300	

Knowledge and attitude scores were divided into quartiles. Quartiles were used to assess an association between score on Knowledge scale and Attitude scale using Chi-Square. Quartiles for knowledge were Q1 (49-80), Q2 (81-85) Q3 (86-90) Q4 (91-101). Attitude quartiles were as follows Q1 (23-45), Q2 (46-49), Q3 (50-54), Q4 (55-62). Results indicated a significant difference in attitude score based on knowledge score: $\chi 2$ (9,417) = 39.33, p<.001. The Bonferroni adjustment corrects the α for the 14 square table resulting in a revised α=.003. The p remains below the threshold α=.003 so the results remain significant. Effect size using Cramer's V indicates a weak, although significant, association V€ =.177.

Results pertaining to attitudes around VD indicate that 27% of RDNs believe there are no clear guidelines regarding prevention, diagnosis and management of VD deficiency (see Figure 1), whereas 63% believe this is not the case. 70% reported that readings or current information regarding VD did not change practices in the last year. Yet, 56% of RDNs believe that VDD is one of the most important public health issues facing the US today (see Figure 2). Only 20% of dietitians believed that VD supplements were not necessary to treat VD deficiency. Sixty four percent believed that in VD deficiency, VD supplementation is more efficient than VD dietary intake for improving status.

Figure 1. RDN VD Questionnaire Regarding Clinical Guidelines

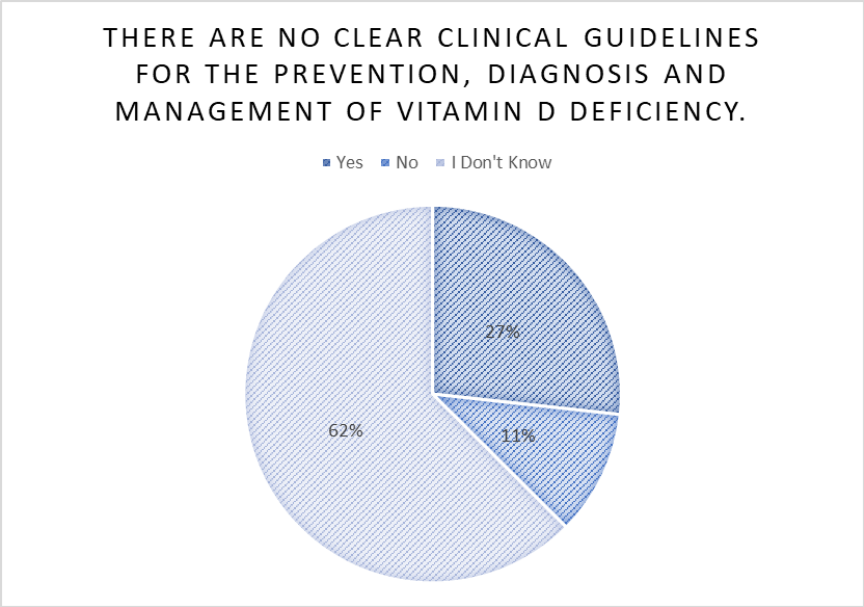
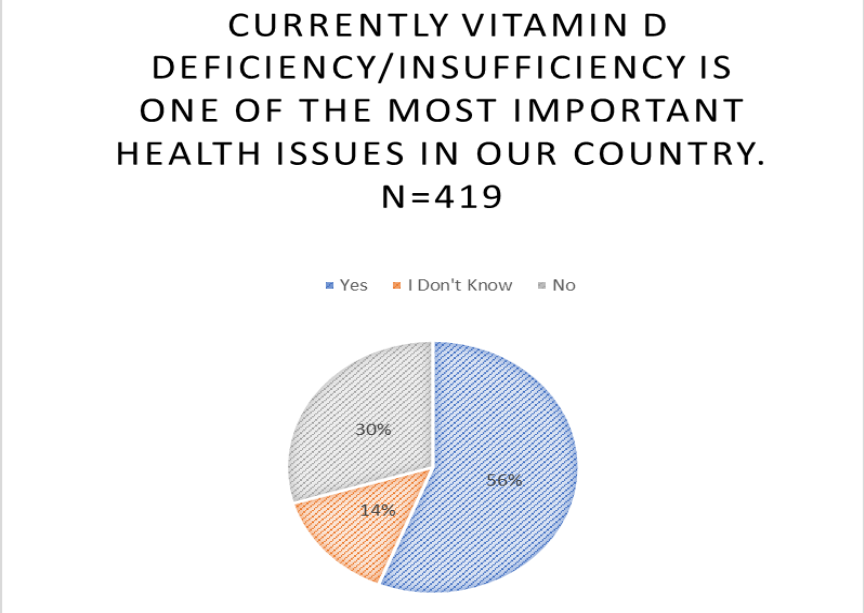


Figure 2. RDN VD Questionnaire VDD as an Important Health Issue



Assessing screening practices, it was found that history of bone fracture was the number one reason to evaluate VD status followed by age, pregnancy and lactation, dietary recall, depression, dark skin, fatigue, muscle weakness and obesity (see Figure 3). The top 3 ways RDNs manage VDD are supplementation, increased dietary intake and increased sunlight in descending order. (See Figure 4)

Behavior influences are evaluated in block 3. Forty one percent of RDNs were unfamiliar with research regarding VD's role in inflammation, immunology, transcription and cytokines. Fifty-two percent rely on Journal of the Academy of Nutrition and Dietetics for articles related to practices around VD. Fifty-six percent do not follow AND guidelines which report the routine VD screening is not necessary in the general population. Regarding use of IOM guidelines for optimal VD status, 46% follow these guidelines and 26% do not. Dietitians who have not read an article about VD in the last 12 months comprised 26%, 71% had read an article in the last 12 months. It was found that 46% of RDNs follow the lead physician regarding the need for VD laboratory assessments. Similarly, 36% defer to other health care providers around practices for VD screening. Twenty percent of RDNs have employer guidelines related to screening and supplementation of VD while 61% do not. RDNs report that 36% rarely disagree with other HCP perspectives regarding screening and supplementation for VD while 43% disagree.

Figure 3. RDN VD Questionnaire Features Prompting Evaluation of VD Status

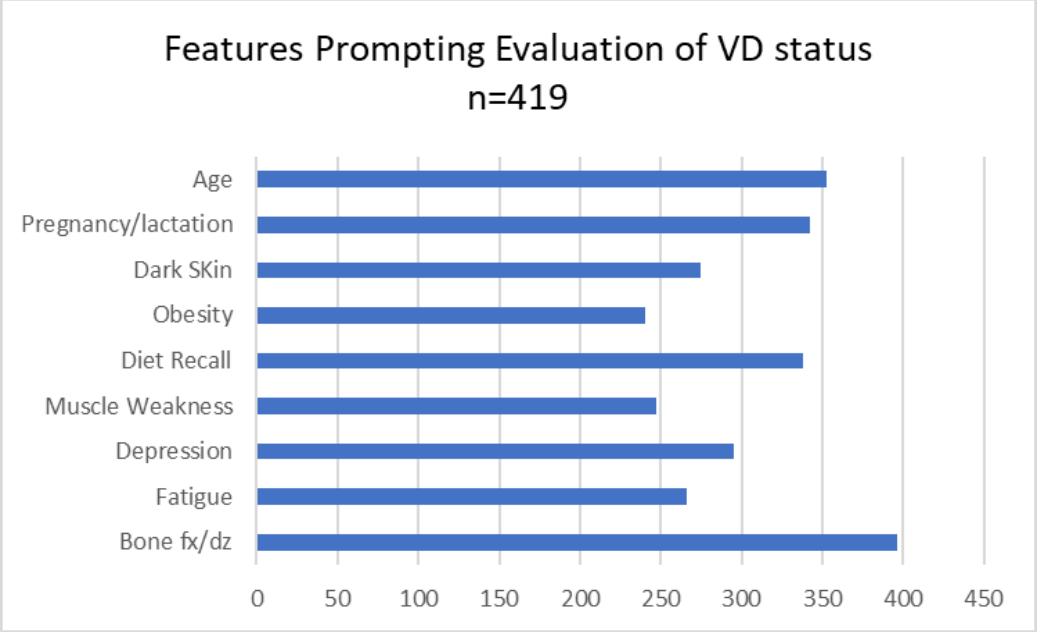
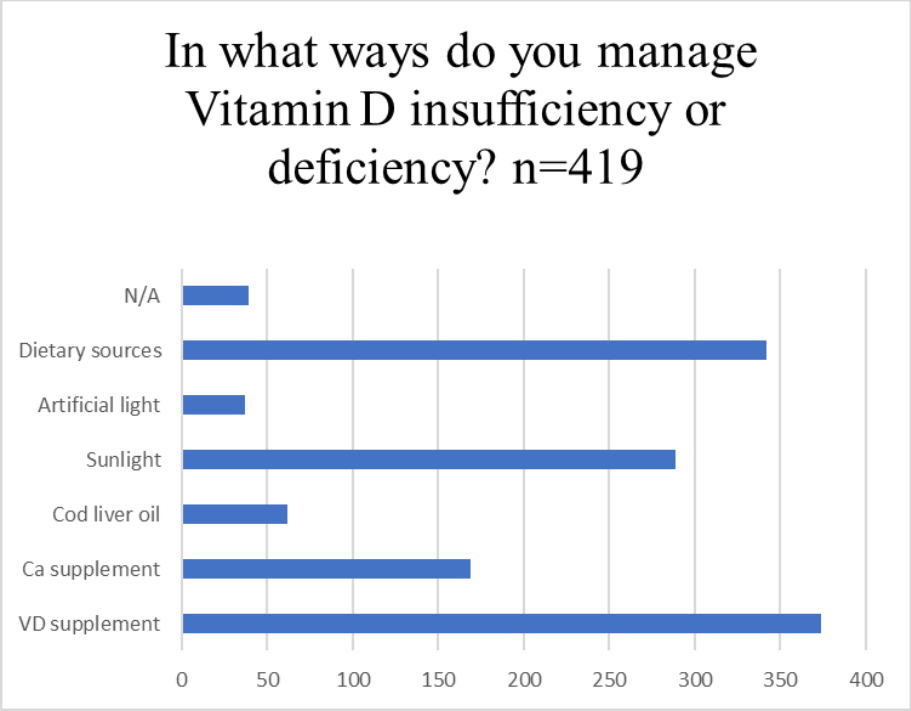


Figure 4. RDN VD Questionnaire Management of VD



When it comes to pharmacological supplementation, 42% of RDNs defer to others who know more about supplementation than they do and 48% do not defer. This analysis leads to rejection of Aim 3 and the null hypothesis: RDN are not influenced by social or subjective norms. RDNs are influenced by social norms and subjective norms and will defer to others who are perceived to have more knowledge about VD than themselves.

Additional analysis of Aim 3 explored prediction of influences on RDN behavior related to VD. Linear regression using the Enter method was run to determine contribution of predictors Knowledge and Attitude scales on the dependent variable of Behavior. It was identified that knowledge was a significant predictor p =.04 although weak based on adjusted r^2 = .008. This represents statistical significance but does not provide practical or clinical value.

Additional analysis on the dependent variable Behavior by predictors of Knowledge scale, Attitude scale and demographic categories of age, gender, education, years in practice and practice setting were evaluated using linear regression enter method. The significant model equation F (3,107) = 4.01, p = <.05) with an r^2 = .101, Adjusted r^2 = .076 indicated predictors of behavior are age, education and certifications. (See Table 7) The regression coefficient for age (B = -.635) indicated that an increase in one scale category resulted in a decrease of .63 in behavior score. The regression coefficient for education (B = -1.47) indicated that an increase in degree earned decreased behavior scale by 1.5 points. The regression coefficient for certifications (B = -.35) indicated that having an additional certification decreased behavior score by .35. However, certifications were not statistically significant p =.128 yet, removing this predictor from the model significantly reduced the value of r^2, therefore it remained in the final model. (See Table 8)

Table 7. Regression Model Summary Predictors of Behavior RDN VD Questionnaire

Model	R	R^2	Adjusted R^2	Std Error of Estimate
1	.318[a]	.101	.076	4.131

Table 8. Coefficients for Behavior Regression Equation RDN VD Questionnaire

Model	Unstandardized B	Coefficients Stnd Error	Standardized Coefficients Beta	*T*	Sig.
1 (constant)	23.866	1.692		14.105	0
Age	-.635	.29	-202	-2.188	.031
Education	-1.47	.669	-.202	-2.198	.03
Certification	-.353	.23	-.141	-1.532	.128

ANOVA analysis was run on variables age, education and certifications in relation to behavior to assess the relationship, including post hoc tests, to identify subcategory differences. ANOVA results for age revealed significant differences in Behavior Scale between RDN age groups. (See Table 9). Effect size is based on Eta-squared ($\eta 2$= .065) indicating a medium effect. Tukey post hoc test revealed significant differences between the Behavior Scale ages 20-30 yrs. (M = 20.59, SD 4.09) and those aged 41-50yrs. (M = 17.49, SD =4.22), 51-60 yrs. (M =18.38, SD 3.75) and 61-70yrs (M=17.56 SD = 3.7). (See Table 10). This indicated the younger RDNs differed in Behavior from older RDNs in their ability to be influenced by social and subjective norms, making them more likely to defer to others. The null hypothesis for Aim 3 is rejected as RDNs are influenced by social norms particularly the youngest practitioners.

9. ANOVA for Behavior Scale by Age Group RDN VD Questionnaire*

	Sum of Squares	**df**	**Mean Square**	***F***	***P***	**η^2**
Between Groups	450.948	5	90.19	5.591	<.001	.065
Within Groups	6532.779	405	16.13			
Total	6983.727	410				

$p < .05$ **$p < .001$

Table 10. Descriptive Data for Behavior Scale by Age Group RDN VD Questionnaire*

Category	N	Mean	SD	Minimum	Maximum
20-30	78	20.59	4.09	11	30
31-40	94	19.28	4.26	10	29
41-50	63	17.49	4.22	10	27
51-60	96	18.38	3.75	10	27
61-70	62	17.56	3.7	10	26
>70	18	17.72	4.07	10	22

*Higher scores in Behavior indicate RDNs are more likely to be influenced according to TPB.

ANOVA identified significant differences between RDNs based on educational degree. (See Table 11). Effect size based on Eta-squared indicates a small effect of education on behavior (η^2=.030). Tukey post hoc analysis noted significant differences between dietitians with PhD/DCN degrees (M =16.83, SD = 3.69) and those with Bachelors' Degrees (M = 19.08, SD =3.94) and between PhD RDNs and those with Masters Degrees (M= 19.02, SD 4.22). (See Table 12). Based on a higher Behavior scale, Bachelor and Master degree holding RDNs were more likely to be influenced by others compared to those with terminal degrees in the nutrition field.

Table 11. ANOVA for Behavior Scale by Education Group RDN VD Questionnaire

	Sum of Squares	df	Mean Square	*F*	*P*	η^2
Between Groups	206.973	2	103.469	6.229	.002	.030
Within Groups	6776.79	408	16.61			
Total	6983.727	410				

Table 12. Descriptives Behavior Scale by Educational Degree RDN VD Questionnaire

Degree	N	Mean	SD	Minimum	Maximum
Bachelor	130	19.08	3.94	10	28
Master	233	19.02	4.22	10	30
PhD/DCN	48	16.83	3.69	10	25

ANOVA performed to assess for differences between RDNs holding certifications with Behavior score revealed significant differences between Certification groups. (See Table 13). Effect size determined by Eta-squared indicates a small effect size (η^2=.220). Tukey post hoc testing revealed significant differences in Behavior Scale among Oncology RDNs (M= 14.17, SD 3.71) and CDEs (M =19.62, SD 3.9), and CSPs (M=21.00, SD 4.31). Behavior Scale of CDEs (M =19.62, SD 3.9) differed significantly from CNSDs (M =16.28, SD = 4.05) and CSO (M= 14.17, SD 3.71). (See Table 14). RDNs certification impact on Behavior indicated that Pediatric RDNs were most likely to be influenced by others while CDEs are less likely, Gerontologist RDNs even less likely and Sports Nutritionist and Oncology RDNs least likely to be influenced by others.

Table 13. ANOVA for Behavior Scale by Certification Type RDN VD Questionnaire

	Sum of Squares	*df*	Mean Square	*F*	Sig.	η2
Between Groups	446.359	6	74.393	4.880	.000	.220
Within Groups	1585.388	104	15.244			
Total	2031.748	110				

Table 14. Descriptive Data for Behavior Scale by Certification Type RDN VD Questionnaire

Certification	N	Mean	SD	Minimum	Maximum
Certified Nutrition Support Clin.[a]	25	16.28	4.05	10	26
Certified Diabetes Educator[b]	55	19.62	3.90	10	28
Certified Specialist Gerontology[c]	6	18.00	3.10	16	24
Certified Specialist Sports Dietetics[d]	5	15.60	3.85	10	20
Certified Specialist Pediatrics[e]	8	21.00	4.31	14	27
Certified Specialist Renal Nutr[f]	6	15.33	3.93	10	22
Certified Specialist Oncology Nutr[g]	6	14.17	3.71	10	19

[a] CNSD, [b] CDCES/CDE, [c] CSG, [d] CSSD, [e] CSP, [f] CSR, [g] CSO

Evaluation of influences on RDN behavior indicated that RDNs are influenced by social and subjective norms evidenced by results of the regression model attributing age, education and certification as predictors of behavior. Knowledge, although statistically significant, does not contribute to behavior and was found not to enhance the final model. As previously noted,

Pearson's did not reveal a correlation with knowledge or attitude with behavior. Although regression revealed influence of age, education and certification on behavior it accounted for only a small contribution. The null hypothesis for Aim 3 is rejected; RDNs are influenced by social and subjective norms in their behavior toward VD.

Chapter 5 Discussion and Conclusion

Discussion

RDNs are the nutrition experts mastering stringent educational requirements, supervised practice hours and passing of an RDN Registration Exam which qualifies them to provide medical nutrition therapy for treatment of health-related nutrition problems. This knowledge and expertise make RDNs a preferred resource for nutrition information. For individuals seeking guidance related to counsel and protocols around VD, it is appropriate to rely on RDN professionals for up-to-date recommendations. With the recent research highlighting an association with VD in the COVID-19 pandemic, combined with poor VD status of Americans, much discussion has identified discrepancies around VD practices. This study has elucidated RDN knowledge and practices related to VD identifying baseline knowledge as well as gaps in recognition for VD's role outside of bone health. Traditional views of VD's role in bone health are well accepted among RDNs consistent with study outcomes, yet knowledge gaps in other areas have been identified. Although VD holds status as one vitamin endogenously produced with adequate exposure to sunlight ideally replacing the need for consumption, little attention has been relegated to its role in public health or the consistently low serum status in the US population. This study identified strengths and weaknesses in VD expertise among RDNs.

Evaluation of the mean RDN score for knowledge at 84.89 suggests good performance regarding VD knowledge. This is further highlighted in quartiles of knowledge scores with quartiles 2 through 4 scoring 81 or higher. Quartile 4 had high scores of 91 or more. Baseline comparison for passing test performance on other nutrition related exams indicates lesser performance expectations. Passing scale for the CDCES exam is set at 70,[85] the CNSC exam at 75[86] and the RDN exam on a scale of 25 out of 50.[87] Findings from this study are similar to Mohamed, et al [56] which found juniors and fellows of ACOG recognized VD status as problematic yet physician practice application was poor in use of VD screening. Similarly, Epling's[65] report on practice and attitudes of physicians regarding VD assessment noted VD screening tests were not routinely practiced but were driven by patient request. This represents influence of others on VD behaviors in the physician group. This study found younger RDNs are more likely to be influenced than older or advanced degree RDNs and more likely to defer to others regarding VD. Behavior scores were predicted by age, educational degree and certification. This suggests more years of experience or advanced training provided RDNs with more confidence and were less likely to be influenced by others.

Weaknesses in Knowledge

Areas of RDN weakness in knowledge identified poor understanding of the relationship between increased calcium intake and VD status as well as the role of physical activity in increasing VD levels.[88] With rising rates of obesity, low rates of physical activity and sequestration of fat-soluble VD in adipose tissues of obese individuals, this poses a health concern for the US population. Additionally, exposure to sunlight is recognized by RDNs as important to increasing VD levels, however, many noted other factors play a role in influencing

status. Sixty percent believe that VD more than the RDA could be harmful. This indicates lack of knowledge of evidence to the contrary and health benefits related to VD based on geographic sun exposure and disease mortality.[89] The belief that excessive intake of VD is harmful is a commonly held perception which may limit supplementation in higher risk individuals, and one which requires clarification, given poor overall VD status of Americans. Discomfort in this area is supported by results indicating 42% of RDNs defer to other healthcare providers regarding VD supplementation and 46% follow the lead physician regarding VD laboratory assessment. It also suggests lack of knowledge of recent research on VD in severity of COVID-19 or associations with poor maternal outcomes in pregnancy. This was confirmed in responses indicating 41% were not familiar with VD's role in inflammation, immunology, transcription and cytokines.

Commonality of RDNs reliance on professional practice guidelines aligns with the findings by the Swiss physician study noting Swiss pediatric physicians had high reliance on practice board recommendations.[59] Excellent application of SSP (Swiss Society of Pediatricians) guidelines was demonstrated by 97% of Swiss pediatricians supplementing VD. American pediatricians were also supplementing VD in infants based on the AAP professional guidelines with 89% reporting supplementation. However, among AAFP (American Academy of Family Practitioners) supplementation was much lower at 63%. Sherman[58] reports the most common reason VD was not supplemented in infants was belief in adequate exposure of infants to sunlight. The next most common reason was unfamiliarity with AAP supplementation guidelines. This affirms the importance of maintaining up-to-date evidence-based practice guidelines kept current based on emerging studies such as those resulting from the COVID-19 pandemic or routinely published NHANES data.

RDNs had split opinions on causes of VD insufficiency with half believing it is not related to poor dietary intake. Yet, many believe that the high cost of VD food sources are barriers to adequate dietary intake. In spite of this discrepancy, recognition of conflicting recommendations by professional organizations regarding VD optimal status was identified by only 27% of RDNs. Unfamiliarity with conflicting organization recommendations also suggests limited knowledge of evidence-based recommendations established based on bone health studies exclusive of other more current research related to VD's role in immunology, insulin production, cardiovascular disease and maternal health.

Given the overall good performance of general VD knowledge and the association that knowledge is related to attitude, it was surprising that behavior was more influenced by age, education and certification than knowledge and attitude. This suggests strong influence of social and subjective norms on RDN practices. Results indicated that age category was significantly associated with behavior scores identifying younger dietitians as more likely to be influenced by others than older RDNs. Education was also found to be significantly associated with behavior indicating RDNs holding terminal degrees of PhD/DCN least likely to be influenced by others compared to entry level RDNs with Bachelor's level education. This may be reflective of advanced education, practice and confidence obtained during completion of the advanced degree. However, an assessment for the relationship between RDNs with advanced certifications and knowledge scores provided no significant differences between certification types. Behavior, however, was significantly associated with advanced certifications of RDNs. Pediatric specialist dietitians are more likely to be influenced than diabetes educators, nutrition support dietitians and oncology dietitians with scores in descending order indicating lowest score least likely to be

influenced. The RDNs with certification in diabetes, nutrition support and oncology may be more familiar with VD's role in immunology due to their work in these specialties and the current research linking VD in these disease states.

Study Strengths and Weaknesses

One strength of this study is the large sample size supported by a strong response rate of RDNs which surpassed calculations recommended by the power analysis. There was good representation across the United States and Puerto Rico with only 7 of 51 states not represented in questionnaire completion. The sampling also included a variety of roles in which RDNs practice leaving no areas unrepresented. In comparison to surveys conducted in other health professional cohorts included in the literature review, this study sample size was far larger, strengthening application of survey results. This allows for application to the broader RDN population. The thoughtfully developed research questionnaire is another strength. It was well researched and tested prior to study use. Subsequently, study results provided a scoping assessment of RDN knowledge and practice attitudes.

One limitation of the present study resulted from non-random sampling by reason of reliance on personal and professional contacts of the research team. Another limitation was the short survey duration and anonymity of respondents which did not allow for reminder emails on completion of the survey. An alternative design may have led to a smaller number of incomplete surveys and is possibly the cause of only partially completed questionnaires. A methodological limitation resulted from use of *Yes, No* and *I Don't Know* as question choices instead of a Likert Scale. A Likert Scale may have allowed more detailed choices providing better assessment of

RDN responses. Additionally, the Qualtrics software question format resulted in unanticipated response errors in two questions in the Attitude block (questions 25 and 26) which were answered incorrectly and were subsequently removed from data analysis. Qualtrics software treats each question choice as a question taking the 30 question inquiries and recording 80 answers. Although these were validated questions from other research surveys, they did not translate into the Qualtrics answer selection format.

Implications for Practice

Information provided as a result of this research can bolster RDN confidence regarding VD practices. Good performance on knowledge questions can allow RDNs to practice with confidence as nutrition experts and succumb less to social and subjective norms. Many RDNs have good baseline VD knowledge but may have opportunities to increase knowledge in current research areas pertaining to public health. This includes metabolic pathways related to immune response implicated in COVID-19 and maternal health outcomes. Study results reveal 46% of RDNs rely on their professional Journal of the Academy of Nutrition and Dietetics for current information. In a recent review posted by the Evidence Analysis Library, it was reported that maternal VD supplementation improves maternal and infant VD serum concentration and may play a role in decreased maternal insulin resistance and improved fetal growth [90]. Post analysis recommendations by authors did not include guidance to increase screening in pregnancy to ensure adequate VD status or increase supplementation during pregnancy to meet optimal serum status in at-risk mothers. Concluding remarks from this review only referred to the need for additional clinical trials to inform practice, yet, evidence was rated as good or strong in benefit of VD supplementation. Evidence noted significantly increased maternal and infant VD levels with

supplementation. Recommendations provided by the evidence-analysis support this study's findings that RDNs often defer to others when they possess adequate knowledge to implement VD recommendations. An increase in VD screening for recognized at risk groups should be applied as this study found RDNs are consistent with their recognition of pregnancy and lactation representing at risk individuals. Suggested guidelines may include requests for laboratory assessments or recommendation for supplementation rather than deferring to lead physicians as indicated by 46% of RDNs or deferring to other HCP as indicated by 42% of RDNs.

Other areas to be addressed are increased education around VD beyond bone health for academic preparation of future RDNs and practitioner continuing education. More practice guidelines for public health issues, such as COVID-19 and at-risk populations, should be available. This includes updating the 2019 AND guidelines for VD and screening recommendations based on strong evidence that the general US population has poor VD status and supplementation confers important biomarker improvements.

Implications for Research

Evidence-based research can enhance RDN leadership and interprofessional education through application in continuing professional education, academic journals and conference presentations focused on increasing VD knowledge, screening practices and treatment recommendations. AND Evidence Analysis Library reviews are very helpful resources which should be brought current to reflect mainstream acceptance of VD's contributions in immunology, genetic transcription, maternal outcomes and insulin availability. This resource should be made easily accessible and effortless to navigate. RDNs should also apply their

understanding about poor VD status, limited dietary contributors, impact of skin color and geography to community nutrition education and public health messaging to improve Americans VD status.

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Appendices

Appendix A

Dissertation RDN Vitamin D Survey

Start of Block: Welcome!

Q1 Hello, this research survey is conducted as part of a dissertation for a University of North Florida doctoral project. I am asking for your help with the '*Knowledge, Attitudes and Practices of US based Registered Dietitians in Relation to Vitamin D'* Survey. You are part of a sample of RDNs asked to complete this anonymous survey-based research project. Participants must be 18 years or older. This research aims to validate a survey about practices among RDNs. Secondarily, this study aims to learn more about influences on practices among RDNs. Your decision to take part in this study is voluntary. You are free to choose whether or not you will take part in the survey. Even after beginning the electronic survey, you may decide to leave the survey or decline to answer any questions at any time without penalty. Your participation will be needed for a total of 15-20 minutes. Please answer all questions honestly and without using any resources as this study aims to get an accurate depiction of RDN knowledge of Vitamin D and usual practices related to screening and supplementation. This project is deemed as no more than minimal risk. The research team does not foresee or anticipate any risk. You may not receive direct benefit for your participation, but the field of nutrition and dietetics may ultimately benefit from the knowledge on attitudes and practices among RDNs that will be obtained in this study. Your cost to participate in the study is the time that you will dedicate to completing this survey. We plan to publish the results of this study. You will not be directly identified in any reports produced as a result of this study. By selecting the yes option below you acknowledge that your participation in the study is voluntary and you may terminate the survey at any time during the questionnaire.

Further information requests, or questions about the survey process, please contact Karen S. Basedow by email to karen.basedow@unf.edu. Alternatively, you may reach the faculty advisor for this research initiative: Dr. Andrea Arikawa, Associate Professor and Co-Director of Doctorate in Clinical Nutrition University of North Florida – Nutrition and Dietetics Office: Bldg 39 – room 3046 Email: andrea.arikawa@unf.edu Phone: (904) 620-1433.

If you have questions about your rights as a research participant, please contact the chair of the UNF Institutional Review Board by calling (904) 620-2498 or emailing IRB@unf.edu.

Please note this survey is best displayed on desktop or laptop computer screen over a mobile phone.

Thank you for your consideration.

O Yes, I consent to participate (1)

O No, I do not consent to participate (2)

Skip To: End of Survey If Hello, this research survey is conducted as part of a dissertation for a University of North Flor... = No, I do not consent to participate

End of Block: Welcome!

Start of Block: Demographics

Q2 Age

O 20-30 (1)

O 31-40 (2)

O 41-50 (3)

O 51-60 (4)

O 61-70 (5)

O >70 (6)

Q3 Gender

- O Male (1)
- O Female (2)
- O Other (3)
- O Decline (4)

Q4 Highest education completed

- O Bachelor's Degree (1)
- O Master's Degree (2)
- O PhD/DCN (3)

Q5 Years in Practice

- O 0-5 (1)
- O 6-10 (2)
- O 11-20 (3)
- O 21-30 (4)
- O >30 (5)

Q6 Practice Setting

- O Clinical (inpatient/outpatient) (1)
- O Community/Public Health (2)
- O Wellness/ Corporate Health (3)
- O Retail/Business (4)
- O Research/Food Science/Pharmaceutical (5)
- O Education (6)
- O Management/Administration (7)
- O Retired/Volunteer/Not working (8)

Q7 Additional Certifications

- O CNSC (1)
- O CDCES/CDE (2)
- O CSG (3)
- O CSSD (4)
- O CSP (5)
- O CSR (6)
- O CSO (7)

Q8 In which state do you practice?

▼ Alabama (4) ... Puerto Rico (54)

End of Block: Demographics

Start of Block: Section 1 Vitamin D Knowledge

Q9 **Section 1 asks you to provide details about Vitamin D which you believe to be true. Please answer to the best of your knowledge using the options provided.**

Which of the following groups do you believe are at increased risk of Vitamin D deficiency?

For each category on the left, select an answer to the right.

	Yes (1)	No (2)	I Don't Know (3)
People who work indoors (1)	O	O	O
Pregnant and lactating women (2)	O	O	O
People over age 65 (3)	O	O	O
People with skin diseases (4)	O	O	O
People who wear clothing covering all of the body (5)	O	O	O
Obese people (6)	O	O	O
People with intellectual disabilities (7)	O	O	O
People with restricted mobility (8)	O	O	O
People with dark skin (9)	O	O	O
People with institutional care (10)	O	O	O

Q10 Which of the following do you believe may prevent Vitamin D deficiency in the general population?

For each category on the left, select one answer to the right.

	Yes (1)	No (2)	I Don't Know (3)
Daily Vitamin D supplements (1)	O	O	O
Adequate intake of Vitamin D fortified foods (2)	O	O	O
Adequate physical activity (3)	O	O	O
Daily exposure to direct sunlight at peak UV times of the day (4)	O	O	O
Daily exposure to direct sunlight at lower UV times of the day (before 9am, after4pm) (5)	O	O	O
Daily exposure to artificial UV light (6)	O	O	O
Daily calcium supplements (7)	O	O	O
Restricting sun protection (use of sunscreen, UV or long sleeve shirts, hats) (8)	O	O	O
There is no effective way to prevent VD deficiency (9)	O	O	O

Q11 What do you believe are good sources of Vitamin D?

For each category on the left, select one answer on the right.

	Yes (1)	No (2)	I Don't Know (3)
Fish with high fat content (salmon, sardines, mackerel, herring) (1)	O	O	O
Fortified milk and margarine (2)	O	O	O
Fortified cereals (3)	O	O	O
Mushrooms (4)	O	O	O
Exposure to sunlight (5)	O	O	O
Exposure to artificial UV light (6)	O	O	O
Exercise (7)	O	O	O

Q12 What amount of unprotected sun exposure of face, hands and arms do you believe is necessary for the general healthy population to get adequate Vitamin D?

Select Yes for best category below, No or I Don't Know for remaining categories.

	Yes (1)	No (2)	I Don't Know (3)
(1)	O	O	O
10-30 min a day (2)	O	O	O
>30 min a day (3)	O	O	O
depends on other factors (4)	O	O	O

Q13 Vitamin D intake requirements should differ by geographic location.

O Yes (1)

O No (2)

O I Don't Know (3)

Q14 Vitamin D intake more than dietary recommendations (DRI) could be harmful.

- O Yes (1)
- O No (2)
- O I Don't Know (3)

Q15 Vitamin D deficiency is related to inappropriate dietary intakes.

- O Yes (1)
- O No (2)
- O I Don't Know (3)

Q16 Dietary Vitamin D intake requirements should differ in various seasons of the year.

- O Yes (1)
- O No (2)
- O I Don't Know (3)

Q17 Urbanization prevents sun exposure and production of required Vitamin D.

- O Yes (1)
- O No (2)
- O I Don't Know (3)

Q18 The high expense and limited food sources are barriers to providing adequate intake of Vitamin D.

- O Yes (1)
- O No (2)
- O I Don't Know (3)

End of Block: Section 1 Vitamin D Knowledge

Start of Block: Section 2 ATTITUDES- 10 Questions

Q19

Section 2. Below are questions which relate to your attitudes and practices regarding Vitamin D. Please answer each statement based on your current practice or beliefs related to Vitamin D.

There are no clear clinical guidelines for the prevention, diagnosis and management of Vitamin D deficiency.

- O Yes (1)
- O No (2)
- O I Don't Know (3)

Q20 Current information about Vitamin D received in the last 12 months has changed my practices.

- O Yes (1)
- O No (2)
- O I Don't Know (3)

Q21 Currently Vitamin D deficiency/insufficiency is one of the most important health issues in our country.

- O Yes (1)
- O No (2)
- O I Don't Know (3)

Q22 Taking Vitamin D supplementation is necessary to treat Vitamin D deficiency and for general health.

- O Yes (1)
- O No (2)
- O I Don't Know (3)

Q23 In Vitamin D deficiency, supplement intake is more effective compared to dietary intake.

- O Yes (1)
- O No (2)
- O I Don't Know (3)

Q24 Which of the following patient features prompt you to evaluate patient Vitamin D status?

Please select an answer for each category on the left from the selections on the right.

	Yes (1)	No (2)	I Don't Know (3)
Past history of bone fractures or current bone disease (1)	O	O	O
Fatigue (2)	O	O	O
Depression (3)	O	O	O
Muscle aches and weakness (4)	O	O	O
Dietary Recall (5)	O	O	O
Obesity (6)	O	O	O
Dark Skin (7)	O	O	O
Pregnant or lactating women (8)	O	O	O
Age (9)	O	O	O

Q25
Estimate the number of patients you have requested Vitamin D levels or supplementation (either yourself or from another health care provider) in the last 12 months:

Select Yes for most appropriate category, No or I Don't Know from remaining categories.

	Yes (1)	No (2)	I Don't Know (3)
None (1)	O	O	O
Less than 5 (2)	O	O	O
5-20 patient (3)	O	O	O
21-50 patients (4)	O	O	O
51-100 patients (5)	O	O	O
More than 100 (6)	O	O	O

Q26 Of the patients for whom you have ordered Vitamin D supplementation or increased dietary intake in the last 12 months, approximately what proportion showed Vitamin D insufficiency or deficiency?

Select Yes for most appropriate category, No or I Don't Know for remaining categories.

	Yes (1)	No (2)	I Don't Know (3)
None (1)	O	O	O
Less than 10 % (2)	O	O	O
10 to 39 % (3)	O	O	O
40 to 59 % (4)	O	O	O
60 to 79 % (5)	O	O	O
More than 80 % (6)	O	O	O
Not Applicable (7)	O	O	O

Q27 In what ways do you manage Vitamin D insufficiency or deficiency?

For each category on the left, select one answer to the right.

	Yes (1)	No (2)	I Don't Know (3)
VD supplements (1)	O	O	O
Calcium supplements (2)	O	O	O
Cod liver oil (3)	O	O	O
Advice to receive more natural sunlight (4)	O	O	O
Advice to receive more artificial light (5)	O	O	O
Nutrition advice on intake of dietary sources (6)	O	O	O
Not applicable (7)	O	O	O

End of Block: Section 2 ATTITUDES- 10 Questions

Start of Block: Section 3 Factors Influencing Your Practices related to Vitamin D

Q28 **Section 3 asks about factors affecting your Vitamin D practices. Please answer the following questions which will provide a consensus of current practices around Vitamin D in the profession.**

I am unfamiliar with current research about Vitamin D related to immunology, inflammation, transcription and cytokine proteins.

- O Yes (1)
- O No (2)
- O I Don't Know (3)

Q29 I rely on my professional Journal of the Academy of Nutrition and Dietetics for professional articles related to practice guidelines regarding Vitamin D.

- O Yes (1)
- O No (2)
- O I Don't Know (3)

Q30 I follow Academy guidelines which state routine Vitamin D screening is not necessary.

- O Yes (1)
- O No (2)
- O I Don't Know (3)

Q31 I follow Institute of Medicine guidelines for optimal Vitamin D status.

- O Yes (1)
- O No (2)
- O I Don't Know (3)

Q32 I have not read an article related to Vitamin D in the last 12 months.

- O Yes (1)
- O No (2)
- O I Don't Know (3)

Q33 I follow the lead of physician with whom I work regarding need for Vitamin D laboratory orders.

- O Yes (1)
- O No (2)
- O I Don't Know (3)

Q34 I defer to practices of other Health Care Providers regarding screening for Vitamin D status.

- O Yes (1)
- O No (2)
- O I Don't Know (3)

Q35 My employer has guidelines related to screening and supplementation of Vitamin D.

- O Yes (1)
- O No (2)
- O I Don't Know (3)

Q36 I rarely disagree with other healthcare providers perspectives regarding screening and supplementation of Vitamin D.

- O Yes (1)
- O No (2)
- O I Don't Know (3)

Q37 When it comes to pharmacologic levels of Vitamin D supplementation, I defer to others who know more about it than I do.

- O Yes (1)
- O No (2)
- O I Don't Know (3)

End of Block: Section 3 Factors Influencing Your Practices related to Vitamin D

Appendix B IRB Approval

IRB#21-094 (1797575-1) Basedow & Ariakwa Dec of Exempt Status Memo 11 10 21 (1)[2649].pdf

Supplement 1 Literature Review Matrix

Literature Review Vitamin D and Adverse Maternal Outcomes

Author	Aim	Outcome	Grade	Reference Range
Roth, D, et al., 2018	Does Vit D supplem during preg. and lac improve fetal growth	Only maternal serum significant difference increasing with dose. No sign difference on SGA, preterm delivery or c-section.	C-poor	def < 30nmol/l (<12ng/ml)
Mirzakhani, H et al., 2016	Assess early Vitamin D supplementation 400 vs 4400 on development preeclampsia	64% VDD. Significant diff. in gravidity between groups. Post tx 39ng/ml in supp. vs 29 in placebo; but RR .97 no difference between groups. Sufficient Vit D > 30ng/ml levels early and late lower PE regardless of tx group. After covariate adj, women with sufficient Vit D levels at 10 and 32wk had reduced risk PE OR .28. Vit D levels in early preg predictor of PE. minimum risk per regression 40-50ng/mL. Vit D levels linked to several immune gene expression.	C-poor	Insuff. <30ng/ml; suff. ≥30 ng/ml

Author	Aim	Outcome	Grade	Reference Range
Pirdehghan,A., et al., 2016	Determine prevalence of Vit D deficiency and relationship to adverse effects: PE, PROM, GDM, O/P hydraminos	No statistically sign result in vit d level to PR, PROM, GDM, sign relationship bet low Vit D and oligo/poly hydraminos	C poor	1,25 (OH)2D3:sev def < 10 µg/l; def 10-20µg/l; insuff. 20-30 µg/l ; suff. 30-50 µg/l; nl or toxic > 50 µg/l
Seto, TL et al., 2016	Evaluate additive effects race and maternal characteristics on vit D deficiency and SGA	Black race and Vit d def. associated with SGA (but not in whites). Min. level Vit d at 50nmol/L protective against SGA in black and white race. Additional significant factors impacting Vit D and SGA were PE, BMI, Medicaid status and PNV.	B-moderate	Def. < 50nmol/L; suff. ≥ 50 nmol/l
Zhao, et al., 2017	To assess vitamin D status and odds of developing severe PE	Vit D high risk factor for severe PE OR 2.2 when adjusted for confounding factors 3.2. Vit D status significantly impacted by maternal age, BMI. pregravid overweight had lower BMI; nl and undwt. no sign diff. No sign diff Vit D in mom w/BW. Nuli vs multiparous sign. diff. and season of blood draw. 78.9% def. in sec tri; 94% >35yrs age.	B-fair	def < 50 nmol/L

Author	Aim	Outcome	Grade	Reference Range
Chrisostomo, et al., 2016	To determine prevalence vit d def in preg. women and assoc. with demographic, pregnancy risk and season	43.7% vit deficiency; 37 vit d insuff. Neg but weak correlation BMI, age PTH. PE was significant and women deficient or insuff. more likely to have PE	C-poor	def <49.92nmol/l, insuff. 49.9-72.38 nmol/l, normal >74.88
Monier, et al., 2019	To investigate association between vit d in first trimester with preterm birth and SGA	45% low vit d. younger age, higher BMI and skin color assoc. with low vit D. No overall risk for total sample with PTB or SGA in lighter skin. Risk for preterm birth with darker skin (Fitzpatrick scale) and low Vit D was significant but not for SGA. Using quartiles lowest quartile had risk for preterm birth for those with dark not light skin. No assn. bet BW and Vit D levels.	B-fair	2 Categories: <20ng/ml, 20-29ng/ml,30+ng/ml; Quartiles <15, 15-21,22-29,30+
Powe, C, et al., 2010	To compare vit d, free vit d and VDBP of first prenatal visit in normal preg. and preg. complicated by preeclampsia	First tri vit D and VDBP positively correlated; both positively correlated with GA at collection, Both inversely correlated with BMI. Total Vit D lower in black and Hispanic, VDBP lower in black vs white, Hisp VDBP not sign from whites free Vit D did not differ black vs Hisp or white. Regression did not show any linear association bet total D and risk of PE No Assn Found.	B-fair	levels <15, 10 or 20 ng/ml -vs those not deficient

Author	Aim	Outcome	Grade	Reference Range
Rostami, Tehrani, et al., 2018	To determine effectiveness of screening to optimize vit D and preventing pregn complications	No PE or GDM in women reaching goal >20ng/ml. Screening reduced risk PE 60%; 50% reduced risk GDM; screening decr pre term delivery by 40%. Following suppl. PTD decreased 30% for mod and 67% for severe. Screening deceased odds of adverse events GDM PE by 55%.	B-fair	Sev def <10ng/ml, mod def 10-20ng/ml, >20ng/ml
Pereira-Santos, M et al., 2019	Evaluate the relationship bet vitamin d levels prenatal monitoring, social det and bw.	32% over wt 27% high gest wt gain; late PNC 60%; 45% insuff. Vit D 21% Def. (tot 66%). Indirect assn with vit d and bw, smoking, closed clothing and winter season impact vit d. Vit D directly affected BW. Each nmol increase in mat Vit D correlated with BW of 3.06g. Low occurrence SGA. LBW 17.18% VLBW 4.7%	C-poor	def <50 nmol/L, insuff. 50-75nmol/L, sufficient >75nmol/L
Meng, Deno-Hong et al., 2020	Estimate role of PTH on the relationship of vit d and FGR	VD status:Severe29.4% moderate 46.9%,non 23.7%.. Weak but stat sign inverse assn with PTH and Vit D. Preg with sev or mod Vit D def -79.8g and -49.4g lower than non-VDD preg. Risk of SGA sign incr only in preg with severe VDD RR2.24. Preg with sev or mod VDD were assoc w/ lower BW regardless of PTH	B-fair	sev VD def <30nmol, mod VD def ≥30-<50; non VDD≥50

Author	Aim	Outcome	Grade	Reference Range
Hemmingway,A., et al., 2018	Assess effect of vit D PTH and vit d def at 15 wk gestation on outcomes: MAP,GHTN, PE and SGA	10% smokers;mean Vit D 56+/-25; 40% MVI; 44% <50, 17%<30. Functional vit d def did not increase GHTN compared to ref. Lowest PE in those vit d >75 nl PTH. Functional Vit D def did not increase GHTN or PE although prevalence lowest in >75. 16% fctnl Vit D def SGA birth. Fct Vit D def increased MAP at 15 wk gest w/o increased GHTN. SGA highest in those with functional Vit D def.	B-fair	low<30ng/ml replete>75ng/ml
Shahraki, et al., 2020	To determine association of Vit D in mothers and neonates with term and preterm infants. Second to assess vit d status in term and PTD.	Concordance with mother and infant Vit D-significant correlation with maternal Vit D grouping and infant both term and preterm. Maternal or neonate Vit D not sign bet term and PTB.	C-poor	def <10ng/ml; insuff. 10-30ng/ml; suff. >30ngmml
Morgan, C., et al., 2016	To determine if vitamin d status in cord blood is assoc. with LBW,SGA,PTB	Compared to>75nmol/l, <50nmol/l had odds lower for LBW than >75nmol/L; No assoc. with SGA and PTB.	C-poor	<50, 50-75, >75nmol/L

Author	Aim	Outcome	Grade	Reference Range
Vivanti, A., 2020	Primary: determine risk of PE w/vit d levels first tri; secondary third tri	1st trimester PE decreased but not statistically significant. Probability of PE decreased w/ incr. Vit D. For ea.10ng increase Vit D risk PE decreased 19% Not stat. sign; third tri risk PE decreased and was stat. sign OR .43. PTB adjusted OR 1.53 in 1st quart <15ng/ml vs . fourth quartile. Dark skin low Vit D had 2.89 higher odds of developing PTB vs higher Vit D. Lighter skin who had no association	A-good	Insuff. <30ng/ml
Thiele. D., et al.., 2019	Quantify relationship maternal vit d to newborn outcomes SPB, Cesarean birth, BW	85% white; mean BMI<25; mean serum analysis 13.2 weeks; mean serum VD 29.96. BW in infant predicted by gestational age not maternal serum. Only reported in categories suff or not sufficient-55% not sufficient. Study underpowered to detect PTB. Vit D not assoc w/ mode of birth.	C-poor	Def <20.9ng/ml; insuff. 21-29.9ng/ml; suff. >30ng/ml.

Author	Aim	Outcome	Grade	Reference Range
Esmeraldo, C., et al., 2019	Relationship of newborn serum VD with maternal serum and BW	Strong correlation maternal serum 25(OH)D and newborn. Serum levels of NB VD were inversely correlated with BW. Serum levels of NB was higher than moms. Only 58 of 225 moms had sufficient VD. 79% dark skinned moms; 72.9% surgical delivery. 32% urinary infection; 8.9%GHTN. SGA infants higher VD than LGA and adequate wt.	B-fair	def<20ng/ml; insuff. 20-30ng/ml; suff. >30ng/ml
Osman, O.,et al., 2020	To compare levels VD in females with PE,E and Normotensive	PE lower VD than controls (M 14.8 vs 19.5) not significant. E lower than control significant (m 10.5 v 19.5) VD def 47% in PE; 80% in E vs only 10.5% in control ;IUGR and Doppler changes sign higher in PE than E; IUFD significantly higher in E group.	A-good	IOM def<12ng/mL; insuff12-20ng/ml; suff>20ng/ml.
Accortt, E., et al., 2018	To assess combined effects of VD and elevated depr sympt on perinatal outcomes (LBW,PE,SGA, PTB)	VD def (<20ng.ml) was sign assoc. with adverse outcomes Women with Vit D def had 3.43 times higher risk of adverse outcomes than women with sufficiency. 16/19 with adverse outcomes non white; 9/19 more than one adverse outcome.	A-good	single cutoff ≤20ng/ml

Author	Aim	Outcome	Grade	Reference Range
Miliku, K., et al., 2016	To evaluate maternal VD conc in second and third tri with fetal growth and birth outcomes (PTB,SGA)	Reduced second trimester VD levels across all quartiles are assoc. with third trimester fetal grow restr, increased PTB, LBW and SGA.	A-good	sev def <25nmol/l; def 25-49.9nmol/l; suff. 50-74.9nmol/l; optimal>75nmol. Quartiles:1.5-24.1;24.2-46.6, 46.7-73.7;73.8-193.3nmol/L.
Fernando, M., et al., 2020	To assess if free, total,VDBP of early preg is assoc with neonatal outcome SGA,BW LGA	Maternal total and free Vit D is assoc. with neonatal BW; high Vit D higher neonate BW	A-good	US Endo: sev def <25nmol/L; def 25-49.9nmol/L; insuff 50-74.9nmol/l; suff>75nmol/l
Al-Shaikh,G., et al., 2016	Correlate VD with neonatal outcomes GDM,GHTN,PE,SPTB, C-Sec	86.4% Vit D def; PE, GHTN, only recorded in women w/insuf or def VD. Vit D conc was not assoc. w/birth or neonatal outcomes**except for high prevalence of miscarriages	C-poor	Def>50nmol/L (20ng/ml); insuff 52-74nmol/l (21-29ng/ml) normal ≥75nmol/L (≥30ng/mL)
Kalinjuma, A., et al., 2019	Describe first trimester VD with adverse outcomes	VD <20ng/mL Had OR 1.82 for adverse pregnancy outcomes; 3-fold increase in still birth with low VD. No assn with premature or SGA.	B-fair	Three Classes: suff. >30ng/ml low <30ng/ml; IOM Def<20ng/ml insuff. 20-29.9ng/ml; suff.>30ng/ml; study value Low VD,40ng/ml.
Djekic-Ivankovic, M.,et al., 2017	Determine if VD status is assoc. w/PE	Case infants primarily C-section, earlier GA and SGA; PE had higher BMI pre gr and at delivery and lower Vit D.	A-good	Severe def <10ng/ml; def<12ng/ml; 20ng/ml target for bone health

Author	Aim	Outcome	Grade	Reference Range
Motamed, S.,et al., 2019	Efficacy of 1000 vs 2000 IU VD	No sign difference in serum Vit D between groups based on suppl. Infants born to 2000IU group had higher BW,HT,HC. IL6 higher in 1000IU.	A-good	def<50nmol/L; inusff. 50-75nmol/l; suff. >75nmol/L
Eggemoen, A., et al., 2017	Explore assn .of maternal VD to neonate anthro-pometric outcomes	Strong association mat Vit D with BW and body composition which were eliminated with ethnicity correction	C-poor	sev def<25nmol/L def<50nmol/L; 3 categories <25nmol?l; <37nmol/L;<50nmol/L
Tian, Y.,et al., 2016	Test assn. maternal VD with low BW/GA and effect of race/ethnicity	In black women BW z-score was positively assoc. with maternal Vit D in whites only assn. with males with half the magnitude of Black outcome.	C-poor	Vit D cutoffs not defined; no VD data provided
Baczynska-Strzecha, M., et al., 2017	Determine correlation of VD and duration of pregnancy	Women having preterm birth had VD lower than control 34% vs 14.2% p=.001; Births between 34-36.6 wk vs<34 wk had significantly higher VD 25.05 vs 16.49. Multivariate analysis did not show significance in VD and association w/PTB.	B-fair	Def <30ng/mL. 4 categories <10ng/ml; 10-20ng/ml;20-30ng/ml; >30ng/ml
Tao, R., et al., 2018	To assess association of VD supplementation at IOM recomm on SGA outcomes	Cord blood 3.5ng/ml higher in supplemented more than 2 mos with significantly decreased SGA with adjusted covariates over non suppl.	B-fair	cord blood <50nmol/L or >50nmol/L
Ong, Y., et al., 2016	Assessment maternal VD status with infant outcomes	No significant association SGA or preterm birth with Vit D	B-fair	def. <50nmol/L; insuff. ≥50-<75nmol/L; suff. ≥75nmol/L

Author	Aim	Outcome	Grade	Reference Range
Lykkedegn, S., et al., 2017	Prevalence Vit D def/ins, risk factors, assoc bet maternal and cord bl w/BW,PW,PW? BW	No assoc. maternal Vit D with outcomes BW, PW but cord blood was positively associated with BW,PW,PW/BW. Cord blood correlated to Maternal Vit D.	B-fair	cord blood def < 25nmol/L; suff. 25-50nmol/L. Also stratified cutoffs: 0-39.9; 30.9-45.4; 45.4-60.8; >60.8.
Van Weert, B.,et al., 2016	Maternal Vit D in early p reg assoc w/PE and PIH	After adjustment no relationship between Vit D and PE, PIH	B-fair	sev def <20nmol/L; def 20-29.9nmol/L; insuff. 30-49.0nmol/l; nor ≥50nmol/L
Kiely, M., et al., 2016	VD assoc w/placental dys identified by PE SGA	Vit D was protective with increasing levels of Vit D assoc. with lower incidence of PE; combined PE and SGA was a robust assn in reference range 50-75nmol/l.	B-fair	<25nmol/L; 25-49.9 nmol/L; 50-74.9nmol/L; ≥75nmol/L
Baca, K., et al., 2016	Relationship maternal VD to PE	After adjustment as Vit D increased PE decreased; 2.4-fold increase in PE for <25nmol/l compared >75nmol	B-fair	sev def. <25nmol/L. def. 25-49.9nmol/L. insuff. 50-74.9 nmol/L normal ≥75 nmol/L
Pashapour, S., et al., 2019	Relationship of vit D to PE in preg women	Vit D deficiency resulted in 4.79-fold increase in PE versus sufficiency	A-good	def <10ng/ml. insuff. 10-30 ng/ml. Suff. >30ng/ml
Gbadegesin, A., et al., 2017	Maternal VD relationship to preg outcomes	No association of maternal Vit D with outcomes/PE	C-poor	def. 0-20ng/ml; insuff. 21-30ng/ml; Suff. >30ng/ml

Literature Review Vitamin D and COVID-19

Author	Aim	Outcome	Grade	Reference Range
Giannini, S, et al., 2021	Examine clinical outcomes of high dose cholecalciferol and if effect of VD modified comorbidity burden	Death or ICU transfer. 36 VD; 55 best available tx. Vit D group had higher comorbidities and smokers-70% 2 or more comorbidities. Vit D in interv. gr sign. lower and D-dimer 3-fold higher. Positive effect of VD was amplified with increasing comorbidity burden. Vit D observed for 43% and 55% reduction in OR of combined endpoint but not statistically significant	C	Not clearly defined; low <50nmol/L or <20ng/mL
Pizzini, A, et al., 2020	Assoc of VD status to COVID Registry with clinical presentation and course of dz	8 weeks after onset C-19 =VD 54nmol demonstrated impaired VD metabolism. VD deficiency is common among COVID pts. Low VD did not predict severity of dz. PTH significantly elevated in those needing prolonged O2	C	Vit D <30 deficiency; between 30-50nmol/L insuff. ; >100nmol/L normal
Radujkovic, et al., 2020	Assn VD with disease severity and survival	Vit D def assoc. with higher IMV/death. 92 out pt, 93 in pt (older, male, more comorbid); VD sign lower in in pt and more need intensive O2; hosp. IL6 significantly higher in VDD hosp. pts than insuff. VDD was assoc. w/ 6-fold higher hazard of severe dz; 15- fold higher risk death	B	<12ng/mL(< 30nM) =deficiency
Vassiliou, A et al., 2020	VD status on ICU admin assoc. w/ worse COVID pneumonia	6% insuf;80%def; Vit D of survivors significantly higher 16.7 vs 9.4ng/mL; all 5 deaths from low Vit D group	B	

Author	Aim	Outcome	Grade	Reference Range
Ling, S, et al., 2020	Is COVID 19 mortality affected by Vit D level, cholecalciferol therapy or other	Tx with cholecalciferol booster therapy protective with OR .13 adjusted. No assn. 25(OH)D and risk COVID 19	B	Insuff. 25-50nmol/L
Sulli, A, et al., 2021	Assessed correlation of VD w/Lung involvement	Vit D significantly lower in COVID vs CTR; also significantly lower in those who died; negative corr VD and radiologic pulmonary involvement, pos correlation PaO2, PaO2/FiO2. VD lower in diffuse and severe interstitial lung dz. 17% incr. in PiO2/FiO2 for ea 1% incr. Vit D.	B	Suff. >30ng/ml, 20-30ng/mL insuff., 10-20 ng/mL; def, <10ng/mL sev def per ES
Entrenas Castillo, M et al., 2020	Does admin of calcifediol impact ICU admission or rate of death	OR.02 for protective calciferol against ICU admiss. Of those tx w/ calciferol no deaths all DC w/o compl.; 13 Not tx were DC; 13 to ICU 2 deaths. Calciferol significantly decreased need for ICU admiss.	A	no vit D levels taken
Jain, A et al., 2020	Assoc of VD status with COVID severity	Significant difference in Vit D status in asympt. (27.89 vs 14.35); Vit D def 31 vs 96% vs severely ill ;IL 6 sign. higher in Vit D def 19.3 vs 12.9. Fatalities high er in Vit D def 21% vs 3%. Severe ill higher TNF 13.2 vs 11.8 in asympt.	B	20ng/mL def.; also used cutoff 30 ng/mL
Bayramoglu,E. et al., 2021	Evaluate association of VD levels with clin severity and inflamm. markers child & adol.	Mean age 12, def 41%, insuff. 38%, suff. 18%; Vit D def A 17, M 35, S 70 resp. By Vit D category 55% def, 17% sudd gr, 15% suff. gr had moderate to severe COVID w/ def group highest fibrinogen and lowest lymphocyte compared to insuff. and nl.	B	sufficient >20ng/ml, def. 12-20ng/mL, insuff. <12ng/mL

Author	Aim	Outcome	Grade	Reference Range
Luo, X., et al., 2021	Evaluate association of VD with incidence and disease severity COVID	Age, Male gender, Vit D def (<30nmol/L=12ng/ml) significantly assoc. w/COVID severity; 2.7x more likely to have severe covid if vit d Def.	B	Vit D def. <30nmol/L =12ng/mL, non-def>30nmol/l
Taslim Pinzon, R., et al., 2020	To report case series of VD in COVID confirmed pts	90% VD def; 10% insuff.; Lowest VD in 3 pts <8ng/mL. 74yo M and 49,56yo F.	C	<20ng/mL def; 20-29 ng/mL insuff., 30-100ng/M; suff. , >100ng/ml potential tox
Maghbooli,Z., et al., 2020	Assess association bet VD and adverse cl outcomes, immune fct and mortality of COVID	Significant assoc. Vit D and reduction in COVID severity, CRP w/incr lymphocyte; Disease severity, % blood lymphocyte and unconsciousness related to poor Vit D status (<30ng/mL)	C	≥30ng/mL sufficiency, 20-29 insuff., <20ng/mL insuff.

Literature Review VD and HCP Questionnaires

Author	Aim	Measure	Outcome	Grade
Alrowaili, M., et al, 2020	determine level of nurse knowledge in GHTN	Questionnaire	70% inadequate knowledge of drugs for PE; 57.8% unable to adequately identify signs of PE; 44% unable to assess fetal condition in GHTN	A-good
Mohamed, . et al, 2016	Assess practice, know, opinion of OB-gyn for screening and suppl VD	On-line questionnaire	45.5% READ OP 495; 68.3% Vit D insuff. problem; 66.3% benefit Vit D ; 82% Vit D considered during preg.; 6.9% all preg. screen; 21% not concerned VD; 48% prenatal suppl low risk VD def.	A-good
Turale, et al, 2020	To capture health beliefs of nurses and origin of same-gen med	60 health beliefs rated 1-5; 1 hour recorded interview	Many nurses found to have false and ungrounded beliefs. Attitudes and feeling not	B-Fair-poor
Gilmartin, et al, 2018	Explore recom. and sources used by HCP to deter safety of oral non-prescr. Preg. suppl	Electronic survey 13 ques plus demogr. Survey pilot tested for usability not validated.	63% felt knowledgeable about CAM*;74% conc about CAM* safety. Ginger rasp leaf, fish oil most rec. Most use online data base MIMS (61%); 40% went to Ph for adv;	B-Fair-poor
Sherman, et al, 2009	Determine prevalence Vit D prescription, factors predict BF suppl, barriers of suppl newborns	22 questions; Survey Monkey; pilot testing w/ endo to test clarity and ease	Many retired,>10 yr practice, So. latitude, 89% AAP-63% AAFP supple VD. Most common barrier belief adeq. sun followed by lack of knowledge AAP rec and belief VD suppl not necessary	A-Good

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Author	Aim	Measure	Outcome	Grade
Santi, et al, 2019	Assess how Swiss providers prescr. VD	Electronic survey 13 ques plus demogr. Survey pilot tested for usability no validated.	97% prescr. 1st yr as rec; 72% prescr. 2-3 yr as rec; more than half seek adv prof when conditions require Vit D; in kids w/ poor VD 88% routinely measure Vit D.	A-Good
Karabulut, et al, 2016	Adherence of Ped to VD prophylaxis prog.	5 ques in online questionnaire	75% rec VD dose 400IU;10% 800 IU; remainder 600 or 1200IU.20% believed stopping VD suppl w/ small anterior fontanelle.	B-Fair-poor
Elitok, et. Al, 2017	Assess knowledge and attitudes re: VD suppl	13 questions; face2face	More pediatricians than residents suppl. Not statis sign; primary use of VD to prevent rickets VDD, fontanelle close, infect. Most freq. dose 400IU until 2yr old	B-Fair-poor
Shaikh, et al, 2004	Determine VD practices and knowl. re prev. of rickets	2pg self admin; pilot tested for face validity by 5 faculty	47% rec suppl for excl BF; 42% ans. incorrect on rarity of rickets	A-good
Buckinx, et al, 2016	Assess profile and determinants of VD suppl in NH	Short self-admin question online or paper option	65% systematically prescribe;31% only Rx "when they think of it". Of those prescribing 92% believe NH def,77% prev. fracture	A-Good
Hassan, et al, 2018	Assess knowledge, attitude, practice doctors	Hand completed questionnaire	29 gyn/188 total. Gov/public hosp. 72%. 9% order on ea. pt; 85% w/ symptoms; 9% none. 53% treat w/clinical features muscle aches, freq. fractures, bone tenderness. More than half of physicians treated empirically with rest using guidelines.	B-Fair-poor
Epling,et al, 2015	Explored att and prac around dx and mgt HypoVD	5 focus group sessions	Belief Vit D above 100 sugg. toxicity; min level Vit D ranged 30 or above. Primary resp- several optimal ranges. Primary source for VD test is pt. Pt sources: media, radio, mag, TV.	A-Good

Author	Aim	Measure	Outcome	Grade
Juanid, et al, 2019	Determine knowledge, attitudes and practices of MBBS students	D-kap38 validated and reliable questionnaire; ques scored	47% had good nutr. knowl. 54% had good general knowl; only 8.8% had good practice; only16% strongly agreed sunscreen decreases exposure to dev VD.	good
Turale, et al, 2020	To capture health beliefs of nurses and origin of	60 health beliefs rated 1-5; followed by 1 hour recorded interview of open-ended ques.	Many nurses found to have false and ungrounded beliefs.	Fair-poor
Hofstede, et al, 2019	Barriers and facilitators to reduce VD and B12 testing	Semi-structured interviews; GPs f2f; pts tele,	2 categories-med or non-med reason for testing. Most common Vit D dark sk. Half advised to take VD suppl w/o testing. GPs not motivated. Also, symptoms resolved after VD suppl.	good

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