Development of a Public Health Model for Translation of Best Practices in Addressing Vitamin D Deficiency

by

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DNP Project
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The DNP Project is designed as a clinical scholarship initiative that allows the graduate student to demonstrate expertise in nursing practice. The project integrates the role of the DNP in a comprehensive healthcare environment that includes utilization of leadership, consultation, advocacy, collaboration and in-depth interaction with experts from Nursing and other disciplines.

Upon satisfactory completion of both the final oral defense and review of the final written manuscript, the advisor initiates the formal approval process.

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Abstract

Vitamin D deficiency (VDD), defined as 25(OH)D <20ng/ml, is a global public health concern. An international group of vitamin D researchers recommends targeting optimal blood levels of 40-60ng/ml to decrease global prevalence of VDD, improve patient outcomes, population health, and decrease costs. A literature review revealed no public health model of evidence-based vitamin D best practices for translating research into practice, and healthcare professionals lack vitamin D knowledge and confidence in translating evidence into practice.

The pre-, post-test, and follow-up survey study design aimed to increase nurses' and dietitians' level of vitamin D knowledge, confidence, translation of evidence into spheres of practice and influence, and identify translation barriers. A vitamin D toolkit was developed and implemented using an online, asynchronous learning management system. Subject matter experts established face validity for the toolkit, including assessments, the *Cycle of Best Practices for Addressing Vitamin D Deficiency* model, educational content, and translational resources.

Participants (n=119) completed the toolkit. Knowledge scores showed a statistically significant increase from 31% to 65% ($p < 0.001$). Follow-up survey confidence scores increased significantly from 2.0 to 3.3 ($p<0.001$) on a scale of 1-5. Respondents reported using the model (100%), sharing VDD knowledge (94%), and identified financial barriers and interdisciplinary team resistance.

Nurses' and dietitians' knowledge and translation of best practices for addressing VDD are critical to improving patient outcomes, population health, and decreasing healthcare costs. Results of this pilot demonstrate implementing an evidence-based toolkit and applying a translational model with accessible resources should be part of vitamin D public health

initiatives. Continuing research should include longitudinal studies in specific practice settings to track improvement in the long-term patient, staff, and financial outcomes.

Keywords: vitamin D, vitamin D deficiency, evidence-based practice, public health model, public health initiative, patient outcomes, population health, global health

Introduction

Vitamin D deficiency (VDD), the most prevalent vitamin deficiency in the world, has been identified as a global public health concern (Cashman et al., 2016; Cashman et al., 2019; Darling, 2020; Darling et al., 2021; Grant et al., 2019; Mendes et al., 2020; Palacios & Gonzalez, 2014). The National Academy of Medicine (formerly the Institute of Medicine) defines VDD as a 25(OH)D level of <20 ng/ml (50 nmol/L) (Rosen et al., 2012). However, due to advances in science, a group of international vitamin D researchers recommends public health initiatives adopt an optimal blood target level of 40-60 ng/ml (100 to 150 nmol/L) to decrease the global prevalence of VDD, health disparities, and costs associated with preventable VDD (Baggerly et al., 2015; GrassrootsHealth, 2015).

Inconsistent vitamin D messaging, poor research design, and published opinion delay the translation of research to practice. To remedy this delay, healthcare professionals (HCP) should increase their knowledge of vitamin D mechanisms related to the consequences of deficiency and health outcomes of interest (Grant et al., 2022). In addition, HCP should improve their skills to design and critically evaluate nutrient research, aiding the translation of vitamin D science into practice and healthcare policy (Grant et al., 2018; Grant, 2022; Grant et al., 2022; Pilz et al., 2022). Translation of vitamin D science into policy and practice is the starting point for improving public health initiatives and embracing the quadruple aim of healthcare: improving patient outcomes, population health, decreasing healthcare costs, and increasing provider satisfaction (Bodenheimer & Sinsky, 2014).

This article describes the development, testing, and implementation of a vitamin D toolkit, including a public health model for addressing VDD and accompanying translation resources, study results, and recommendations for its use to increase knowledge and confidence

in the translation of evidence to practice and policy among healthcare professionals as step one for a public health initiative addressing VDD.

Background/Significance

Vitamin D is critical to cellular health, and nearly every cell in the human body has a vitamin D receptor (VDR) (Bikle, 2021; Muñoz & Grant, 2022). Vitamin D plays a significant role in most physiologic and pathologic processes in the body, including gene expression, DNA repair mechanisms, preventing cancer cell proliferation, lowering viral replication rates, lowering pro-inflammatory cytokine concentrations, and innate and adaptive immune system homeostasis (Grant et al., 2020; Muñoz & Grant, 2022, Shin & Kwun, 2016).

Vitamin D has several forms critical to the biochemical function of cellular health and organ systems. Vitamin D compounds function as a vitamin- nutrient, cell-signaling molecule, prehormone, or hormone, depending on their molecular structure, function, and place in the vitamin D lifecycle (Bikle, 2021; Heaney & Armas, 2015; Holick, 2007; Muñoz & Grant, 2022; Vieth, 2020).

Once thought to be biologically inactive, research has shown vitamin D_3 is directly delivered to many cells and body tissues; converted, then utilized by the organ or cell for many essential functions, including cellular health and repair (integumentary system), autoimmune and immune function, and promoting endothelial and vascular stability (Gibson et al., 2015; Hollis & Wagner, 2013; Sassi et al., 2018). In addition, vitamin D_3 is the form found in breast milk (Hollis et al., 2015). Vitamin D_3 is the preferred form to leverage in public health initiatives as people can obtain it naturally and inexpensively through sensible exposure of skin to sunlight, consumption of food sources (fortified or naturally occurring), and supplementation (Al-Khalidi

et al., 2015; Darling, 2020; Darling et al., 2021; Grant et al., 2022; Kimball & Holick, 2020; Mocanu et al., 2009; Vieth, 2020; Wacker & Holick, 2013).

The totality of vitamin D evidence has increased significantly since 2000, and the Hill criteria for causality have been satisfied for many healthcare concerns (Grant et al., 2022; Grant, 2022). Studies have shown improved patient outcomes, population health, and decreased healthcare costs with higher serum vitamin D levels in many communicable, non-communicable, and chronic diseases in a variety of research, patient care, and community settings (Fakhoury et al., 2020; Grant et al., 2022; Grant et al., 2022; Holick, 2017; Lacey et al., 2022; Muñoz & Grant, 2022; Niedermaier et al., 2021; Peiris et al., 2008; Suárez-Varela et al., 2022).

Research suggests that individual body systems and conditions may have different blood level minimal thresholds for functioning, i.e., decreased incidence of Diabetes Type 2 (>40ng/ml), improved pregnancy outcomes (>40ng/ml), improved thyroid function (50ng/ml), improved immune function (50ng/ml) and cancer reduction benefits (80ng/ml) (McDonnell et al., 2016; McDonnell et al., 2017; Mirhosseini et al., 2017; Muñoz & Grant, 2022; Wimalawansa, 2022). HCP can leverage body systems' minimal vitamin D thresholds to offset risk factors for disease, such as pre-existing health conditions, lifestyle, family history, genetics, and medication use, or in population health, such as during pregnancy.

Experts recommend public health action to prevent VDD, including routine assessment and supplementation of vitamin D_3 as a standard component of public health initiatives and patient care (Amrein et al., 2020; Baggerly et al., 2015; Cavoretto & Vigano, 2022; Chen et al., 2022; Darling, 2020; Darling et al., 2021; Grant et al., 2019; Grant et al., 2022). Grant et al. (2022) stated, “raising serum 25(OH)D concentrations to optimal concentrations will result in a significant reduction in preventable illness and death.” Testing patient vitamin D levels is

essential to assess if an individual is getting enough vitamin D to reach target levels. Therefore, individualized patient care protocols, such as testing, vitamin D_3 supplementation, and re-assessment, should be performed as a standard of primary care to reduce the incidence of disease and decrease healthcare costs (Grant et al., 2020; Kimball & Holick, 2020).

Problem Statement

Global health concerns include preventable illness and increased healthcare costs attributed to vitamin D deficiency and insufficiency. A potential factor in global VDD and insufficiency is the lack of knowledge and confidence in vitamin D best practices among HCP. A literature search did not reveal a public health model of best practices for addressing VDD. Providing HCP with evidence-based vitamin D education, including a public health best practice translational model and key resources, may increase confidence in translating vitamin D science and best practices in patient care and public health policy.

Clinical Question

How effective is a vitamin D toolkit, including a public health translational model and accompanying resources, in increasing nurses' and dietitians' knowledge, confidence, and ability to translate vitamin D best practices into their practice or sphere of influence to improve patient outcomes and population health?

Purpose of the Project

This pilot project aimed to improve patient outcomes and population health by developing and implementing an evidence-based toolkit and public health model of best practices to:

1) increase North Dakota nurse and dietician knowledge about vitamin D deficiency (VDD)

2) increase confidence levels and translation of evidence into practice by North Dakota nurses and dietitians, and
3) identify barriers to translation of VDD evidence into practice

Review of the Literature

As of September 8, 2022, PubMed had 97,388 publications related to vitamin D, with the earliest article published in 1922. The totality of scientific evidence on the physiological role of vitamin D_3 (beyond bone health), and its benefit to the human body, improving patient outcomes and population health, has significantly increased since the year 2000 (Grant et al., 2022; Grant et al., 2022)

Subject Matter Experts Call to Global Public Health Action

Due to the accumulation of evidence, first in 2008 and updated in 2015, an international group of vitamin D experts issued *The Scientists' Call to D*Action* (Baggerly et al., 2015; GrassrootsHealth, 2015). These subject matter experts recommend a global public health initiative to address VDD and insufficiency from all levels of prevention to improve patient outcomes, population health, increase workforce productivity, and decrease healthcare costs (Baggerly et al., 2015; GrassrootsHealth, 2015). As a starting point, they recommend: 1) increasing awareness and education for the public and HCP, and 2) creating a standard of care, including testing to target vitamin D levels of 40-60ng/ml (100-150 nmol/L) (Baggerly et al., 2015; GrassrootsHealth, 2015). Since then, many vitamin D experts and researchers have also recommended addressing preventable VDD as a standard of global public health and practice (Grant et al., 2020; Kimball & Holick, 2020).

Lack of Vitamin D Knowledge and Confidence Among HCP

Research shows health care professionals (HCP) lack confidence in their vitamin D knowledge and how to translate vitamin D research into practice (Fallon et al., 2020; Lhamo et al., 2019; Mekonnen et al., 2020; Reeder et al., 2012; Sharma et al., 2022; Uko & Utley, 2020; Walker et al., 2019; Zgliczyński et al., 2021).

Lack of Translation of Vitamin D Knowledge to Policy and Practice

HCP may benefit from a translational model to guide decision-making processes and resources to improve their understanding of Vitamin D and VDD and increase the opportunity for practice change. Unfortunately, literature is lacking in public health models and translational resources to aid the movement of vitamin D science into practice. An opportunity exists to educate HCPs on the global epidemic of VDD, current vitamin D science, deficiency outcomes, how to evaluate vitamin D research critically, and the cost-effectiveness of addressing VDD from all levels of prevention.

In addition, educational interventions should include translational resources, including how to identify, assess, screen, and educate patients and at-risk populations; supplement dosing; follow-up testing; and blood level monitoring to aid in the translation of knowledge to practice (Griffin et al., 2021; Heaney et al., 2015; Sharma et al., 2022; Sherman & Svec, 2009; Shirvani et al., 2020; Uko & Utley, 2020; Zgliczyński et al., 2021). Vitamin D education aimed at HCPs may result in feelings of enhanced self-efficacy and increased sustainability of EBP (Sharma et al., 2022; Uko & Utley, 2020; Zgliczyński et al., 2021).

In addition, highlighting e-tools, such as the evidence-based *Vitamin D Deficiency Risk Assessment Quiz* and Vitamin *D*Calculator* ™, may optimize workflow and increase confidence when screening patients for VDD or calculating a patient's individualized vitamin D loading or maintenance dose (GrassrootsHealth, 2022). Thus, improving the clinician experience.

Education sessions effectively increase knowledge about vitamin D science and best practices (Uko & Utley, 2020). However, translation methods are recommended to sustain a long-term practice change (Uko & Utley, 2020). Access to a best practices translational model and resources may increase confidence and translation of vitamin D science into practice. Professional organizations are a reliable source of health information for HCP and are a key venue for introducing practice changes. In addition, professional organizations are composed of HCP who influence all practice settings allowing for broad dissemination of EBP parallel to levels of the SEM: interpersonal, organization, community, and health policy levels.

Organizational Assessment

Local Context

North Dakota is a northern-tier state with distinctive determinants of health for VDD, including inclement weather and lack of vitamin-D-producing sunlight for seven months of the year. These determinants of health contribute to the VDD risk for the entire population. North Dakota borders Minnesota and South Dakota, with a similar VDD prevalence (Bunde et al., 2012; Huntington et al., 2010; Kerber et al., 2021).

Professional Organizations as a Platform to Disseminate Evidence-Based Practice and Call for a Change in Practice

Leaders of the North Dakota Nurses Association (NDNA) and the North Dakota Academy of Nutrition and Dietetics (NDAND) noted abundant vitamin D research in the scientific literature and more recent reports about its connection to COVID-19 severity. They also observed their professions' lack of understanding of vitamin D evidence and best practice recommendations. A review of continuing education and conference topics provided by both organizations in the last five years revealed no Vitamin D and VDD education by either

organization (S. Miller, personal communication, March 8, 2021; A. Davis, personal communication, March 8, 2021).

As state-wide chapters of national professional organizations, the NDNA and NDAND are well-positioned leaders to influence evidence-based practice (EBP) initiatives within their sphere of influence. Their publications reach over 21,000 nurses and dietitians in various practice settings, including in-patient care, long-term care, and community health settings. Both organizational missions demonstrate a commitment to advancing their profession through professional development, empowering state-wide leaders, encouraging high practice standards, connecting members with resources, and advocating to address health disparities that affect the health of patients and populations.

Research shows professional organizations can aid in reducing health disparities by creating focused health initiatives to promote EBP through the dissemination of scientific discovery and translational support materials on multiple levels of the Socio-Ecological Model (SEM): interpersonal, organizational/community, and policy (CDC, 2017; Ross et al., 2014). State or regional professional organizations can guide the translation of EBP to the local cultural context and determinants of health. EBP can be disseminated through many avenues, such as encouraging involvement in professional organizations, networking among members, and hosting continuing education seminars/webinars, poster presentations, and conferences (Ross et al., 2014; Titler, 2008).

Conceptual and Theoretical Framework

Social-Ecological Model

SEMs guide public health with the understanding that individual health is a dynamic interaction between the individual and social determinants of health or factors outside of the

person, including interpersonal relationships, workplace, community, physical environment, sociocultural context, healthcare, and political systems (CDC, 2017; Golden, 2019; Golden & Wendel, 2020). SEMs are used to identify disparities in health outcomes and analyze and address factors at each level. An SEM adapted by Golden in 2019 has five levels that address multiple influences on each level impacting health-related behaviors: individual, interpersonal, community/organizations/institutions, policies, and culture.

The SEM adapted by Golden was chosen for this project to guide HCP in understanding their sphere of influence from a systems-level perspective. HCP have an impact beyond their practice setting, interacting on the interpersonal, organizational, community, and policy levels within their local cultural context as family members, friends, coworkers, community members, professional organization members, and constituents to policymakers.

Knowledge to Action Model

The Knowledge to Action (KTA) model was selected as the translational framework for this project because it aimed to facilitate the movement of research knowledge into practice using two cycles, including the Knowledge Creation phase and the Action Phase (Graham et al., 2006). The Knowledge Creation phase involves a significant investment in the literature to explore, review, and synthesize the research area of interest, tailoring it toward a practice problem or clinical question (Graham et al., 2006). The Action Cycle phase includes identifying the problem, followed by selecting, tailoring, and implementing interventions to promote the use and adaption of knowledge to the local context. After assessing barriers to knowledge use, team members should again tailor interventions before implementation (Graham et al., 2006). The KTA model has built-in intentional feedback mechanisms within all phases and between the

knowledge and action cycles (Graham et al., 2006). The KTA model was utilized when considering evaluation, sustainability processes, and dissemination plans.

The adapted SEM and both phases of the KTA model were used to guide a thorough literature search and synthesis, search for existing models and tools, interview subject matter experts, identify a gap in practice, and complete an organizational needs assessment of facilitators and barriers. There was dynamic interaction between the adapted SEM and both cycles of the KTA model when interacting with the leaders of the NDNA and NDAND and subject matter experts to tailor information specific to the local context, their organizations, and toolkit design and follow-up survey development.

Methods

Setting and Participants

The project leveraged a relationship with NDNA and NDAND to implement the project, focusing on nurses and dietitians as target participants. The NDNA and NDAND maintain an active website and social media presence, including continuing education opportunities. Both organizations publish periodic email and paper newsletters and post social media updates. The link for the course was made available through publications brought forth by the NDNA and NDAND, including newsletters, emails, and social media. Reminders and advertising supported recruitment and completion of the project to access eligible participants.

Intervention Design

Bandura's Social Cognitive Theory

Bandura's Social Cognitive Theory (SCT) contains the central concept of the dynamic interaction between three domains of Behavior, Personal, and Environment (1986). These domains guided the toolkit's development through the provision of EBP resources meant to

change the environment/situation for participants. Behavior would be affected through an increase in their competence for applying EBP to patient and population care based on previous experience with continuing education. Finally, self-efficacy (confidence and satisfaction) increases as perceived barriers to implementation decrease.

Toolkit Development

Following knowledge synthesis, an online, asynchronous toolkit was developed using an internet-based learning management platform. Toolkit content included:

- A vitamin D education e-course
- *The Cycle of Best Practices for Addressing Vitamin D Deficiency* model (translational model) (Sanford & Aliano, 2022) (Appendix A)
- Existing evidence-based e-tools to aid in translating research to practice
- Downloadable research & translation resources

After participants were introduced to the toolkit and learning objectives, they confirmed consent to participate in the project and moved directly into the pretest. The pretest included demographic questions and ten questions capturing baseline vitamin D knowledge. Participants then moved through the educational modules and were assessed with the same ten questions during the posttest, followed by a toolkit satisfaction survey. Subject matter experts reviewed and approved all questions, establishing face validity. The learning management system captured participants' consent and responses (Easygenerator, n.d.). Participants rated the delivery, time, and ease of the training during the posttest on a ten-point Likert-style scale.

E-Course Development

The e-course was designed to be a self-paced, interactive learning experience accommodating different types of adult learners. Principles of SCT were used to create

anticipation for an increase in self-efficacy after completing the course. The e-course contains an introduction, learning objectives, and modules on vitamin D science, including vitamin D myths, critical appraisal of nutrient research, cost-effectiveness, the science behind optimal levels, supplementation dosing & toxicity and testing, and the consequences of VDD. In addition, the toolkit guides the translation of research to practice by providing the Best Practices model, the SEM, and levels of prevention as guiding frameworks. An abundance of downloadable peer-reviewed journal articles and translation resources accompanied the e-course as part of the toolkit to encourage the translation of research into practice. Subject matter experts established the face validity of participant assessments, the model, and all educational and translational content. The NDNA and NDAND offered one contact hour of continuing education to participants who completed the toolkit, including the pre-post-test as a CNE and CPEU.

Model Development: Inspired by the GrassrootsHealth Vitamin D Protocol & SBIRT

As part of the project, Sanford and Aliano developed a translational public health model, *The Cycle of Best Practices for Addressing Vitamin D Deficiency*, as a best practice standard for early intervention and referral treatment and follow-up care for vitamin D deficiency based on current vitamin D science, GrassrootsHealth's D*Action Project vitamin D protocol and Screening, Brief Intervention, and the Referral to Treatment (SBIRT) model (GrassrootsHealth, 2021; SAMSHA, 2022; Sanford & Aliano, 2022). The GrassrootsHealth D*Action Project protocol (also used in the pregnancy outcomes research at the Medical University of South Carolina) includes initial testing, providing vitamin D_3 supplements, patient education, and retesting (GrassrootsHealth, 2021; Wagner et al., 2016). The SBIRT model is a public health approach to early intervention and treatment that encourages a brief screening, intervention, and

referral to follow-up treatment; a model that is feasible and sustainable for HCP (SAMHSA, 2022).

The translational model uses five components, including Assess, Screen, Calculate, Educate, and Refer, as outlined below:

- Assess for individual and population risk factors as well as signs and symptoms of vitamin D deficiency
- Screen (or test) using the *Vitamin D Risk Assessment Quiz* or a blood test, depending on clinical indications (GrassrootsHealth, 2022)
- Calculate a vitamin D supplement loading dose and maintenance dose needed to achieve and maintain target vitamin D blood levels (using the *Vitamin D*calculator*™) (GrassrootsHealth, 2022).
- Educate with an individualized vitamin D deficiency risk reduction plan, which includes:
    - Vitamin D supplementation routine based on the calculations above
    - Incorporating safe sun or UVB exposure routine based on skin type, lifestyle, and determinants of health
    - Maintaining a healthy diet to maximize vitamin D absorption and co-nutrient supplementation
- Refer for a blood test or follow-up test to evaluate the individual's response to the dosing routine. HCP should consider follow-up testing every 3-6 months to obtain the target level of 40-60ng/ml, then retest annually or as needed to maintain optimal blood levels (See Appendix A).

Development of Translational Resource: KNOW "D" NUMBER Patient and Provider Guide to Understanding Vitamin D, Testing, & Results

As part of the project, a translational resource guide, *KNOW "D" NUMBER Patient and Provider Guide to Understanding Vitamin D, Testing, & Results* (PPG), was created to educate patients and providers about VDD, testing, & results (GrassrootsHealth, 2022). The PPG is currently available in English.

Leveraging Existing Patient Care Technology: Evidence-Based E-Tools

The toolkit included two existing evidence-based e-tools to improve the HCP experience and satisfaction in providing care: 1) The *Vitamin D*calculator* (the calculator) and 2) The *Vitamin D Deficiency Risk Assessment Quiz* (the quiz) (advertised in the toolkit as "coming soon"; now in beta mode) (GrassrootsHealth, 2022)

GrassrootsHealth's *Vitamin D*calculator*™ was developed and validated in 2015 and updated in 2020 by a team of vitamin D researchers using GrassrootsHealth data (GrassrootsHealth, 2022). The calculator will calculate the estimated amount of vitamin D intake required to achieve and maintain a desired vitamin D level quickly and safely in the form of an optional loading dose and a maintenance dose. It is easy and convenient, and the maintenance dose is capped at 10,000 IU per day to match the No Observed Adverse Effect Level (NOAEL). This maintenance dose is the customized daily dose recommended to achieve target vitamin D levels by weight entered. The calculator includes a practical loading dose regimen that would enable the rapid correction of VDD based on the following formula published by van Groningen et al. (2010): dose (IU) = 40x (target – starting vitamin D level in nmol/L) x body weight in kilograms. (This formula can be converted to Dose (IU) = 40x (target – starting vitamin D level in ng/mL) x body weight in pounds.) The calculator has starting points for patients with or without a known vitamin D level. The toolkit includes a downloadable PDF of how to use the Vitamin D*Calculator.

The Vitamin D Deficiency Risk Assessment Quiz is an e-tool that was developed and validated in 2022 by a team of vitamin D researchers (GrassrootsHealth, 2022). The quiz was designed to increase awareness and knowledge of VDD for patients and HCP and screen for necessary referrals for blood testing in various patient care and community health settings when blood testing is unavailable or affordable (GrassrootsHealth, 2022). Quiz results show patient risk for VDD (low, medium, or high) and list patient-specific risk factors based on answers provided for use in patient education.

Follow-Up Survey

Two weeks post-education, a follow-up survey was sent to those participants who completed the entire knowledge assessment. Follow-up questions assessed participants' confidence, use of the model and best practice resources in their sphere of practice and influence, as well as perceived barriers to moving research into practice. Subject matter experts reviewed and accepted all questions, establishing face validity.

Human subject and IRB approval

Rasmussen University IRB determined this study to be non-human subject research (April 7, 2022). Data were transferred under an educational affiliation agreement (June 2, 2022) and data use agreement (April 4, 2022).

Data Collection, Management, and Analyses

Data Collection, Management, and Storage

The project was implemented from April 18 through June 8, 2022. Follow-up surveys were sent out individually to participants two weeks after toolkit completion. Participant answers and scores were downloaded from LMS as an Excel spreadsheet and then anonymized

using a participant number. After that, the data was cleaned and recoded for statistical analysis. All data was kept in the primary author's password-protected computer per IRB requirements.

Statistical Tests Used

The following statistical tests were used in this project: demographic frequencies, knowledge scores: pre vs. post: paired two-tailed t-test, and confidence levels (Likert Scale 1-5): pre vs. post: paired two-tailed t-test.

Results

Participant Demographics

The pretest, educational content, and posttest were completed by 119 participants. Eighty-seven participants (73%) completed the two-week post-intervention follow-up survey. On average, participants took 1.5 hours to complete the toolkit. Of the participants completing the toolkit, 86%, were nurses (n=112) and 13% (n=16) were dietitians. One participant chose not to disclose their healthcare discipline. The educational degree of the participants ranged from bachelor's 45% (n=54), master's 23% (n=27), licensed practical nurse 14% (n=23), associate 12% (n=14), and doctoral 5% (n=6). The largest group of participants were bachelor's prepared Registered Nurses (36%). When asked about retirement and employment status, most participants indicated they were not retired (96%) and were currently employed as a healthcare professional (91%) (Appendix B).

Demographics of the follow-up survey (n=86) were as follows: 83% nurses, 16% dietitians, and 1% other (Appendix C).

Knowledge Assessment Results

Using a paired t-Test, mean pre-post knowledge scores (n=119) showed a statistically significant increase from 31% to 65% ($p<0.0001$). The sample size was too small to do subgroup analyses between nurses and dietitians.

Toolkit Feedback

Participants provided feedback about the course: "The course contained a ton of research-based information and resources. I was amazed at the data and how nicely it was compiled in this format. Well done!! Although I haven't had much time yet to pass along the information since taking the course, I definitely plan to!" "Thought the course was well done, format easy to follow, provided actionable steps." "I was impressed with the quantity and quality of resources. Thank you for sharing! I plan to use some of the materials in my teaching practice."

Follow-Up Survey Results

The follow-up survey demonstrated five outcomes:

1) Increased confidence in translating research to practice: participants (n=86) reported increased confidence in translating research to practice. A paired t-test showed that participants' confidence scores increased significantly from 2.0 to 3.3 on a scale of 1-5 ($p<0.0001$).
2) Of the participants (n=72) who responded to the question on the use of the translational model, 100% reported that they had used at least one component, with the top three components being: referred (54%), assess (50%), and educate (46%).
3) Translation of research to practice or sphere of influence: participants 94% (n=85) shared knowledge within their practice or sphere of influence, with the most common levels being:
    a. 84% Interpersonal (friends, family, and patients)

b. 73% Organizational/ Community (coworkers and community members)

c. 7% Policy (professional organization members, legislators, or health department staff) (See Appendix D).

4) The most reported resource used to translate research into practice was the *Know "D" NUMBER: Patient and Provider Guide to Understanding Vitamin D, Testing & Results.*

5) The participants reported the most perceived barrier to translating vitamin D knowledge into practice was financial barriers, including the cost of testing and lack of insurance coverage. Other identified barriers included resistance from interdisciplinary team members and individual or patients' lack of interest in vitamin D information.

Discussion of Findings

The SEM was an effective model to include in the toolkit to guide HCP to think outside their practice to their sphere of influence. Participants moved the knowledge externally, sharing the information within their sphere of influence and practice parallel to levels within the SEM. The most common levels reported were interpersonal and organizational/community, as participants shared information with family/friends, patients, coworkers/colleagues, and community members. The KTA model effectively guided the knowledge synthesis process toward the ultimate development and implementation of the toolkit, model, and translational resources, which aided HCP in translating vitamin D research into practice.

This pilot project successfully synthesized existing vitamin D science and research into an easily accessible toolkit and public health translational model with key resources that increased HCP knowledge and confidence in translating best practices and verified barriers to moving research into practice. The toolkit makes years of vitamin D research readily available and digestible to HCP who are looking to understand vitamin D evidence-based best practices

and their role in the health of their patients and communities. The self-paced toolkit alleviates the perceived barrier that translation of scientific literature and evidence is time-consuming (Khammarnia et al., 2015).

Key findings support previous research that HCP lack knowledge and confidence in vitamin D science and best practices. However, exposure to continuing education, a best practice model, and evidence-based resources increase knowledge and confidence in translating research into practice and sphere of influence. Results demonstrate that global and public health initiatives should implement an evidence-based vitamin D toolkit, translational model, and easily accessible resources as the standard of care and policy.

Addressing Barriers to Implementing Vitamin D Evidence-Based Practice

This pilot confirmed barriers to the successful implementation of EBP: financial issues and resistance from the interdisciplinary team. Two strategies have been successful in decreasing financial barriers to the implementation of vitamin D EBP:

1. Collaboration with community partners and local healthcare facilities to decrease vitamin D testing costs as part of community-based public health initiatives (C. Baggerly, personal communication, January 6, 2021).
2. Leveraging e-tools in patient care-- the *Vitamin D Deficiency Risk Assessment Quiz* and *Vitamin D*calculator* ™, can be used to potentially decrease the number of tests needed to achieve and maintain optimal blood levels in settings where blood testing is not available or affordable. E-Tools should be incorporated into standards of practice with the understanding that drawing vitamin D blood levels is the gold standard for assessing vitamin D status because of individual risk and absorption factors (GrassrootsHealth, 2022).

Addressing Resistance from the Interdisciplinary Team

Resistance to implementing evidence-based practice has previously been identified as a barrier to translating research to practice (Dagne & Beshah, 2021). Continuing education and exposure to the dissemination of research through poster presentations and supplemental materials, have shown to be effective ways of increasing knowledge, improving attitudes, and changing behavior (IIic & Rowe, 2013: Uko & Utley, 2020). However, additional translational strategies for long-term sustainability are recommended, such as top-down organizational structures and continual processes to support and maintain the change, such as continuing education, outcomes monitoring, and practice champions.

When attempting to initiate vitamin D education, research, or quality improvement initiatives, the following steps have proven successful in achieving HCP and key stakeholder buy-in and subsequent systems-level change: 1) measure blood levels of key stakeholders and decision-makers before providing education as a "hook" and personal connection, 2) provide an engaging presentation on current vitamin D science and best practice that creates a sense of urgency, incorporating personal success stories, case studies, subject matter expert testimony and cost savings data, 3) present the criteria for nutrient study/initiative design, 4) emphasize the need to track specific patient, population, staff, and financial outcomes, and 4) allow time for discussion of the potential initiative impact within the local context (C. Baggerly, personal communication, January 6, 2021; French-Bravo & Crow, 2015; Kotter, 1996).

Improving Nutrient Study Design and Critical Appraisal Skills

Regarding vitamin D, unfortunately, there is an overabundance of poorly designed research and published opinion in the media, healthcare community, and scientific literature, leading to confusion in the healthcare community. Research and education initiatives should

include information to improve skills of proper study design and critical appraisal as they relate to nutrient research. In 2014, Dr. Robert Heaney published nutrient study design criteria to standardize research design based on nutrient physiology and improve critical appraisal skills (Heaney, 2014). These five criteria (six for systematic reviews) can be used to design and critically appraise nutrient research (see Appendix E) (Heaney, 2014).

Research following these protocols has shown consistent results that can be used to move research into practice and as the basis for formulating public health policy. At the same time, poorly designed studies lead to conflicting results that diminish the value of appropriately addressing VDD or cite the need for additional research; ultimately delaying the translation of evidence into practice (GrassrootsHealth, n.d; Grant et al., 2022).

Additional Successful Strategies to Reducing Barriers and Enhance Sustainability

When attempting to initiate vitamin D education, research, or quality improvement initiatives, the following steps have proven successful in achieving HCP and key stakeholder buy-in and subsequent systems-level change: 1) measure blood levels of key stakeholders and decision-makers before providing education as a "hook" and personal connection, 2) provide an engaging presentation on current vitamin D best practice that creates a sense of urgency, incorporating personal success stories, case studies, subject matter expert testimony and cost savings data, 3) emphasize the need to track patient, population, staff, and financial outcomes, and 4) allow time for discussion of the potential initiative impact within the local context (C. Baggerly, personal communication, January 6, 2021; French-Bravo & Crow, 2015; Kotter, 1996).

Implications for Nursing

Nurses are the largest of the healthcare professions and ranked the most honest and ethical for the twentieth consecutive year (Gallup, 2022). Nursing voice exists at all levels of the SEM, from direct patient care to community and occupational health to administration and nurse legislators. Nurses are the primary providers of patient and family education, working closely with all interdisciplinary team members. Research shows nurses are highly invested in their local communities (McCollum et al., 2017). Nurses are positioned to play a strategic role in public health initiatives, communicating health education information to patients and the public, and sharing EBP with other HCP within their sphere of influence, personally and professionally. Therefore, nurses must be knowledgeable and confident in their ability to translate vitamin D research into practice and their sphere of influence advocating for public health measures that will improve patient outcomes, population health and preserve healthcare resources.

Sustainability Plan

The sustainability plan for this project leverages the relationships built with vitamin D science networks and professional organizations to disseminate the toolkit, Best Practices model, and resources. The project's preliminary results were disseminated at the DNP, Inc. conference in Tampa, FL, in August of 2022 (DNP, Inc., 2022).

Limitations

A limitation of this pilot project was participants included nurses and dietitians in the state of North Dakota and may not be representative of other HCP populations. Relying on newsletters, email advertising, and social media may have been a barrier to recruiting participants. In addition, participants may not have had the interest or time to complete the toolkit, download and use the resources, or complete the follow-up survey. Nurses and dieticians may have anticipated challenges or barriers in implementing the knowledge. The time window

between the education intervention and the follow-up survey was only two weeks; therefore, it may be challenging to project participants' long-term knowledge retention, confidence, and use of translational models and resources within their practice and sphere of influence. Results of this pilot demonstrate the need for ongoing improvement initiatives geared toward increasing HCP knowledge and translation of research into practice.

Conclusions

This project demonstrates a successful pilot of a vitamin D toolkit available to multidisciplinary individuals, workgroups, organizations, and policymakers to increase knowledge and translation of vitamin D best practices. The strengths of the toolkit include its ease and convenience for dissemination in an online, asynchronous, self-paced format, and its included translational resources.

The problem of preventable VDD must continue to be addressed as a global priority. The most efficient way to address vitamin D deficiency is to create a global health initiative exerting influence on multiple, simultaneous socioecological leverage points for the most significant impact, supporting initiatives at the community, regional, and national levels based on local or regional determinants of health. Recommendations include implementing the Vitamin D toolkit, including the public health translational model and key resources to all levels in the SEM, including 1) policymaking venues such as community, regional, or national workgroups, 2) institutions of higher learning and 3) continuing education venues, leveraging professional organizations and networks for dissemination.

The toolkit should be included as pre-education to guide the design of research and quality improvement initiatives or changes to the standard of care, strengthening existing translational research efforts and care initiatives. Further research recommendations include the

implementation of the toolkit in institutions and specific practice settings to track outcomes in patients, populations, staff, and resulting cost-effectiveness.

Individual HCP and policymakers are encouraged to lead as advocates and change champions addressing preventable VDD within their sphere of influence and practice, putting the health of patients, populations, and their communities first.

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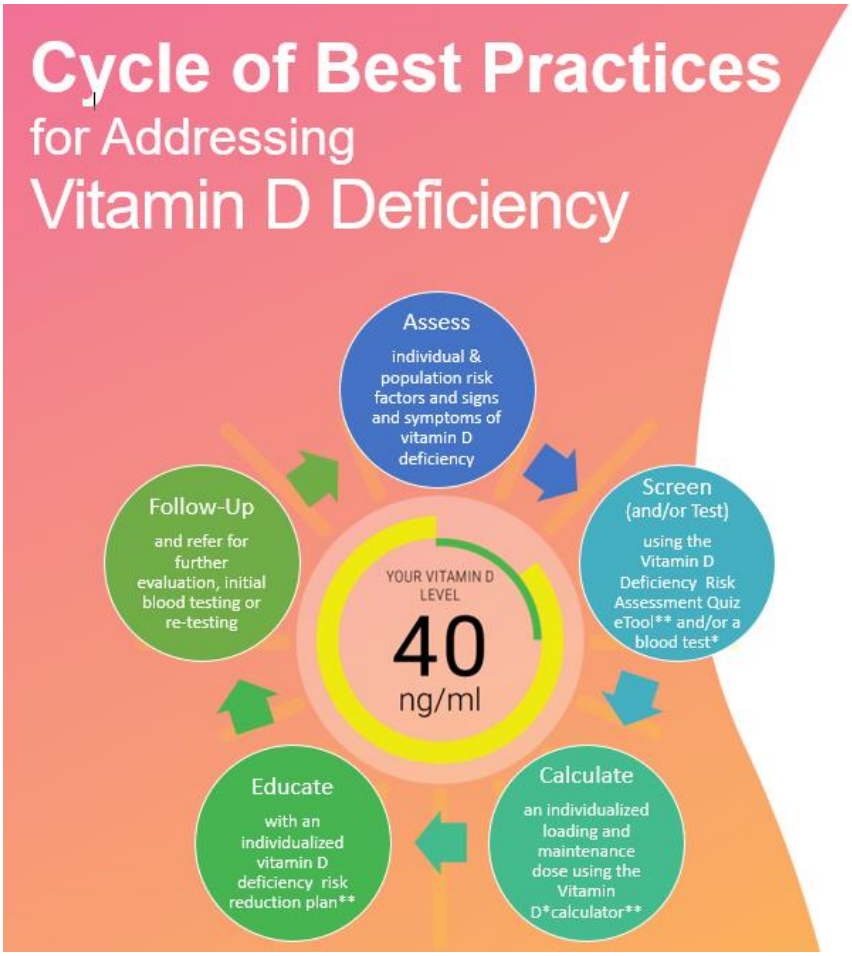
Appendix A

Cycle of Best Practices for Addressing Vitamin D Deficiency model



***A 25(OH)D blood test screening is strongly recommended for at-risk populations*
***The evidence-based e-tools: Vitamin D Deficiency Risk Assessment Quiz & Vitamin D*calculator™, and Know "D" Number: Patient and Provider Guide to Understanding Vitamin D, Testing & Results can be found at* https://grassrootshealth.net/project/achieve-manage-optimal-vitamin-d-levels/

*

Appendix B

Table 1: Toolkit Participant Characteristics (N=119)

Healthcare Discipline	**N (Percent)**
Nurses (RN/LPN)	102 (86%)
Dietitians (LDN/LRD)	16 (13%)
Did not disclose	1 (1%)
Educational Degree	
Licensed practice nurse	17 (14%)
Associate degree	14 (12%)
Bachelor's degree	54 (45%)
Master's degree	27 (23%)
Doctoral degree	6 (5%)
Prefer not to state	1 (1%)
Retired	
Yes	5 (4%)
No	114 (96%)
Currently Employed in Healthcare	
Yes	108 (91%)
No or preferred not to state	11 (9%)

Appendix C

Table 2: Follow-Up Survey Participant Characteristics (N=86)

Healthcare Discipline	**N (Percent)**
Nurses	72 (83%)
Dietitians	14 (16%)
Did not disclose	1 (1%)

Appendix D

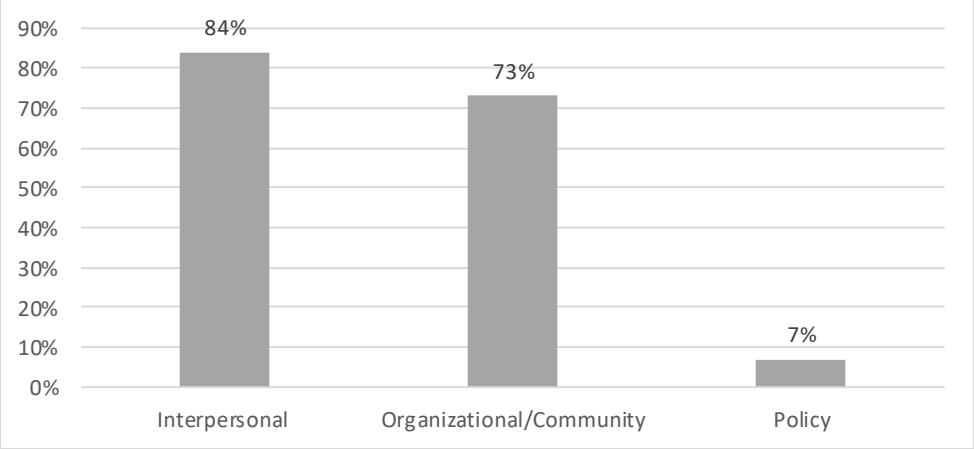


Figure 1: Translation of research to practice or sphere of influence shared by SEM level (n=85)**.**

Interpersonal (friends, family, and patients); Organizational/Community (coworkers and community members); Policy (professional organization members, legislators, or health department staff)

Appendix E


GrassrootsHealth
How to Assess the Validity of
Vitamin D Research
Based on Dr. Robert Heaney's "Guidelines for optimizing design and analysis of clinical studies of nutrient effects," published December 2013
When considering the validity of conclusions made by published vitamin D research, consider the following first:
Criteria #1 - Ask Yourself:
Does the paper mention vitamin D levels of participants at the beginning of the study? Were participants enrolled into the study only if their starting vitamin D level was below a specified cut-off level?
Criteria #2 - Ask Yourself:
Was the dose of vitamin D given to participants in the treatment group large enough to result in a change in vitamin D level?
Criteria #3 - Ask Yourself:
Are vitamin D levels reported for participant groups after the dose of vitamin D had been given, and especially, at the end of the trial?
Criteria #4 - Ask Yourself:
Did the study consider whether the change in vitamin D level was substantial enough to have an effect within that body system, on that particular outcome? Were the study conclusions made based on the change in vitamin D level, not just the change in intake?
Criteria #5 - Ask Yourself:
Were co-nutrients known to affect the disease outcome also tracked and supplemented if needed?
Other Important Questions to Ask Specific to Vitamin D Research:
Was vitamin D given on a daily or weekly basis (supplements in the form of vitamin D3)? Was the study period long enough to have an effect on the disease outcome being studied?
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