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Relationship between Vitamin D Deficiency and Type 2 Diabetes in Saudi Arabia: A Cross-Sectional Study

Basil Elsir Abdalrahiem Mahmoud, MBBS, MD [1]; Emran A. Abu Aqoulah, RN, MSc, PhD [2];

Amal Qasem Alruwaili, RN, MSc (c) [1]; Salam Bani Hani, RN, MSC, PhD [2*]

1 *Regional Health Command and Control Center, Aljouf Branch, Ministry of Health, Saudi Arabia.*
2 *Faculty of Nursing, Nursing Department, Irbid National University, Irbid, Jordan.*
** Corresponding Author. Emails: banihani.salam@yahoo.com; s.banihani@inu.edu.jo.*

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ABSTRACT

Background: Vitamin D deficiency represents a serious concern, particularly for patients diagnosed with type 2 diabetes mellitus, as the general belief states. ***Purpose***: The study aims to evaluate the prevalence of vitamin D deficiency and its relationship to socio-demographics, as well as type 2 diabetes mellitus (T2DM). ***Methods***: A cross-sectional study was conducted among adult residents of Tabarjal Province. Stratified random sampling was used to select primary healthcare centers (PHCCs), followed by consecutive sampling of eligible participants within each selected center. ***Results***: The prevalence of participants with vitamin D deficiency was 45.0%. Although age (25-44 years), marital status, and educational level showed significant associations in unadjusted analyses, only sex remained independently associated with vitamin D deficiency in the adjusted model. ***Conclusion***: Vitamin D deficiency was quite prevalent in the population under study and was linked to a number of socio-demographic factors, but not to type 2 diabetes mellitus. Larger population study designs are needed for the generalizability of the above-stated results. ***Implications for Nursing***: The nursing professional is instrumental in determining vulnerable groups who are prone to reduced levels of vitamin D. Screening and health education campaigns must be incorporated into primary healthcare programs.

Keywords: Vitamin D deficiency, Type 2 diabetes mellitus, Sociodemographic factors, Predictors; Saudi Arabia.

What does this paper add?

1. It offers region-specific information about the prevalence of vitamin D deficiency (45%) and type 2 diabetes mellitus (13.3%) among the population of adults within the Tabarjal Province of Saudi Arabia.
2. It indicates the absence of a strong connection between the concentration of vitamin D and T2DM within this population, contrary to the general belief.
3. Sex is indicated as the only independent predictor of vitamin D deficiency, with females being at higher risk, whereas older age, male sex, unmarried status, and lower educational level were found to be associated with T2DM.
4. It presents findings to inform public health policy regarding a possible more effective screening for vitamin D based on risk factors rather than on disease status alone.
5. It supports nursing and health practice through emphasis on educational and preventive interventions for vitamin D deficiency in high-risk

populations, hence promoting effective public health initiatives.

Introduction

Diabetes mellitus (DM) is a non-communicable disease identified by a malfunction in insulin secretion or function (Harreiter & Roden, 2023). The pancreas has specialized cells known as beta-cells, which produce and regulate the secretion of the hormone insulin, but due to compensatory hyperinsulinemia triggered by hyperglycemia, problems with the secretion of this hormone result in failure of the β-cells of the pancreas (Al-Suhaimi et al., 2022). Blood sugar levels have an impact on the pancreas's ability to secrete insulin (Marshall, 2020). However, in a cycle of action and counteraction, insulin is influenced by other hormones to metabolize sugar (Kalogiannis, 2017). DM can shorten life expectancy even if the patient can continue to lead a normal lifestyle (Hammad et al., 2025; Li et al., 2020).

There are multiple classifications for DM (Kuo et al., 2020). Categorization based on the cause is separated into primary and secondary diabetes (Sharma et al., 2016). Although it can be treated, basic diabetes mellitus is an idiopathic disease (Negrini et al., 2018). Conversely, secondary diabetes mellitus is a form of diabetes that several other illnesses, such as endocrine disorders like thyroid disease or pancreatic disorders like pancreatitis, can bring on (Petrov & Basina, 2021). Vitamin D deficiency has been considered a widespread health problem in Saudi Arabia, affecting a significant proportion of people, despite having a large number of sunlight hours (Al-Daghri et al., 2021). There are various epidemiological studies conducted that revealed a high prevalence of hypovitaminosis D in the adult population, especially in young and middle-aged populations (Liu, 2018; Wang et al., 2020). For instance, in a 10-year cross-sectional study conducted in the central region of Saudi Arabia, Al-Daghri (2021) found that vitamin D deficiency was declining, but it was still a significant health problem, where individuals aged 18-40 years showed a higher prevalence than older individuals, showing a significant problem in the middle-aged population.

Three methods are used to diagnose DM. The first is the Glycosylated Hemoglobin (HbA1c), which is 6.5% or greater when DM is diagnosed; Second, a fasting plasma glucose test of 126 mg/dl or greater is used to diagnose DM; and thirdly, the Random Plasma Glucose Test, which detects severe diabetic symptoms together with DM at 200 mg/dl (Pippitt et al., 2016). Diabetes mellitus can manifest clinically as acute, subacute, or asymptomatic (Hajam et al., 2022). Polyuria, thirst, and weight loss form the traditional trio of symptoms (Kiss et al., 2017). Acute symptoms last between two and six weeks, but subacute effects last for several months. Patients who are typically elderly may present with complications, such as recurring infections, retinopathy, or tingling (polyneuropathy) during routine visits to the optician (Cole & Florez, 2020).

Vitamin D and its deficiency impact the entire world. Its origin dates back to the 1600s and is a prohormone. It comes in two forms: Ergocalciferol (D2) and Cholecalciferol (D3) (Al-Zohily et al., 2020). The process follows sun activation in plants and human skin, from which active vitamin D goes to the liver and kidneys (Amrein et al., 2020). Additionally, vitamin D derived from sun activation can be obtained from animal foods, such as fatty fish, milk, liver, and eggs. The vitamin is stored in fatty tissue and helps control calcium and Parathyroid Hormone levels in the body; hence, it is involved in controlling bone health and pancreatic gland health (Bilezikian et al., 2021).

Vitamin D deficiency is primarily caused by reduced skin synthesis, age, lack of sun exposure, race, hyperpigmentation, increased breastfeeding demands, and poor vitamin D consumption (Cashman, 2020). Symptoms include recurrent infections, fatigue, backaches, depression, wound healing, hair loss, and muscle aches (Hind Al Shikh et al., 2024; Vehapoglu et al., 2015).

One billion individuals may need vitamin D, as 15% of the world's population either have vitamin D deficiency or insufficiency (Cashman, 2020). The Middle East has the highest global vitamin D deficit, regardless of age, despite the region's sunshine and the fact that sunlight is the primary source of vitamin D (Gaffar et al., 2025). Saudi Arabia and Yemen have the highest rates of vitamin D insufficiency in the Middle East (Elrayah et al., 2020). Several theories in the literature report that vitamin D and diabetes are related to each other (Aleksova et al., 2020; Griz et al., 2014).

Owing to the potential implications in the prevention, treatment, and understanding of the management of DM, the association between vitamin D and DM must be investigated and studied. The role of calcium in the functioning of pancreatic beta-cell secretions makes vitamin D the controller of insulin secretion and sensitivity. Insulin resistance, the hallmark of type 2 Diabetes Mellitus (T2DM), has been linked with vitamin D deficiency (Lips et al., 2017). Its anti-inflammatory activities can also counteract chronic inflammation, thereby reducing the risk of T2DM and perhaps type 1 DM by modulating the immune system. The population at risk for DM shows a consistent inverse relationship with the levels of serum vitamin D according to epidemiological information (Sacerdote et al., 2019). In addition, vitamin D sufficiency could prevent the development and progression of diabetes mellitus-related complications, such as cardiovascular diseases and neuropathic manifestations. This could open an avenue for finding and developing novel, more inexpensive, and more accessible treatment modalities, like vitamin supplements, and could validate the development and execution of vitamin-fortification programs, particularly among the underserved population in Tabarjal Province in the Kingdom of Saudi Arabia.

This research aimed to investigate the relationship between type 2 Diabetes Mellitus and vitamin D deficiency among adults in Tabarjal Province, Kingdom of Saudi Arabia, to determine the prevalence rate of vitamin D deficiency in Tabarjal, and to assess the correlation between vitamin D deficiency and type 2 Diabetes Mellitus among adults in Tabarjal Province, Kingdom of Saudi Arabia.

Materials and Methods

Study Design

A cross-sectional design was used.

Settings and Population

The study was conducted among the people residing in the city of Tabarjal in Al-Jouf Province in Saudi Arabia, because the area has a majority male population totaling 48,525 with about 65% in the middle-aged group based on the last 2019 census report (Gu et al., 2021). The healthcare delivery in the city is made up of a single general hospital and eight primary healthcare centers run by the government. There was a random selection carried out among the PHCCs using a lottery system where each center was given a special identification number and the selected ones needed by the study were determined using a lottery process whereby numbers were selected randomly and without replacement, because there are not many healthcare facilities. The target population included all adult residents in Tabarjal City aged 18-60 years, excluding vulnerable groups. Those aged above 60 years were intentionally excluded, as this would create a relatively homogeneous study group, and also because the middle-aged individuals are the majority and the greatest risk group for both vitamin D deficiency and type 2 Diabetes Mellitus. Those above 60 years of age also would have confounded the results as individuals tending to have multiple ailments and differences in pharmacokinetics and pharmacodynamics regarding vitamin D.

A two-stage sampling strategy was adopted to balance methodological rigor with practical feasibility. At the first stage, PHCCs were randomly selected by the use of a lottery method to ensure some randomization at the facility level and taking into account the volume of patients. Hospitals and private facilities were excluded from the study, because of the small numbers present and their overlap in catchment areas. During the second stage, all consecutive adult attendees of the selected PHCCs were recruited during the period of data collection. This method granted each eligible patient who was present a potential chance to participate, thus increasing participation rates and ensuring feasibility at a logistical level. Combining random selection of centers with consecutive recruitment of participants will enhance representativeness within the bounds of a practical and efficient data collection process.

Participant Recruitment and Eligibility

A total of 412 people were screened for eligibility, of whom 65 people did not take part. Non-participation criteria included ineligibility on account of being below 18 years (n = 21) or above 60 years (n = 18), inability to independently carry out questionnaire administration (n = 14), or refusing to take part after receiving study details (n = 12). Therefore, 347 people met the study inclusion criteria. Missing data was seen among these participants for the following variables: vitamin D supplement use (n = 9; 2.6%), duration of exposure to sunlight (n = 14; 4.0%), and variables related to vitamin D intake on the VIDEO-FFQ (n = 18; 5.2%). As the method for handling missing data was a complete-case analysis, the study eliminated from the models all the participants with missing values, leaving a final study sample of 240. All variables had less than 10% rates of missing values, making it less likely for much bias to be introduced. Figure 1 shows a flow diagram of participant recruitment and selection.

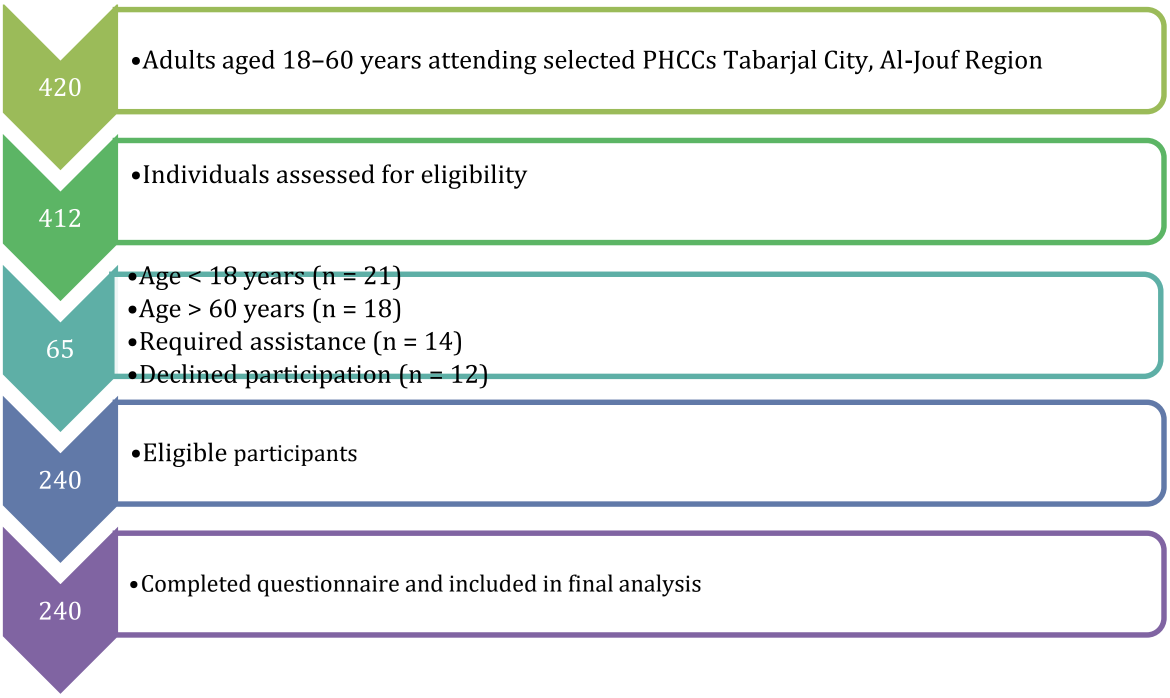

Figure 1. Flow diagram of participant recruitment and selection

Sample Size

Sample size was primarily calculated using the single-proportion formula as described by Charan and Biswas (2013), based on the prevalence of vitamin D deficiency in Saudi Arabia (29%). With a 95% confidence level and a margin of error of 5%, the minimum required sample size was 316 participants. After accounting for an anticipated 10% missing data rate, the final estimated sample size was 347 participants. Additionally, a power-based calculation using Epi Info StatCalc indicated that a minimum of 240 participants would be sufficient to detect associations related to T2DM prevalence at 80% power and a 95% confidence level. The larger sample size was adopted to ensure adequate precision and statistical power for both prevalence estimation and multivariable analysis.

Instrument

Data collection was carried out through a structured, self-completion questionnaire comprising two segments. The first segment obtained the general information of the participants that included sociodemographic data and health-related details relevant to the status of vitamin D. These included the presence of chronic ailments, especially type 2 diabetes mellitus; vitamin D supplement usage; the pattern of sun exposure, and symptoms which are most likely associated with vitamin D deficiency as claimed by the participants themselves. This segment was specifically devised to account for non-dietary influencers of vitamin D status. Segment two consisted of the VIDEO-FFQ - Vitamin D Estimation Only-Food Frequency Questionnaire - originally developed by Głąbska et al. (2016).

The VIDEO-FFQ is a nutrient-specific dietary assessment tool designed to estimate habitual vitamin D intake from food sources and supplements. It focuses exclusively on vitamin D-rich and fortified foods, including fatty fish, eggs, dairy products, fortified products, and vitamin D-containing supplements. Participants reported the frequency and portion size of consumed items over the previous month. Total daily vitamin D intake was calculated in micrograms (μg/day) or International Units (IU/day) based on reported intake and standardized food composition data. Previous validation studies have demonstrated moderate validity of the VIDEO-FFQ when compared with dietary records and serum 25-hydroxyvitamin D levels, acknowledging that serum levels are also influenced by sun exposure (Głąbska et al., 2016; Hribar et al., 2022).

For this study, the VIDEO-FFQ was adapted to include vitamin D-dense foods that are common to the region of Saudi Arabia and the Middle East. Content validity for this study was determined through a review process with nutrition experts from the region. A pilot study among 20 volunteers helped validate the questionnaire for its understandability and practicability. It further showed internal consistency with Cronbach's alpha = 0.81. This helped establish reliability among the respective study population.

Data Collection Procedure

Participants were sought from PHCCs, and their purpose and objectives were considered. Middle-aged participants, 18-60 years old, and non-assisted patients of both genders qualified. Participants under 18 years of age and those over 60 years of age were excluded.

This was carried out through self-administered questionnaires that could be evaluated by the researchers or participants, and data was entered into secure Excel software to enhance the validity and accuracy of data. Following that process, data was archived securely in a cabinet for a period of five years. Further, these electronic pieces of information were also archived for a period of five years in a safeguarded external hard drive. A file involving an Excel data matrix, completed and submitted for class review, contains the information.

Ethical Considerations

The study was carried out under the Declaration of Helsinki's guidelines, and all procedures involving human subjects were approved by the Institutional Review Board (IRB) (IRB ref. #: 19-050E) using ethics forms. With the option to withdraw at any moment, each participant completed a participant consent form. The researchers prepared the participant debriefs and completed the participant consent form themselves. In a private setting, confidentiality and privacy were ensured, and participants' identities were kept private, where no personal information was disclosed.

Data Analysis

Data was entered into the Statistical Package for Social Sciences (SPSS), version 26. Descriptive statistics were used to summarize participants' demographic and clinical characteristics, including means and standard deviations for continuous variables and frequencies and percentages for categorical variables. Age was categorized into predefined age groups to facilitate descriptive presentation.

Regression models were run to conduct inferential analyses of the association of vitamin D status with T2DM. Multivariable models included sociodemographic and lifestyle variables that were available and remained in the final analysis, specifically age, sex, marital status, and educational attainment. Selection was based on previous evidence of these factors' associations with vitamin D status and glycemic outcome and their relevance in this population. Although sun exposure duration, body mass index (BMI), vitamin D supplementation, and the presence of chronic comorbidities are biologically plausible confounders, they were excluded from the final regression models because of data limitations, issues of multicollinearity, or model parsimony. Consequently, in line with the principle of presenting only those variables that have been utilized in the final multivariable analysis, the reporting of regression and tables is carried out only for the variables that go into the final models.

Vitamin D status was classified according to established clinical cut-offs: vitamin D deficiency (<20 ng/mL), insufficiency (20-29 ng/mL), and sufficiency (≥30 ng/mL). The prevalence of vitamin D deficiency was calculated by dividing the number of participants classified as deficient by the total study population and was expressed as a percentage. All statistical tests were two-tailed, with a p-value of < 0.05 considered statistically significant.

Vitamin D intake from diet was measured through the Vitamin D Estimation Only Food Frequency Questionnaire (VIDEO-FFQ). The subjects were able to indicate their dietary intake of vitamin D foods per unit and frequency of consumption for a period of a month. The vitamin D intake was measured in units of micrograms per day (µg/day) and International Units per day (IU/day); 1 µg = 40 IU. The VIDEO-FFQ was validated for moderate levels when compared to food diaries and blood levels of 25(OH)D. This acknowledges that vitamin D levels in blood may be influenced by non-dietary components, such as sunlight exposure (Głąbska et al., 2016; Hribar et al., 2022). Serum vitamin D status was determined by circulating 25-hydroxyvitamin D [25(OH)D], the established circulating biomarker of vitamin D status. Venous blood samples were collected from participants under standardized conditions throughout the study period.

Results

The study recruited 240 participants, of whom almost one third (31.3%, n=71) fell in the age group of 45 years and older. The predominant sex is female (51.2 %, n= 123). Most of the participants (83.3%, n=201) were married. The majority of the study population was from an Asian ethnicity (91.2 %, n=219), while the remaining were from an African ethnicity (8.8 %, n=21). In spite of the existence of illiterate participants (13.8 %, n= 33), there were a large number of educated participants (85.8 %, n= 206). On the other hand, the study population who were unemployed was large (56.3%, n=135) in contrast to those who worked indoors (38.3 %, n=92) or outdoors (5.4 %, n=13).

The majority of the participants (77.5%, n = 185) reported not utilizing supplements, according to the results in Table 2, but some of them utilized supplements frequently (8.3%, n = 20). Although a small percentage (12.1%, n=29) used medications as a source of vitamin D, the majority (63.3%, n=152) of the study population believed that the sun was the primary source of vitamin D, while others (22.1%) thought that food was the primary source of the vitamin. Most of the study participants (63.%, n = 153) were exposed to sunlight. Despite the favorable sun exposure, it was found that a greater proportion of participants (67.9%, n = 163) did not expose their arms and faces in comparison to those who did (31.7%, n = 76).

The majority of participants (45.0 %, n = 108) showed vitamin D deficiency, as shown in Figure 2. Moreover, about one-third (34.2%, n = 82) of the subjects had inadequate vitamin D levels. A comparatively small percentage of the study population (20.8%, n = 50) is in the sufficiency area. Serum vitamin D levels demonstrated a mean concentration of 22.4 ± 8.1 ng/mL, with a median value of 21.8 ng/mL (interquartile range: 16.2-27.6). Based on established cut-off values, the largest proportion of participants exhibited vitamin D insufficiency (45.0%, n = 108), followed by vitamin D deficiency (34.2%, n = 82). Only a minority of the participants (20.8%, n = 50) had sufficient vitamin D levels.

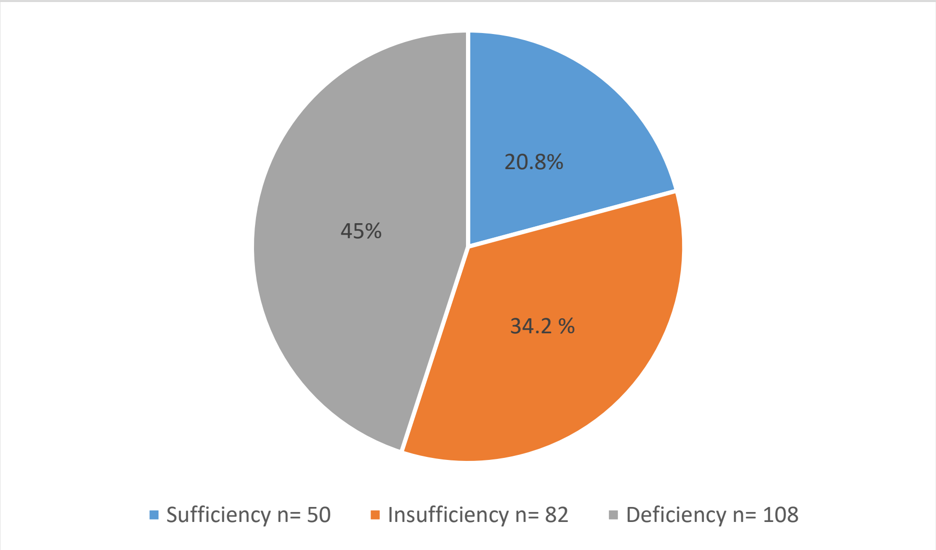

Figure 2. Prevalence of vitamin D intake

The majority of the participants (84.2%, n=202) reported not having diabetes. Among those diagnosed with DM, 32 participants (13.3%) had type 2 diabetes, while only 6 participants (2.5%) had type 1 diabetes.

As shown in Table 1, the largest proportion of the participants were classified as having vitamin D deficiency (45.0%, n = 108), followed by vitamin D insufficiency (34.2%, n = 82), while only 20.9% (n = 50) had sufficient vitamin D levels. Among participants with T2DM, the highest frequency was observed in the vitamin D-deficient group (n = 20), compared with those with insufficiency (n = 8) and sufficiency (n = 4). However, the association between vitamin D status and T2DM was not statistically significant (Pearson χ^2 = 7.11, p = 0.53).

Table 1. Cross-tabulation of vitamin D level and T2DM

			T2DM		
			Yes	No	Total
Vitamin D Level	Sufficiency	Count	4	46	50
		%	1.7	19.2	20.9
	Insufficiency	Count	8	74	82
		%	3.3	30.9	34.2
	Deficiency	Count	20	88	108
		%	8.3	36.7	45.0
	Total	Count	32	208	240
		%	13.3	86.7	100

Note: Pearson chi-square 7.11; P-value 0.53.

Besides, regarding the relationship between vitamin D levels and T2DM, it was observed that among the participants with sufficient vitamin D levels, only 8% had T2DM, while the prevalence slightly increased to 9.8% among those with insufficient vitamin D levels. Notably, the highest proportion of T2DM cases (18.5%) was observed in individuals with vitamin D deficiency. This suggests a possible trend where lower vitamin D levels are associated with higher rates of T2DM. However, the Pearson chi-square value of 7.11 with a p-value of 0.53 indicates that this observed trend is not statistically significant. Therefore, while there appears to be a pattern linking vitamin D deficiency with greater T2DM prevalence, the data does not provide strong enough evidence to confirm a significant association.

Pearson correlation was used to assess the association between vitamin D and sociodemographic factors. It was revealed that a large number (24 %, n= 58) of the common (54.5 %, n= 128) age group (25-44 years) had vitamin D deficiency. Also, it appears that females had more (27.9 %, n= 67) of having vitamin D deficiency than males, with a significant p-value (0.007). The study subjects who are married are better (17.6%, n= 32) in the sufficiency of vitamin D than the unmarried subjects, but at the same time, they are also more (37.6%, n= 89) than the unmarried subjects.

In the domain of education, it was reported that higher education level did not affect the health of vitamin D. The deficiency of vitamin D among graduate participants was (17.2 %, n=41), in contrast to insufficiency of vitamin D, which was (13.4 %, n=32) in the same group, see Table 2.

Table 2. Pearson correlation between sociodemographic variables and vitamin D

			Vitamin D Level					
			Sufficiency	Insufficiency	Deficiency	Total	r	P-value
Age	18-24	Count	5	12	20	37	11.673	0.766
		%	2.1	5	8.3	15.4		
	25-44	Count	29	44	58	128		
		%	12.2	18.3	24	54.5		
	45-60	Count	16	26	33	75		
		%	5.7	10.9	13.8	30.4		
	Total		50	82	108	240		
		Count	20.0	34.2	45.0	100		
Sex	Male	Count	31	45	41	117	14.232	0.007
		%	13	18.8	17.1	48.8		
	Female	Count	19	37	67	123		
		%	7.9	15.4	27.9	51.2		
	Total	Count	50	82	108	240		
		%	20.7	34.2	45	100		
Marital Status	Single	Count	4	6	13	23	11.031	0.808

		%	1.7	2.5	5.4	9.6		
	Married	Count	42	70	89	201		
		%	17.6	29.5	37.6	84.8		
	Divorced	Count	2	1	3	6		
		%	0.8	0.4	1.3	2.5		
	Separated	Count	0	0	3	3		
		%	0.0	0.0	1.3	1.3		
	Widowed	Count	0	4	3	7		
		%	0.0	1.7	1.3	3.0		
	Total	Count	48	81	108	240		
		%	20.1	34.1	45	100		
Education	No Education	Count	6	10	17	33	14.085	0.826
		%	2.5	4.2	7.1	13.8		
	Primary	Count	19	17	23	59		
		%	7.9	7.1	9.6	24.6		
	Secondary	Count	12	17	23	52		
		%	5	7.1	9.6	21.8		
	Graduate	Count	20	32	41	93		
		%	8.4	13.4	17.2	38.9		
	Postgraduate	Count	2	0	1	3		
		%	0.8	0.0	0.4	1.3		
	Total	Count	42	64	86	240		
		%	17.5	26.8	36	100		

On the other side, a cross-tabulation was used to assess the relationship between T2DM and sociodemographic factors. The results revealed statistically significant associations between type 2 diabetes mellitus (T2DM) and several sociodemographic variables. A significant relationship was found between age and T2DM (χ^2 = 58.081, p = 0.000), with the highest prevalence of T2DM observed in the 45-60 years' age group (10.8%), compared to 2.5% in the 25-44 years' age group and 0.0% in the 18-24 years' age group. Marital status was also significantly associated with T2DM (χ^2 = 16.744, p = 0.033); the majority of T2DM cases were among married individuals (11.0%), while no cases were reported among single or separated individuals. A strong and significant association was also noted between education level and T2DM (χ^2 = 50.879, p = 0.000); individuals with no education had the highest prevalence (6.3%), whereas those with graduate (2.5%) and postgraduate (0.4%) education showed much lower prevalence. In contrast, sex was not significantly associated with T2DM (χ^2 = 1.334, p = 0.513), indicating a similar distribution of T2DM among males (7.5%) and females (5.8%), see Table 3.

Table 3. Cross-tabulation of T2DM and sociodemographic factors

			T2DM		Total	Chi-square χ^2	P-value
			Yes	No			
Age	18-24	Count	0	34	34	58.081	0.000*
		%	0.0	14.2	14.2		
	25-44	Count	6	125	131		
		%	2.5	52.1	54.6		
	45-60	Count	26	49	75		
		%	10.8	20.4	31.2		
	Total		32	208	240		
		Count	13.3	86.7	100		

Sex	Male	Count	18	99	117	1.334	0.513
		%	7.5	41.2	48.8		
	Female	Count	14	109	123		
		%	5.8	45.5	51.2		
	Total	Count	32	208	240		
		%	13.3	86.7	100		
Marital Status	Single	Count	0	20	20	16.744	0.033*
		%	0.0	8.4	8.4		
	Married	Count	26	175	201		
		%	11.0	73.8	84.8		
	Divorced	Count	3	3	6		
		%	1.3	1.3	2.5		
	Separated	Count	0	3	3		
		%	0.0	1.3	1.3		
	Widowed	Count	3	4	7		
		%	1.3	1.7	3.0		
	Total	Count	32	205	237		
		%	13.5	86.5	100		
Education	Illiterate	Count	15	18	33	50.879	0.000*
		%	6.3	7.5	13.8		
	Primary	Count	1	10	11		
		%	0.4	4.2	4.6		
	Secondary	Count	5	47	52		
		%	2.1	19.7	21.8		
	Graduate	Count	6	87	93		
		%	2.5	36.4	38.9		
	Postgraduate	Count	1	2	3		
		%	0.4	0.8	1.3		
	Total	Count	31	208	239		
		%	13.0	87.0	100		

P-value statistically significant at ≤0.05.

As shown in Table 4, the results of the multivariate logistic regression analysis examining the association between sociodemographic variables and vitamin D deficiency revealed that sex was a significant predictor, after adjusting for age, marital status, and education level. Specifically, females had higher odds of vitamin D deficiency compared to males (OR = 2.084; 95% CI: 1.223-3.549, $p < 0.001$). Although age (OR = 1.05; 95% CI: 0.95-1.15, $p > 0.05$), marital status (OR = 0.98; 95% CI: 0.62-1.54, $p > 0.05$), and education level (OR = 0.94; 95% CI: 0.65-1.35, $p > 0.05$) were included as covariates due to their potential confounding effects, they were not significantly associated with vitamin D deficiency. The model explained approximately 14% of the variance in vitamin D deficiency ($R^2 = 0.14$), suggesting that other factors may also contribute.

Similarly, in the multivariate logistic regression analysis examining type 2 diabetes mellitus (T2DM), age emerged as a significant predictor after adjusting for sex, marital status, and education level. Older individuals had over four times the odds of developing T2DM compared to younger participants (OR = 4.126; 95% CI: 2.519-6.758, $p < 0.001$). In contrast, sex (OR = 1.05; 95% CI: 0.78-1.41, $p > 0.05$), marital status (OR = 1.10; 95% CI: 0.73-1.65, $p > 0.05$), and education level (OR = 0.89; 95% CI: 0.61-1.30, $p > 0.05$) were not significantly associated with T2DM. The overall model accounted for 14% of the variance in T2DM status (R^2=0.14), highlighting that while age is a key determinant, other unmeasured factors may also influence disease risk.

Table 4. Multivariate logistic regression for sociodemographic factors with vitamin D deficiency and T2DM

Variables and vitamin D	Wald Chi-square	SE	df	Odds Ratio	95% CI of OR	
					Lower	Upper
Constant	1.519***	0.734	1			
Age	0.097***	0.114	1	1.036	0.829	1.294
Sex	7.302***	0.272	1	2.084	1.223	3.549
MS	0.013*	0.187	1	0.979	0.678	1.413
Education	0.036*	0.075	1	0.986	0.851	1.141
Variables and T2DM						
Constant	22.624***	1.420	1	.001		
Age	31.701***	0.252	1	4.126	2.519	6.758
Sex	0.022*	0.465	1	0.934	0.375	2.322
MS	0.221***	0.342	1	0.852	0.436	1.664
Education	0.639***	0.131	1	1.110	0.859	1.435

n = 240, ***P > 0.05, **P<0.001 *P<0.05. R2 = 14%.

Discussion

This article points out a possible link between a deficiency in vitamin D and the prevalence of T2DM, emphasizing how certain sociodemographic factors may be involved in this problem, particularly within Tabarjal Province in Saudi Arabia.

However, this study clearly showed that roughly one-third of the population analyzed is either 45 years old or older, though the majority of this group could be attributed to the younger population, thereby making this group predominantly working and actively involved. Furthermore, this population is predominantly female and married. However, married status, as analyzed in this study, is not significantly related to the deficiency in vitamin D. These pieces of evidence clearly show that married status by itself is not an attributing factor for the prevalence of this deficiency. Furthermore, this particular study group is predominantly Asian and well-educated, as well as unemployed, as per the government. These particular findings are similar to those reported by Hovsepian et al. (2011). They clearly elaborated that the deficiency of vitamin D is prevalent in the adult population in the city of Isfahan, particularly among women, as well as among the younger generation, thereby showing that this particular deficiency required supplementation in case sun exposure is not possible, such as when cloth requirements are to be adhered to.

The current study disclosed that a considerable proportion of the population failed to use vitamin D supplements, and such a finding aligns with a study by Alhamed et al. (2024), where a lack of necessity or awareness contributes to low compliance regarding the use of vitamin D supplements among young adults in Saudi Arabia. A study by Al-Qudah et al. (2023) in Jordan indicated that even though the prevalence rates of the deficiency show a considerable level of inadequacy, the use of supplements remained poor, especially among males and those of a lower level of education.

This is quite uncompensated and might be attributed to a misconception that natural sources are adequate, even though some human practices, like dressing habits and restricting exposure of the skin, are factors that overcome the effective synthesis of vitamin D. As evident, Grant et al. (2020) mentioned that even though Middle Eastern nations receive great amounts of sunlight, vitamin D deficiency is quite evident.

This research found that there was an excess of T2DM compared to T1DM in the participants, which was also supported by literature across the world and in this region. T2DM is still most prevalent in terms of diabetes, especially in the Middle Eastern population, owing to the increasing incidence of sedentary lifestyle, obesity, and advancing age (Lawrence et al., 2021). In addition, this study noted the possible relationship between low levels of vitamin D and the increased prevalence of Type 2 Diabetes Mellitus (T2DM); yet, this relationship was not found to be statistically significant in the present study. Although the results showed the possible relationship, the data does not support the existence of a significant relationship between vitamin D deficiency and T2DM. However, the results are in line with the emerging evidence that vitamin D could affect insulin sensitivity and glucose regulation. For instance, Contreras-Bolívar et al. (2021) found that vitamin D is involved in the regulation of pancreatic β-cell function and insulin sensitivity, which could be a contributing factor to the development of T2DM.

In the present study, crude data indicated tendencies of variable vitamin D levels by age groups; however, age did not independently predict the deficiency of vitamin D after adjustment for variables of sociodemographic and lifestyle factors. Although there was a statistically significant association between younger adults aged 25-44 years and vitamin D levels after adjustment, it failed to achieve significance in the multivariable model. This data appears consistent with reports suggesting that, based on the findings of studies carried out in regions considered to be of a Middle-Eastern background, work patterns and lifestyles suggestive of younger adults remaining indoors with minimal sun exposure may affect vitamin D levels; however, age itself fails to independently predict differences of vitamin D deficiency after adjustment for certain variables (Alfredsson et al., 2020; Shahudin et al., 2020).

There was a considerable difference in the result among sexes, with a larger number of females experiencing a higher prevalence of vitamin D deficiency than males. The result supports the study carried out by Al Ghafri et al. (2025), which showed that a substantial number of females experience a higher prevalence of vitamin D deficiency compared to males.

Regarding marital category, the findings indicated that married people reported a mix of both slightly higher and lower levels of vitamin D sufficiency compared to the unmarried group, though they also represented the larger proportion of those who are vitamin D-deficient. There is very little information available in the literature regarding married/ unmarried as predicting variables for vitamin D levels, though some research indicates that married persons could have healthier habits as a result of shared activities and responsibilities (Wang et al., 2020). This study demonstrated statistically significant associations between T2DM and multiple sociodemographic variables, particularly age, marital status, and education level, while sex showed no significant association. These results align with a substantial body of literature identifying older age, lower education, and certain social determinants as major risk factors for T2DM. The strong association between age and T2DM, with the highest prevalence among older adults, reflects the natural progression of metabolic dysfunction over time. This finding is widely supported by epidemiological data, including the International Diabetes Federation (Ceriello & Colagiuri, 2025), which shows that T2DM incidence rises sharply after the age of 40 years due to cumulative exposure to risk factors, such as physical inactivity, poor diet, and increasing insulin resistance.

Marital status was also significantly associated with T2DM, with a higher prevalence among married individuals. Although marriage is generally associated with better health outcomes, this association might be context-dependent. Married individuals may have more stable lifestyles, but they may also experience weight gain and reduced physical activity over time. This finding was in line with a study performed by Wang et al. (2020), who suggested that married adults are more likely to develop lifestyle-related chronic diseases, particularly in environments with poor dietary habits or limited physical activity. In contrast, this study denied the significance of sex with T2DM supporting mixed evidence in the literature. While some studies reported a slightly higher prevalence among males, often due to higher rates of central obesity and smoking, others found no significant difference between sexes after controlling for lifestyle and socioeconomic variables. This suggests that, when adjusted for other risk factors, sex may not be an independent predictor of T2DM in many populations, including the studied sample.

On the other hand, the current study revealed that sex was a significant predictor of vitamin D deficiency, with females having more than twice the odds of being deficient compared to males. This finding is strongly supported by Al-Daghri et al. (2022) who reported that vitamin D deficiency among females is widely attributed to cultural practices, such as clothing styles that limit skin exposure to sunlight, lower levels of outdoor physical activity, and dietary inadequacies.

In contrast, age, marital status, and education level were not statistically significant predictors of vitamin D deficiency in the adjusted model. While bivariate analyses often show associations between these variables and vitamin D status, their effects may diminish after controlling for confounding factors. For instance, although older age is sometimes associated with lower vitamin D levels due to reduced skin synthesis capacity, behavioral factors, like supplement use or sun exposure, may offset this risk (Saleem et al., 2021). Similarly, education level and marital status may not directly influence vitamin D status if they do not lead to healthier behaviors or improved health literacy in the population studied.

Conversely, sex, marital status, and education level were not significant predictors of T2DM in the regression model. While lower education and marital status may correlate with T2DM risk in unadjusted analyses, their influence can weaken when accounting for age and other variables. This reflects findings from large-scale studies such as the PURE study performed by Hystad et al. (2020), which showed that behavioral and lifestyle factors often mediate the relationship between sociodemographic variables and chronic disease outcomes.

Even though the current study did not find a significant correlation between vitamin D deficiency and T2DM, when taken separately, each condition poses a significant social and financial burden. A lack of vitamin D is linked to a higher risk of musculoskeletal disorders, decreased functional ability, and increased use of healthcare services, all of which raise medical expenses and reduce productivity (Chevalley et al., 2022). In the same line, T2DM has a well-established financial burden due to long-term complications, frequent medical visits, medication use, and disability, all of which put a strain on healthcare systems and have an impact on workforce participation (Malkawi & Bani Hani, 2025). So, effective public health planning, resource allocation, and population-level preventive strategies continue to depend on acknowledging and addressing the separate burden of vitamin D deficiency and type 2 diabetes mellitus.

Strengths and Limitations

The main strength of the study lies in the strong epidemiologic design. Because of its design, the study could very easily perform a detailed analysis on the primary data of various variables. A longer period of the study and cost effectiveness are additional advantages of the study. Moreover, the use of a recognized unit of data measurement, viz. Vitamin D Estimation Only-Food Frequency Questionnaire (VIDEO-FFQ), to collect data on the intake of vitamin D solely on the basis of the food frequency, is a strength of the study.

Despite the above strengths of the work, several limitations need to be addressed. Firstly, time and distance factors associated with the visit between the six PHCCs, particularly when the researchers have the same work hours, can pose difficulties for data collection. Secondly, despite using a validated method (video-FFQ), it is less frequently used in the region and hence requires written translation or clarification for some of the participants. The mentioned difficulties can lead to participant attrition and can potentially affect the quality of the responses obtained and received. Furthermore, a cross-sectional study findings using the method of convenience sampling may pose a threat to the generalizability of the study findings and may potentially result in the under- or over-estimation of the rates of vitamin D and T2DM. Finally, the study did not apply any analyses of the data from a perspective of gender differences or the age group and the supplements used, because of the limited sample size of the study and the fact that it may pose certain limitations due to statistical power. Such analyses may need to be addressed by future studies using the same approach, but potentially larger samples.

Although there is very informative data about the magnitude of vitamin D deficiency and T2DM, as well as about the contributing factors, in adults visiting Tabarjal primary health care facilities, one has to be cautious about generalizing these findings at a broader population level. Some aspects could be made representative through non-probability sampling, and there is a focus on a particular city. However, the socio-demographics of a particular sample seem very similar to data found in various Saudi Arabian regions, and hence, there could be a few commonalities between this population and others at a national level. Additionally, because Middle Eastern nations tend to be similar in lifestyle elements, food patterns, and environmental influences, this data could also project an initial picture of a particular pattern at a Middle Eastern nation level, but this does not seem particularly surprising.

Implications for Nursing

This particular research emphasizes the need for evidence-based nursing practice in the primary healthcare environment. Given that this research found that there was no significant relation between vitamin D deficiency and type 2 diabetes mellitus, the need for routine vitamin D testing among individuals with T2DM does not exist. Yet the focus of NPs ought to be on the evaluation for vitamin D deficiency among the broader adult populations based on specified risk factors. Additionally, education for patients regarding nutritional and sun exposure practices ought to continue.

Conclusion

The results from this study showed that sex was the only significant predictor in obtaining vitamin D deficiency in the model, while others, such as age, marital status, and education level, were not statistically significant. The outcomes from this study emphasize the importance and need to develop strategies in targeting higher-risk groups based on sex and overall strategies aimed at improving vitamin D levels in the whole adult Saudi Arabian population. These strategies may include strategies aimed at safe sun exposure and nutritional fortification programs to decrease vitamin D deficiency and related outcomes in the community. Type 2 diabetes mellitus was not shown to be related to vitamin D deficiency in this study; however, both diseases have a high prevalence and therefore both of them remain to be closely monitored and investigated.

Future studies should adopt longitudinal approaches to examine further the possible link between vitamin D levels and type 2 diabetes mellitus while controlling for other variables. In addition, assessing the efficacies of vitamin D interventions in tackling these matters will also help in formulating evidence-based public-health policies to enhance overall health outcomes in Saudi Arabia.

Ethical Approvals and Participation Consent

The study had ethical approval from each involved clinical setting. All the participants were assured that participation in the study was voluntary. Data collection was initiated after obtaining ethical approvals for the study. Procedures were strictly aligned with applicable standards and laws, including the Declaration of Helsinki. Informed consent to participate was obtained from all the study participants. A self-reported questionnaire was used to collect data.

Data Availability

The datasets generated during and/or analyzed in the current study are available from the corresponding author upon reasonable request.

Conflict of Interests

All authors have no conflict of interests to declare.

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Authors' Contributions

Study Design: **BEAM**. Data Collection: **BEAM, EAA**. Data Analysis: **AQR**. Study Supervision: **SBH**. Manuscript Writing: **SBH**. Critical Revisions for Important Intellectual Content: **SBH**.

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