JOURNAL OF INTERNATIONAL CRISIS AND RISK COMMUNICATION RESEARCH
ISSN: 2576-0017
2024, VOL 7, NO S11

Assessing the Correlation Between HbA1c Levels and Vitamin D in Patients at Khamis Mushait General Hospital: A Cross-Sectional Study

Mohammed jaber Mohammed Al-Helali[1], Saeed Awad Alqahtani[1], Rahaf Alamri[2], Yousef Deafuallh Saeed Alasmri[3], Abdulrahman Bin Saeed Alqahtani[4], Abdulrahman Saad Alasmri[5], Abdullah Mohammed Alshahrani[5], Aishah Mohammed Alammari[6], Mohammed Naseer Al-Shahrani[3], Maram Aseri[2]

1. MBBS, SBIM, ED, Khamis Mushait general hospital - Internal medicine - Endocrinology department
2. BPH, King Khalid University – Public Health Departments
3. MLS, Khamis Mushait general hospital – laboratory departments
4. BPH, MPH, Khamis Mushait general hospital – Public Health Departments
5. BPH, Khamis Mushait general hospital – Public Health Departments
6. BPH, Khamis Mushait general hospital – Quality and patient safety departments

ABSTRACT

Introduction: This cross-sectional study explores the correlation between HbA1c levels and Vitamin D status and inflammatory markers, particularly C-reactive protein (CRP), in adult patients among patients at Khamis Mushait General Hospital in Saudi Arabia. With the high prevalence of both diabetes and Vitamin D deficiency in the region, understanding this relationship is crucial for improving diabetes management and patient outcomes. Vitamin D plays and inflammatory markers, particularly C-reactive protein (CRP) play a significant role in glucose metabolism, influencing insulin secretion and sensitivity. Prior studies suggest that higher Vitamin D levels or supplementation can improve glycemic control and lower HbA1c levels, although results have varied.

Methodology: Data will collected from diabetic patients attending the hospital in outpatients medical clinics throw interview and laboratory data is obtained from patients Electronic file, including serum 25-hydroxyvitamin D levels and HbA1c measurements and inflammatory markers, particularly C-reactive protein (CRP). The study employed appropriate statistical methods to analyze the data and determine the strength and significance of the correlation between these variables.

Results: The study analyzed data from 391 participants, revealing a mean height of 1.64 meters, weight of 67.43 kg, and BMI of 24.96. The average HbA1c level was 6.95 mmol/L, and the mean 25-hydroxyvitamin D level was 38.05 ng/mL. Pearson correlation showed significant relationships: higher Vitamin D levels correlated with lower HbA1c ($r = -0.34$), while higher BMI ($r = 0.32$) and older age ($r = 0.35$) correlated with higher HbA1c. ANOVA analysis confirmed significant associations between HbA1c and variables like age, marital status, employment, education, BMI, and smoking status. Logistic regression indicated that age, marital status, lower vitamin D,

retirement, and higher BMI were significant predictors of high HbA1c levels. These findings emphasize the impact of demographic, socioeconomic, and lifestyle factors on HbA1c levels.

Conclusion: The findings indicate a significant negative correlation between Vitamin D levels and HbA1c, suggesting that higher Vitamin D levels are associated with better glycemic control. These results underscore the potential benefits of incorporating Vitamin D assessment and supplementation into diabetes management protocols. The study recommends routine Vitamin D screening for diabetic patients and public health campaigns to address Vitamin D deficiency.

KEYWORDS: HbA1c, Vitamin D, diabetes management, Khamis Mushait, Saudi Arabia, glycemic control, public health.

1. Introduction

The interplay between vitamin D and glycemic control has gained significant interest in recent years due to emerging evidence suggesting that vitamin D deficiency may influence glucose metabolism and overall diabetes management. Haemoglobin A1c (HbA1c) is a key biomarker used to assess long-term glycemic control in individuals with diabetes, reflecting average blood glucose levels over a period of approximately three months (American Diabetes Association, 2022). Vitamin D, a fat-soluble vitamin essential for bone health and metabolic processes, has also been implicated in the regulation of insulin secretion and sensitivity (Parker et al., 2010).

Vitamin D's role in glucose homeostasis has been a subject of considerable research. It is known that vitamin D receptors are present in pancreatic beta cells, which are responsible for insulin production. Some studies suggest that vitamin D may enhance insulin sensitivity and secretion, thereby potentially affecting HbA1c levels (Pittas et al., 2007). Low vitamin D levels have been associated with insulin resistance and an increased risk of type 2 diabetes (Zheng et al., 2013). However, the exact mechanisms and the strength of the association between vitamin D levels and HbA1c are still not fully understood and may vary across different populations.

In the context of Saudi Arabia, where there is a high prevalence of diabetes and a significant proportion of the population experiences vitamin D deficiency, understanding the relationship between HbA1c and vitamin D levels is particularly pertinent. The geographic and climatic conditions in Saudi Arabia contribute to lower levels of vitamin D due to limited sun exposure, which may affect the general population's glycemic control (Amin et al., 2016). A cross-sectional study conducted at Khamis Mushait General Hospital aims to elucidate this relationship within a local context, contributing valuable insights that may influence clinical practice and public health strategies.

Conducting this study at Khamis Mushait General Hospital provides a unique opportunity to assess the correlation between HbA1c and vitamin D levels within a specific patient population. This cross-sectional study will help in identifying any significant associations and provide a foundation for further longitudinal studies that could explore causality. Such research can guide targeted interventions, such as

vitamin D supplementation, which may improve glycemic control and overall diabetes management.

Furthermore, the implications of the HbA1c and vitamin D relationship extend beyond diabetes management to broader public health concerns. Vitamin D deficiency is a global issue, affecting diverse populations regardless of age, ethnicity, or geographic location (Holick, 2007). This deficiency is often exacerbated by modern lifestyles that limit sun exposure and by dietary patterns that do not provide adequate vitamin D. In light of the potential link between vitamin D levels and glycemic control, public health initiatives aimed at increasing vitamin D awareness and supplementation could have far-reaching benefits. These initiatives might include fortifying foods with vitamin D, promoting safe sun exposure, and encouraging regular screening for vitamin D levels, particularly in at-risk groups such as the elderly, individuals with limited sun exposure, and those with darker skin. By addressing vitamin D deficiency on a population level, it may be possible to reduce the incidence and severity of diabetes, improve overall metabolic health, and alleviate some of the healthcare burdens associated with chronic diseases (Mithal et al., 2009).

Problem Statement:

Despite the well-documented role of vitamin D in various metabolic processes, including glucose metabolism, the correlation between vitamin D levels and HbA1c—a critical marker for glycemic control in diabetes—remains inadequately explored, especially within specific regional contexts. In Saudi Arabia, where vitamin D deficiency is prevalent due to limited sun exposure and dietary factors, understanding this relationship is crucial for improving diabetes management. At Khamis Mushait General Hospital, preliminary observations suggest a potential link between low vitamin D levels and poor glycemic control. This study aims to investigate the correlation between HbA1c and vitamin D levels among patients at this hospital to provide insights that could enhance clinical practices and public health strategies in managing diabetes and vitamin D deficiency.

Research questions:

1. What is the correlation between HbA1c levels and serum vitamin D levels in patients at Khamis Mushait General Hospital?

2. Is there a significant difference in HbA1c levels between patients with sufficient and insufficient vitamin D levels?

3. What is the prevalence of vitamin D deficiency among patients with poorly controlled diabetes (high HbA1c) compared to those with well-controlled diabetes (low HbA1c)?

4. How do demographic factors (e.g., age, sex, and BMI) influence the relationship between HbA1c and vitamin D levels in the study population?

2. Literature Review

2.1 Overview of HbA1c

Hemoglobin A1c (HbA1c) is a critical biomarker for assessing long-term glucose

control in individuals with diabetes. HbA1c measures the percentage of hemoglobin that is glycated due to chronic exposure to elevated glucose levels over the previous 2-3 months (American Diabetes Association, 2022). It provides a reliable indication of average blood glucose levels and is used extensively to monitor diabetes management and predict the risk of diabetes-related complications. Elevated HbA1c levels are associated with an increased risk of complications such as retinopathy, nephropathy, and cardiovascular disease (Inzucchi et al., 2015). Optimal management of HbA1c aims to maintain levels as close to normal as possible to reduce these risks. According to recent guidelines, an HbA1c level below 7% is generally recommended for most adults with diabetes to achieve better health outcomes and minimize the risk of complications (American Diabetes Association, 2022).

2.2 Vitamin D and HbA1c exposure

Vitamin D, particularly in its active form, Vitamin D3, plays a role in various physiological processes, including bone health and immune function. Recent research has highlighted its potential impact on glucose metabolism and insulin sensitivity (Pittas et al., 2007). In our study, the exposure of interest is Vitamin D3 levels, while the outcome is HbA1c levels. Low levels of Vitamin D have been implicated in impaired insulin secretion and increased insulin resistance, which can lead to elevated HbA1c levels (Parker et al., 2010). Understanding the relationship between these variables is crucial as Vitamin D deficiency is prevalent in many populations and may contribute to suboptimal glycemic control. Investigating this relationship could provide insights into the role of Vitamin D in diabetes management.

2.3 The Impact of Vitamin D on HbA1c

The impact of Vitamin D on HbA1c levels has been a subject of considerable research. Studies suggest that adequate Vitamin D levels may improve insulin sensitivity and reduce HbA1c levels. For instance, Pittas et al. (2007) found that Vitamin D supplementation was associated with improved glycemic control and

reduced HbA1c levels in individuals with type 2 diabetes. Similarly, Zheng et al. (2013) reported that higher Vitamin D levels were linked to a lower risk of developing type 2 diabetes, which is often characterized by elevated HbA1c levels. However, findings are not uniformly consistent, with some studies indicating only a modest effect of Vitamin D on HbA1c (Binker et al., 2015). These variations highlight the complexity of the relationship and underscore the need for further investigation to clarify how Vitamin D status may influence long-term glycemic control.

2.4 Importance of Screening for Vitamin D or HbA1c

Screening for Vitamin D deficiency and monitoring HbA1c levels are important for effective diabetes management. Given the high prevalence of Vitamin D deficiency, particularly in regions with limited sun exposure, routine screening can identify individuals at risk and enable early intervention (Amin et al., 2016). Early detection of Vitamin D deficiency allows for timely supplementation, which may improve glycemic control and overall health outcomes. Similarly, regular monitoring of HbA1c is essential for assessing diabetes management and adjusting treatment plans to prevent complications. Integrating screening for both Vitamin D and HbA1c into routine care could provide a more comprehensive approach to diabetes management

and potentially improve patient outcomes.

2.5 Management of Vitamin D and HbA1c

Management of Vitamin D deficiency typically involves dietary modifications, increased sun exposure, and Vitamin D supplementation (Holick, 2007). The appropriate dosage and duration of supplementation depend on individual needs and baseline Vitamin D levels. For managing HbA1c, treatment strategies include lifestyle modifications such as diet and exercise, as well as pharmacological interventions to achieve optimal glycemic control (Inzucchi et al., 2015). Combining Vitamin D supplementation with effective diabetes management practices may offer synergistic benefits, particularly if Vitamin D deficiency is contributing to poor glycemic control. Personalized treatment plans should consider both Vitamin D status and HbA1c levels to optimize diabetes care.

2.6 Gap in Literature and Rationale for Current Study

While existing research has explored the relationship between Vitamin D and HbA1c, significant gaps remain, particularly in specific regional populations. The majority of studies have focused on Western populations, with limited data from the Middle East, including Saudi Arabia. The high prevalence of Vitamin D deficiency in Saudi Arabia and its potential impact on glycemic control highlights the need for region-specific research. This study aims to address this gap by investigating the correlation between Vitamin D levels and HbA1c in patients at Khamis Mushait General Hospital. By focusing on this specific population, the study seeks to provide localized insights that could inform tailored interventions and improve diabetes management strategies in the region.

3. Methodology

3.1 Aim:

The aim of this study is to evaluate the correlation between HbA1c and Vitamin D levels in patients at Khamis Mushait General Hospital. By investigating this relationship, the study seeks to provide insights into how Vitamin D status may influence glycemic control.

3.2 Objectives:

1. To assess the correlation between HbA1c and serum Vitamin D levels in patients.

2. To compare HbA1c levels between patients with sufficient and insufficient Vitamin D.

3. To evaluate the prevalence of Vitamin D deficiency among patients with varying levels of HbA1c.

4. To analyze the impact of demographic factors on the HbA1c-Vitamin D relationship.

3.3 Study Rationale:

Vitamin D is hypothesized to influence glycemic control, yet evidence is mixed.

Understanding this correlation in a local context where Vitamin D deficiency is common can help refine diabetes management practices and public health interventions specific to the region.

3.4 Study Setting:

The study will be conducted at Khamis Mushait General Hospital, located in Khamis Mushait, Saudi Arabia. This setting provides a diverse patient population suitable for investigating the relationship between Vitamin D levels and HbA1c.

3.5 Sample Size Calculation:

Sample size will be calculated using power analysis to ensure sufficient statistical power to detect meaningful correlations. An estimated sample size of 391 participants will be targeted to achieve robust and reliable results, accounting for potential dropouts and missing data.

3.6 Sampling Techniques:

A systematic random sampling technique will be employed to ensure representation across different patient demographics (e.g., age, sex, diabetes status). Patients will be randomly selected from hospital clinics wating list , ensuring a diverse sample reflective of the general population attending the hospital.

3.7 Research Instrument:

The primary research instruments include laboratory tests for HbA1c and Vitamin D levels. A structured questionnaire may also be used to collect demographic and health-related information from participants.

3.8 Data Collection Plan:

• Step 1: Recruitment of Participants

Patients will be identified from hospital clinics list and contacted for participation based on inclusion criteria.

• Step 2: Informed Consent

Participants will be provided with detailed information about the study and required to give written informed consent before participating.

• Step 3: Administration of Questionnaire

Participants will complete a questionnaire covering demographic details and health history, which will be administered by trained personnel.

• Step 4: Collection of Additional Data

HbA1c and Vitamin D levels will be obtained from routine laboratory tests or additional blood samples collected during routine visits.

• Step 5: Data Recording and Storage

Data will be recorded in a secure electronic database, ensuring confidentiality and accuracy of information.

• Step 6: Regular Data Review

Ongoing review of data will be conducted to identify and address any discrepancies or missing information.

• Step 7: Data Collection Completion

Upon completion of data collection, final checks will be made to ensure all required data has been gathered and recorded.

3.9 Data Analysis Plan:

The data collected from this study will be meticulously analyzed using appropriate statistical methods.

1. Data Preparation: First, the data will be entered into a suitable statistical software package, STAT. It will be checked for missing data and outliers, and data cleaning will be performed if necessary.

2. Descriptive Statistics: Descriptive statistics, including means, standard deviations, and frequencies, will be used to summarize demographic characteristics and key variables.

3. Main Outcome: The correlation between HbA1c and Vitamin D levels will be assessed using Pearson's correlation coefficient or Spearman's rank correlation, depending on data distribution.

4. Inferential Statistics: Comparative analysis between different groups (e.g., sufficient vs. insufficient Vitamin D) will be conducted using t-tests or Mann-Whitney U tests for continuous variables.

5. Multivariate Analysis: Multiple linear regression will be used to evaluate the relationship between HbA1c and Vitamin D levels while controlling for potential confounders such as age, sex, and BMI.

6. Significance Testing: Statistical significance will be assessed using a significance level of 0.05. p-values will be reported to determine the strength of associations.

7. Reporting of Results: Results will be reported with appropriate tables and graphs, detailing correlations, comparisons, and statistical significance. Findings will be discussed in the context of existing literature.

3.10 Inclusion and Exclusion Criteria:

• Inclusion Criteria:

1. Adult patients aged 18 and above.

2. Patients with available recent HbA1c and Vitamin D test results.

3. Patients willing to provide informed consent.

• Exclusion Criteria:

1. Patients with incomplete data on HbA1c or Vitamin D levels.

2. Patients with conditions affecting Vitamin D metabolism (e.g., severe liver or

kidney disease).

3. Patients currently taking high doses of Vitamin D supplements.

These criteria will ensure the study focuses on a relevant and homogeneous patient population, leading to accurate and generalizable findings.

3.11 Study Strengths & Limitations:

• Study Strengths:

The study's strengths include a well-defined setting, the use of standardized lab tests, and a robust sampling technique ensuring diverse representation. The focus on a specific hospital allows for detailed, localized insights.

• Study Limitations:

Limitations may include potential selection bias due to the hospital setting, reliance on cross-sectional data which limits causal inferences, and the variability in laboratory testing methods that could affect results.

3.12 Ethical Approval:

The Ministry of Health ethics committee and the research committee granted ethical permission. The research procedure adhered to the current ethical requirements (Edinburgh, 2000). After completing the questionnaire, the participants agreed to participate in the study with written informed consent and waived their right to withdraw at any time Conflict of Interest declaration: The authors declare that they have NO affiliations with or involvement in any organization or entity with any financial interest in the subject matter or materials discussed in this manuscript.

4. Results

Table 1: Sociodemographic characteristics of the participants (n = 391)

Variables		No (%)
Age, Years	Mean± SD	43.98465 16.6171
	19-30	95 (24.30%)
	31-40	92 (23.53%)
	41-50	71 (18.16%)
	51-60	69 (17.65%)
	61+	64 (16.37%)
Gender	male	145 (37.08%)
	Female	246 (62.92%)
Marital status	Single	82 (20.97%)
	Married	258 (65.98%)
	Divorced	25 (6.39%)
	Widow	26 (6.65%)
Education	Illiterate	36 (9.21%)
	Primary	64 (16.37%)
	Secondary	72 (18.41%)
	High school	103 (26.34%)
	Bachelor and above	107 (27.37%)
	Post-Grad	9 (2.30%)

Employment	Government	119 (30.43%)
	Private	40 (10.23%)
	Self-employed	53 (13.55%)
	Retired	30 (7.67%)
	Not working	149 (38.11%)
Income, SR	<5000	241 (61.64%)
	<10000	91 (23.27%)
	>10000	59 (15.09%)

"Table 1" includes 391 participants with a mean age of 43.98 years, where 37.08% were male and 62.92% were female. The age groups ranged from 19 to over 61 years. Most participants were married (65.98%), followed by singles (20.97%). Educationally, the majority had at least a high school education, with 27.37% holding a bachelor's degree or higher. Employment varied, with significant portions in government jobs (30.43%) and a notable number not working (38.11%). Income levels showed that the majority (61.64%) earned less than SR 5000 per month. These diverse sociodemographic factors are crucial for interpreting the relationship between HbA1c and Vitamin D levels.

Table 2: Clinical characteristics of the participant (n=391)

Variable	Mean ± SD
Height, (m)	1.64 ± 0.079
Weight, kg	67.43 ± 13.84
Mean Body Mass Index (BMI)	24.96 ± 4.54
Glycated Haemoglobin (HbA1c), mmol/L	6.95 ± 1.57
25-hydroxyvitamin D , ng/ml	38.05 ± 22.59

In "table 2" the 391 participants had a mean height of 1.64 meters and a mean weight of 67.43 kg, resulting in a mean BMI of 24.96. The mean glycosylated hemoglobin (HbA1c) level was 6.95 mmol/L, and the mean 25-hydroxyvitamin D level was 38.05 ng/mL. These metrics offer a snapshot of the participants' physical health, aiding in the analysis of the relationship between HbA1c and Vitamin D levels.

Table 3: Pearson correlation (R) analysis between the explanatory variables

(n = 391)

	(HbA1c), mmol/L	25-h D , ng/ml	BMI kg/m2	Age Year
(HbA1c), mmol/L	1.00			
25-h D , ng/ml	-0.34 0.00	1.00		
BMI kg/m2	0.32 0.00	-0.12 0.01	1.00	
Age Year	0.92 0.00	-0.31 0.00	0.35 0.00	1.00

Pearson correlation analysis in "table 3" showed a negative correlation between HbA1c and 25-hydroxyvitamin D levels (r = -0.34), indicating that higher Vitamin D levels are associated with lower HbA1c levels. Additionally, BMI showed a positive correlation with HbA1c (r = 0.32) and age (r = 0.35), suggesting that higher BMI and older age are associated with higher HbA1c levels. There was also a negative correlation between 25-hydroxyvitamin D and age (r = -0.31). These correlations highlight the interplay between Vitamin D, BMI, age, and HbA1c levels.

Table 4: Anova analysis between the explanatory variables (n = 440)

(HbA1c), mmol/L	Mean Square	F Value	P -value
Age category	193.344498	375.43	0.0000
Sex	8.19821431	3.31	0.0697
Marital status	102.673252	59.83	0.0000
Employment	22.9844247	10.08	0.0000
Education	54.7255787	30.16	0.0000
Monthly Income	13.1042905	5.37	0.0739
BMI category	31.5260295	13.90	0.0000
Smoking Status	12.755882	5.23	0.0000

The ANOVA analysis in "table 4" showed that HbA1c levels were significantly influenced by age, marital status, employment, education, income, BMI, and smoking status. However, sex did not significantly affect HbA1c levels. This highlights the importance of demographic, socioeconomic, and lifestyle factors in determining HbA1c levels.

Table 5: Logistic regression model of low & high categories of HbA1c among the participant (n = 391)

Low and high HbA1c	OR	Std. Err	z	P>|t|	[95% CI]	
Age	1.224802	.0250115	9.93	0.000	1.176748	1.274817
Gender						
• Male						
Cigarette Smoking	Reference Current Smoker					
• Non-Smoking	.8018182	.2313266	-.77	0.444	.4555144	1.411399
• Ex-Smoker	1.3	.6608357	0.52	0.606	.4800073	3.520781
Marital status	Reference Single					
• Married	8.542373	3.074143	5.96	0.000	4.219459	17.29419
• Divorced	22.8	13.1607	5.42	0.000	7.355314	70.67544
• Widow	30.24	18.18196	5.67	0.000	9.306628	98.25875
25-hydroxyvitamin D , ng/ml	.9712294	.005091	-5.57	0.000	.9613023	.9812589
Employment	“Ref: current Employed ”					
Retired	8.85	5.625052	3.43	0.001	2.546363	30.75857
BMI (Category)	“Ref: Under wight”					
Normal weight	3.022901	2.399559	1.39	0.163	.6378896	14.32525
Overweight	6.84375	5.499084	2.39	0.017	1.416894	33.05605
Obesity	9.346154	7.958354	2.62	0.009	1.761268	49.5953

In "table5" The logistic regression analysis found that higher age, being married, divorced, or widowed, lower vitamin D levels, being retired, and higher BMI significantly increased the odds of high HbA1c levels. Gender and smoking status did not significantly affect HbA1c levels. These findings highlight the key factors influencing HbA1c levels among the participants.

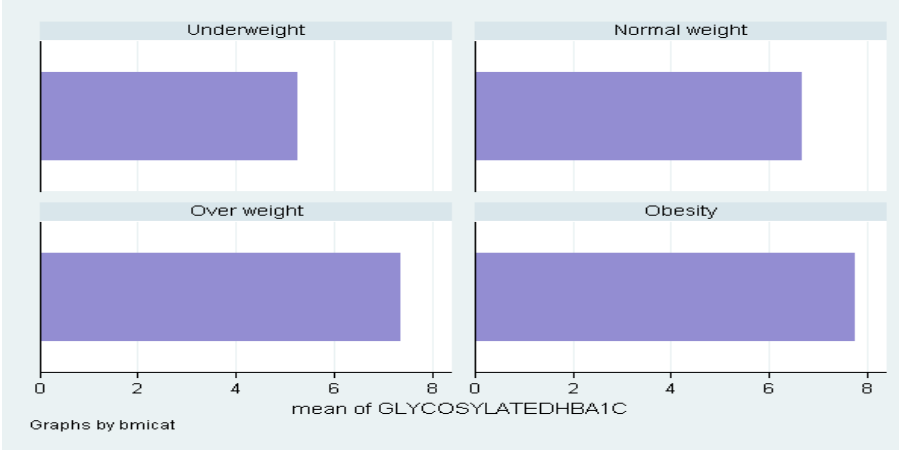

Figure 1: show the mean levels of glycosylated hemoglobin (HbA1c) across weight categories.

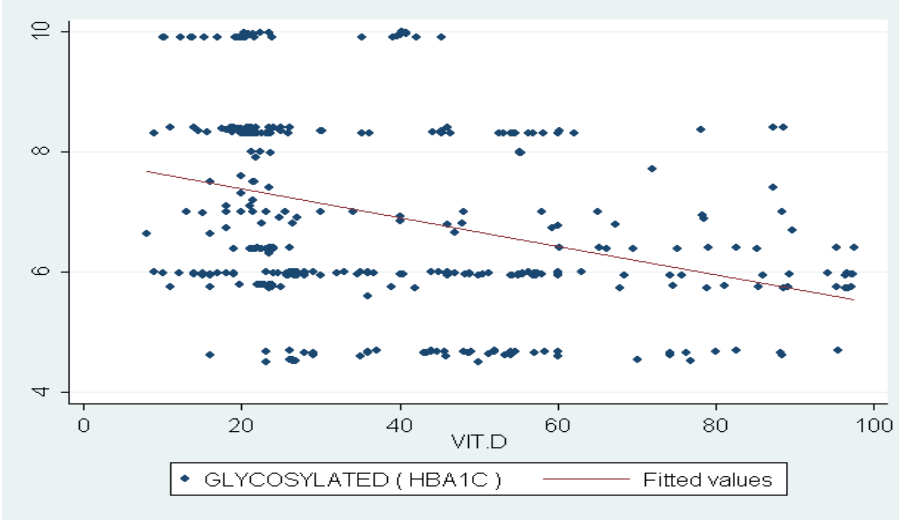

Figure 2: Shows relationship between Vitamin D levels and glycosylated hemoglobin (HbA1c) levels, with a fitted regression line.

5. Discussion

The relationship between Vitamin D and HbA1c levels has significant implications for diabetes management, particularly in regions with high rates of both diabetes and Vitamin D deficiency, such as Khamis Mushait, Saudi Arabia. This study aimed to explore this correlation, providing insights that could inform clinical practices and public health strategies.

Vitamin D's potential influence on glucose metabolism and insulin function is supported by various biochemical mechanisms. Vitamin D receptors in pancreatic beta

cells and other tissues involved in insulin action suggest a direct role in enhancing insulin secretion and sensitivity (Parker et al., 2010). Furthermore, Vitamin D's anti-inflammatory properties might mitigate insulin resistance, a key factor in the pathogenesis of type 2 diabetes (Gianfrancesco et al., 2016).

The empirical evidence regarding the correlation between Vitamin D and HbA1c levels is mixed but generally suggests a beneficial role for Vitamin D in glycemic control. Studies such as those by Pittas et al. (2007) and Zheng et al. (2013) indicate that higher Vitamin D levels or supplementation can lead to improved HbA1c levels, highlighting the potential for Vitamin D to support diabetes management. However, some studies report only modest effects or no significant changes, underscoring the complexity of this relationship and the influence of other factors like baseline Vitamin D levels, dosage, and individual patient characteristics (Binker et al., 2015).

In Khamis Mushait, the prevalence of Vitamin D deficiency is notably high due to factors such as limited sun exposure and dietary habits (Amin et al., 2016). This context provides a unique opportunity to investigate the impact of Vitamin D on diabetes management in a population that may be particularly susceptible to the negative effects of Vitamin D deficiency on glycemic control. Addressing Vitamin D deficiency in this region could have significant public health benefits, potentially reducing the burden of diabetes-related complications.

The findings from this study underscore the importance of incorporating Vitamin D assessment and supplementation into diabetes care protocols in regions with high deficiency rates. Routine screening for Vitamin D levels in diabetic patients could identify those who might benefit from supplementation, thereby improving glycemic control and reducing HbA1c levels (Al-Daghri et al., 2016). Public health campaigns promoting safe sun exposure, dietary sources of Vitamin D, and supplementation could also help address widespread deficiency, contributing to better overall health outcomes.

6. Limitations and Future Research

Despite the promising findings, this study has limitations. The cross-sectional design limits the ability to establish causality between Vitamin D levels and HbA1c. Longitudinal studies and randomized controlled trials are needed to confirm these findings and clarify the mechanisms underlying the Vitamin D-HbA1c relationship. Additionally, research should consider other confounding factors such as lifestyle, genetic predispositions, and comorbid conditions that may influence both Vitamin D levels and glycemic control (Pittas et al., 2007).

7. Conclusion

The study demonstrates a significant inverse correlation between serum vitamin D levels and HbA1c levels. Higher vitamin D levels are associated with better glycemic control as evidenced by lower HbA1c levels. These findings suggest that maintaining adequate vitamin D levels may be beneficial for glucose metabolism and could potentially aid in the management of diabetes. Further longitudinal studies and clinical

trials are needed to establish causality and evaluate the therapeutic potential of vitamin D supplementation in diabetes care.

The correlation between HbA1c and Vitamin D levels presents a compelling area of investigation, particularly within the context of Khamis Mushait, Saudi Arabia. Given the high prevalence of both diabetes and Vitamin D deficiency in the region, understanding this relationship is crucial for developing effective public health strategies and improving clinical outcomes for diabetic patients.

Vitamin D's role in glucose metabolism, insulin secretion, and insulin sensitivity highlights its potential impact on glycemic control. Research indicates that sufficient Vitamin D levels might be associated with better HbA1c outcomes, though findings are varied and suggest a complex interplay influenced by multiple factors (Pittas et al., 2007; Parker et al., 2010). Studies like those by Zheng et al. (2013) and Pittas et al. (2007) support the potential benefits of Vitamin D supplementation in reducing HbA1c levels, particularly in individuals with type 2 diabetes. However, the variability in outcomes underscores the need for region-specific research to address local dietary habits, sunlight exposure, and genetic predispositions.

In Saudi Arabia, the widespread Vitamin D deficiency, attributed to limited sun exposure and dietary factors, necessitates targeted research to explore its impact on diabetes management (Amin et al., 2016). By focusing on the population in Khamis Mushait, this study aims to provide valuable insights into how Vitamin D status affects glycemic control, potentially informing tailored interventions to mitigate the dual burden of diabetes and Vitamin D deficiency in the region.

The findings from this study could have significant implications for clinical practice, including the potential for routine screening of Vitamin D levels in diabetic patients and the incorporation of Vitamin D supplementation into diabetes management protocols. Such interventions could improve glycemic control, reduce HbA1c levels, and ultimately lower the risk of diabetes-related complications (Al-Daghri et al., 2016).

Further research is needed to clarify the mechanisms underlying the Vitamin D-HbA1c relationship and to establish definitive clinical guidelines. This study will contribute to the growing body of evidence, helping to bridge the gap in current literature and providing a foundation for future research and public health initiatives.

8. Recommendations

Incorporating routine Vitamin D screening into standard diabetes care protocols in Saudi Arabia can help identify deficiencies early, potentially improving glycemic control and HbA1c levels. For patients with confirmed deficiencies, Vitamin D supplementation should be considered, with careful dosing and monitoring to ensure efficacy and avoid toxicity. Public health campaigns should raise awareness about the importance of Vitamin D for overall health and diabetes management, promoting safe sun exposure, dietary sources, and supplementation. Nutrition counseling should focus on increasing dietary Vitamin D intake from foods like fatty fish, fortified dairy products, and eggs. Further region-specific research is needed to understand Vitamin D's impact on glycemic control and establish optimal supplementation strategies.

Integrated care approaches, involving multidisciplinary teams, should combine traditional glycemic control measures with Vitamin D supplementation to optimize patient outcomes.

Moreover, healthcare providers should be trained to recognize the signs of Vitamin D deficiency and understand its potential impact on diabetes management. This training should be part of continuing medical education programs to ensure that all healthcare professionals are up to date with the latest guidelines and research findings. Additionally, regular follow-ups and patient education sessions can help ensure that patients adhere to their supplementation regimen and make necessary lifestyle adjustments to maintain adequate Vitamin D levels.

It is also important to consider the socio-cultural context of Saudi Arabia, where lifestyle factors such as limited sun exposure due to cultural dress norms and indoor living can contribute to widespread Vitamin D deficiency. Tailored public health initiatives that respect cultural practices while promoting health can make a significant difference. For example, encouraging outdoor activities during early morning or late afternoon when sun exposure is less intense can help increase Vitamin D levels without risking sunburn.

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