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Vitamin D Among Type 2 Diabetic Patients Attending Aden Diabetic Center During May-July 2023: A Descriptive Study

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Abstract

Introduction: Vitamin D plays a crucial role in the pathogenesis and management of type 2 diabetes mellitus (T2DM). However, limited data are available regarding the status of vitamin D among T2DM patients attending healthcare centers, particularly in the Aden Diabetic Center, Yemen. The study aimed to assess the prevalence of vitamin D deficiency among T2DM patients and explore its association with potential factors such as demographics, diabetes characteristics body mass index (BMI).

Methods: A descriptive cross-sectional study was conducted on 138 T2DM patients attending Aden Diabetic Center (ADC) between May and July 2023. Data on age, sex, diabetes characteristics (diabetes duration, family history of diabetes, and medication use), RBS, BMI, and serum vitamin D level were measured. Vitamin D status was categorized as deficient, insufficient, or sufficient based on established cutoffs. Descriptive statistics and chi-square tests were used for data analysis.

Results: Majority of patients had vitamin D deficiencyy (73.2%) and the remaining had insufficient (17.4%), and sufficient (9.4%) status. Males comprised 53.6% and females 46.4%. Mean age was 53.70±12.93 years, with the highest proportion (60.9%) were in the age group 40-60 years. Majority of the patients (62.3%) had T2DM duration ≥ 5 years, and 89.1% were receiving diabetes medications, and 68.8% had a family history of DM. The mean RBS level was 220.13±86.90 mg/dl, with more than half (55.6%) having RBS levels ≥ 140 mg/dl. Also, the mean BMI was 27.00±5.90 kg/m², and more than half of the patients had overweight and obesity. The study found no significant association between serum vitamin D levels with age, diabetes characteristics, or BMI categories, while a significant association to sex was observed (P = 0.006).

Conclusion: The study highlights the high prevalence of vitamin D deficiency among T2DM patients attending the ADC in Aden. The majority of patients were found to have deficient levels of vitamin D, with limited differences based on age, diabetes characteristics, and BMI. The significant association between vitamin D levels and sex, indicating that sex may contribute to the risk of deficiency in T2DM patients. These findings emphasize the importance of assessing and addressing vitamin D status in T2DM patients to optimize their overall health and diabetes management.

Keywords: Vitamin D, Deficiency, type 2 diabetes mellitus

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فيتامين د بين مرضى السكري من النوع الثاني المترددين على مركز السكري في عدن خلال شهري مايو-يوليو 2023: دراسة وصفية

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ملخص الدراسة

المقدمة: يلعب فيتامين د دورًا حاسمًا في التسبب في مرض السكري من النوع الثاني وعلاجه. ومع ذلك، تتوفر بيانات محدودة فيما يتعلق بحالة فيتامين د بين مرضى السكري من النوع الثاني الذين يترددون على مراكز الرعاية الصحية، وخاصة في مركز عدن للسكري، اليمن. هدفت الدراسة إلى تقييم انتشار نقص فيتامين د بين مرضى السكري من النوع الثاني واستكشاف ارتباطه بالعوامل المحتملة مثل العوامل الديموغرافية وخصائص ومرض السكري ومؤشر كتلة الجسم.

المنهجية: أجريت دراسة وصفية مقطعية على 138 مريضاً من مرضى السكري من النوع الثاني الذين يترددون على مركز عدن للسكري في الفترة ما بين مايو ويوليو 2023. تم أخذ بيانات العمر والجنس وخصائص مرض السكري (مدة الإصابة بالسكري، والتاريخ العائلي لمرض السكري، واستخدام الدواء)، وقياس سكر الدم العشوائي، ومؤشر كتلة الجسم، ومستوى فيتامين د في الدم. كانت حالة فيتامين د مصنفة على أنها ناقصة أو غير كافية أو كافية استنادًا إلى القيم الحدودية المعتمدة. وتم استخدام الإحصاء الوصفي واختبارات مربع كأي لتحليل البيانات.

النتائج: غالبية المرضى يعانون من نقص فيتامين د (73.2٪) والباقية صنفت حالة الفيتامين انها غير كافية (17.4٪) أو كافية (9.4٪) شكل المرضى الذكور (53.6٪) والإناث (46.4٪). كان متوسط عمر المرضى 53.70±12.93 عاماً، وكانت أعلى نسبة (60.9٪) تقع ضمن الفئة العمرية 40-60 عاماً. مدة إصابة غالبية المرضى بالسكري من النوع الثاني (62.3٪) تزيد أو تساوي 5 سنوات، وكان (89.1٪) يتلقون أدوية السكري و(68.8٪) لديهم تاريخ عائلي لمرض السكري. كان متوسط مستويات سكر الدم العشوائي 86.90±220.13 ملغم/ديسيلتر، مع أكثر من نصف المرضى (55.6٪) مستويات سكر الدم العشوائي تزيد أو تساوي 140 ملغم/ديسيلتر. أيضاً، كان متوسط مؤشر كتلة الجسم 5.90±27.00 كجم/م^2، وكان أكثر من نصف المرضى يعانون من زيادة الوزن والسمنة. لم تجد الدراسة أي ارتباط إحصائي بين مستويات فيتامين د في الدم مع العمر، أو خصائص مرض السكري، أو فئات مؤشر كتلة الجسم ، في حين لوحظ وجود علاقة ذات دلالة إحصائية بالجنس ($P = 0.006$).

الخلاصة: تسلط الدراسة الضوء على ارتفاع معدل انتشار نقص فيتامين د بين مرضى السكري من النوع الثاني المترددين على مركز عدن للسكري في عدن. وُجد أن غالبية المرضى يعانون من نقص مستويات فيتامين د، مع اختلافات محدودة بناءً على العمر وخصائص مرض السكري ومؤشر كتلة الجسم. ومع ذلك، لوحظ وجود ارتباط كبير بين مستويات فيتامين د والجنس، مما يشير إلى أن الجنس قد يساهم في خطر النقص لدى مرضى السكري من النوع الثاني. تؤكد هذه النتائج على أهمية تقييم ومعالجة حالة فيتامين د لدى مرضى السكري من النوع الثاني لتحسين صحتهم العامة وإدارة مرض السكري.

كلمات مفتاحية: فيتامين د، نقص، داء سكري من النوع الثاني.

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Introduction

Type 2 Diabetes Mellitus (T2DM) is a metabolic disorder characterized by reduced insulin action, secretion, or both. T2DM is mostly a consequence of interactions among genetic, environmental, and other risk factors contributing to its development. The progression of the disease may initially lead to microvascular complications, which culminate in macro-complications and cardiovascular events [1,2].

Low- and middle-income countries have the highest incidence of T2DM internationally. This is most likely due to the rapid and progressive social and economic development in these countries, which has led to the urbanization of their lifestyle and the westernization of their diet [3]. The Middle East and North Africa region reached an estimated 35.4 million cases in 2015 and is expected to reach 72.1 million by 2040 [3]. In Yemen, T2DM is also prevalent. A population-based survey in semirural area near Sana'a in Yemen reported 10.4% prevalence of diabetes [4]. Moreover , a local study in Aden Diabetes Center (ADC) have reported a higher prevalence of T2DM than type 1 diabetes mellitus (T1DM) [5]. In Saudi Arabia, diabetes is a significant public health issue that is increasing along with the global diabetes epidemic. Aaccording to the Saudi Arabian Ministry of Health, there is a significant increase in the number of diagnosed diabetes cases in Saudi Arabia. In 1992, 0.9 million individuals were reported to have diabetes. However, by 2010, this number had risen to 2.5 million people, indicating a 2.7 times increase in incidence rates within a span of less than two decades. Furthermore, in 2015, a total of 4,660 patients with diabetes sought medical care at family and medical clinics across Saudi Arabia [6].

Vitamin D deficiency is alarmingly prevalent in the United Arab Emirates (UAE) with a significant proportion of the population suffers from inadequate levels of vitamin D [7]. In the past, UAE had the second highest prevalence of T2DM in the world, specifically among the Emirati adult population aged 20-70 years, with a prevalence rate of 18.7%. However, more recent estimates suggest that other Gulf countries, including Saudi Arabia, Bahrain, Kuwait, and Qatar, have surpassed the UAE in terms of T2DM prevalence. Nevertheless, the UAE still holds the 16th position globally in terms of T2DM prevalence [8].

Obesity is acknowledged as a risk factor for the onset of numerous chronic conditions, including T2DM. It is worth noting that a majority of individuals who are obese possess risk factors that increase their susceptibility to developing T2DM [9]. According to the World Health Organization (WHO), the global impact of overweight and obesity is substantial, with at least 2.8 million people dying each year due to these conditions. Notably, approximately one-third of the world's population falls into the overweight or obese category, as determined by the Body Mass Index (BMI) measurement. Between 1980 and 2013, there was a significant increase in the proportion of adults worldwide with a BMI of 25 kg/m^2 or greater. In males, the percentage rose from 28.8% to 36.9%, while in females, it increased

from 29.8% to 38%. These findings highlight the growing prevalence of overweight and obesity on a global scale [10].

The increased burden of T2DM, including an increased risk of mortality, significant long-term morbidity, and high healthcare costs for individual patients, their families, and countries [11] calls for increased investment in effective diabetes prevention and management to combat this global epidemic. However, despite the increasing prevalence of diabetes and its associated disease burden in Yemen, dietary interventions are still poor, and nutritional management therapies are inadequate.

A growing body of evidence has shown that vitamin D deficiency may play an important role in the pathogenesis of T2DM in humans. Since vitamin D influences the influx of Ca^{2+} into the β-cells and thus leads to insulin secretion, and also regulates insulin action in tissues, either directly via the expression of insulin receptors or indirectly via the activation of peroxisome proliferator-activated receptors (PPARs), its deficiency is implicated in the development of T2DM [12]. Furthermore, several studies have reported an association between obesity and T2DM and its complications [1] and the deficiency in vitamin D is implicated in cardiovascular complications, which represent one of the leading causes of morbidity and mortality in patients with T2DM [13]. Therefore, the present study aimed to assess the prevalence of vitamin D among T2DM patients attending the ADC and its potential associations with age, sex, diabetes characteristics, RBS, and BMI.

Methods

Study design and setting

This descriptive cross-sectional study was conducted at the ADC in Al-Gamhuoria Modern General Hospital, Aden, Yemen included a random sample of participants, between May- to July 2023. Patients participating in the study had been previously diagnosed with T2DM via primary care physician in the ADC, where their HbA1c levels were found to be plasma glucose ≥ 200 mg/dl (11.1 mmol/L) or ≥ 6.5% (48 mmol/mol) based on the WHO criteria [14].

Inclusion criteria

Adult both male and female patients (≥18 years) included in this study attending the ADC for follow up after being diagnosed with T2DM according to American Diabetic Association (ADA) criteria [15] and treated with antidiabetic drugs such as oral hypoglycemic drugs and insulin.

Exclusion criteria

Patients with T1DM or taking drugs that interfere with vitamin D, such as antipsychotics (carbamazepine, sodium valproate, gabapentin), were excluded. Additionally, patients with comorbidities such as hepatic or renal disease, malignancy, or those taking vitamin D supplement were excluded.

Sampling and sample size

ADC at Al-Gamhuoria Modern General Hospital receives diabetic patients from all Aden districts and most governorates around. In the year 2022, 1159 diabetic patients have visited the center with an average of 97 patients monthly. Figure 1. a

simple random sampling method was used to select the study sample.

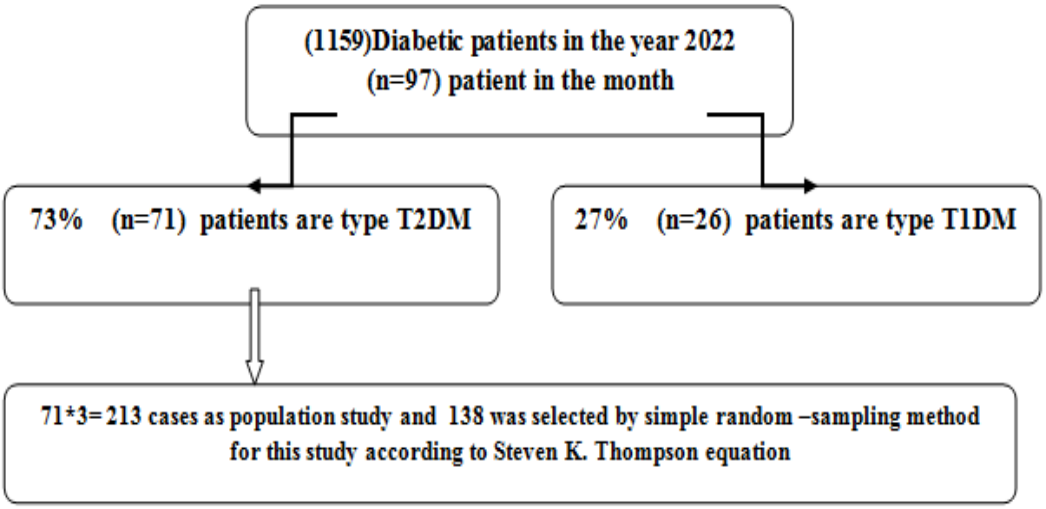

Figure 1: Sample size determination

A sample size of 138 was decided based on these data. Therefore, there were 213 subjects during the three-month study period. The study sample was selected using a simple random-sampling method, calculated using the equation developed by Steven K. Thompson method [16]:

$$n = \frac{N \times p(1-p)}{[[N-1 \times (d^2 \div z^2)] + p(1-p)]}$$

N: population study
Z: score corresponding to the level indication (0.95) and equal to (1.96)
d: Standard Error equal (0.05)
P: Property availability and neutral and equal (0.50)

$$n = \frac{213 \times 0.5(1-0.5)}{[[213-1 \times (0.05^2 - 1.96^2)] + 0.5(1-0.5)]}$$

$$n = \frac{53.25}{[[212 \times (0.0025 \div 3.8416)] + 0.25]} = 137.58$$

Data collection

Patients who attended the morning session between 8:30 and 11:30 at ADC were individuals previously diagnosed with T2DM according to the WHO criteria. After obtaining oral informed consent from each participant, structured interviews and a review of medical records were conducted with all T2DM patients. A study questionnaire that is modified from Alhiassah [17] was used to collect relevant data, including age, sex, family history of diabetes, and duration of diabetes.

All participants' samples were collected using a disposable syringe (3 ml) from the venous blood into tubes containing a chemical compound used as an anticoagulant, ethylenediaminetetraacetic acid (EDTA), at room temperature (25°C). Serum separation was achieved by centrifugation at 3000 rpm for 5 minutes using a Centrifuge 800 device (China). RBS levels were measured directly. The remaining serum aliquots were transferred to clear, dry Eppendorf tubes and immediately stored at -20°C for

subsequent analysis of serum vitamin D levels [18].

Definitions of variables Vitamin D levels

Vitamin D status was classified as follows: A serum vitamin D level < 20 ng/ml was defined as vitamin D deficiency. A serum level of 20-29 ng/ml is defined as vitamin D insufficient. In addition, a serum level of more than 30-100 ng/ml is considered sufficient [19]**.**

BMI

Classified as underweight (< 18.5 kg/m^2), normal weight ((18.5-24.9 kg/m^2), overweight (25-29.9 kg/m^2), and obese (≥ 30 kg/m^2) [20, 21].

RBS

RBS was classified as normal (< 140 mg/dl), prediabetes (140 -199 mg/dl) and diabetes (≥ 200 mg/dl) [15].

Statistical analysis

Data analysis was performed with SPSS software version 22 (IBM Corp, Armonk, NY, USA). Descriptive statistics was calculated by using mean and standard deviation for quantitative variables such as age, RBS levels, BMI and 25-hydroxy vitamin D levels, while numbers and percentages were used for qualitative variables, including demographics, vitamin D categories, groups of BMI and clinical parameters. Association between two groups was made using the Chi-square test. Scatter plots were used to demonstrate relationships between vitamin D and age. *P* value less than 0.05 based was considered statistically significant.

Ethical consideration

Ethical approval was granted by the Research Ethics Committee of the Faculty of Medicine and Health Sciences University of Aden (REC-187-2024). The study was conducted after obtaining oral informed consent from each participant. Each study participant was given adequate information about the objectives of the study, the content of the questionnaire, as well as the confidentiality of the information.

Results

The present study included a total of 138 patients with T2DM. Among them, 53.6% were males, and 46.4% were females. In terms of age distribution, the mean age of the patients was 53.7±12.93 years. The majority of patients (60.9%) were in the age group 40-60 years. The next largest age group was over 60 years, comprising 24.6% of the sample. Patients under the age of 40 years constituted only 14.5% of the study population [Table 1].

Table 1: Study Sample by Age and Sex (n=138)

Variables	No.	%
Sex		
Male	74	53.6
Female	64	46.4
Age (Mean ± SD (53.70±12.93) years		
less than 40 years	20	14.5

40-60 years	84	60.9
More than 60 years	34	24.6

Among diabetic patients, 62.3% had a duration of T2DM ≥ 5 years, while 37.7% had a duration of less than 5 years. Regarding the medications used, the majority (89.1%) took medications for diabetes management. In terms of family history of diabetes, 68.8% of patients had family history, indicating that diabetes was present in their family members as shown in Table 2.

Table 2: Study Sample by Diabetic Mellitus Characteristics (n=138)

Variables	No.	%
Duration of T2DM		
< 5 years	52	37.7
≥ 5 years	86	62.3
Diabetes medications		
Taken medications	123	89.1
No taken medications	15	10.9
Family History of T2DM		
Yes	95	68.8
No	43	31.2

In Table 3, the mean RBS of the study sample was 220.13±86.90 mg/dl. Among the patients, 55.1% had RBS levels ≥200 mg/dl, indicating elevated blood sugar levels. On the other hand, 23.2% of patients had RBS levels within the normal range. Regarding the BMI, the mean BMI of the study sample was 27.0±5.90 kg/m^2. Patients with overweight (BMI 25-29.9 kg/m^2) accounted for 29.0% of the total study sample, while those with obesity (BMI ≥30 kg/m^2) constituted 29.7%. Together, patients with overweight and obesity comprised more than half of the study sample.

Table 3: Study Sample by BMI Group and RBS Groups (n=138)

Parameters	No.	%
RBS Mean ± SD 220.13±86.90 mg/dl		
Normal (< 140 mg/dl)	32	23.2
Prediabetes (140 -199 mg/dl)	30	21.7
Diabetes (≥ 200 mg/dl)	76	55.1
BMI Mean ± SD 27.00±5.90 kg/m^2		
Under weight (< 18.5 kg/m^2)	6	4.4
Normal weight (18.5-24.9 kg/m^2)	51	37.0
Overweight (25-29.9 kg/m^2)	40	29.0
Obese (≥ 30 kg/m^2)	41	29.7

Table 4 shows that vitamin D deficiency present in 73.2% of patients. Insufficient vitamin D levels (20-29 ng/ml) accounted for 17.4% o. Only a small percentage (9.4%) of patients had sufficient vitamin D levels (30-100 ng/ml).

Table 4: Distribution of study sample by Vitamin D groups (n=138)

Parameters	**No.**	**%**
Vitamin D Mean ± SD 16.15±9.71 ng/ml		
Deficiency (< 20 ng/ml)	101	73.2
Insufficient (20-29 ng/ml)	24	17.4
Sufficient (30-100 ng/ml)	13	9.4

As illustrated in Table 5, vitamin D deficiency was slightly higher in females (39.9%) compared to males (33.3%). There is a significant difference between sex and vitamin D deficiency (*P*=0.006). Vitamin D deficiency was higher in the age group of 40-60 years, making 46.4% of the study patients, and followed by the age group of more than 60 years, 15.9% of the sample. However, statistical analysis did not reveal a significant difference in the prevalence of vitamin D deficiency among the different age groups (p > 0. 05). Concerning BMI categories, the results revealed that 29%, 21. % and 19.6% of the patients with normal weight, obesity, and overweight, respectively were found to be vitamin D deficient, and there was no statistical difference between them.

Table 5: Association between Vitamin D Status and Sex, Age, BMI and RBS of patients with T2DM (n=138)

	Deficient		Insufficient		Sufficient		*P*
Sex							
Male	46	33.3%	19	13.8%	9	6.5%	
Female	39	39.9%	5	3.6 %	4	2.9%	0.006
Age (years)							
< 40	15	10.9%	5	3.6%	0	0.0%	
40-60	64	46.4%	11	8.0%	9	16.5%	
> 60	22	15.9%	8	5.8%	4	2.9%	0.290
BMI							
Under weight	5	3.6%	1	0.7%	0	0.0%	
Normal weight	40	29.0%	7	5.1%	4	2.9%	
Overweight	27	19.6%	9	6.5%	3	2.2%	
Obese	29	21.0%	7	5.1%	6	4.3%	0.747
RBS							
< 140 mg/dl	23	16.7%	6	4.3%	3	2.2%	
≥ 140 mg/dl	78	56.5%	18	13.0%	10	7.2%	0.973

Note: % taken from the total of cases (138). Chi-square test considers significance when p-value <0.05 .

Discussion

In the present study, vitamin D status among patients of both sexes attending ADC in the study period and its link to patients' parameters were assessed among 138 patients with T2DM. Males constituted slightly more than half of the study sample. This result was much more than that found by Jawad and Baiee from Iraq, in which two-thirds of the patients were females [22].

The mean age of the patients was 53.70±12.93 years. This result was in line with the mean age of 52.5 years of T2DM patients reported by Oko *et al*. from Nigeria [23] and agreed with the mean found by Anyanwu *et al.* (52±7.6 years) [24]. Concerning age groups, 60.9% of the study T2DM patients were in the age group 40-60 years, which reflect the prevalence of T2DM in adulthood and elderly patients [25].

Evidence from several studies has shown that vitamin D deficiency is highly prevalent in T2DM [6, 11, 26]. Correlation between vitamin D levels and T2DM was studied, but controversial results were obtained [27]. The present study reveals that the concentration of vitamin D is 16.15±9.71 ng/ml which lies within the level of vitamin D deficiency; with two third of the sample showed vitamin D concentration less than 20 ng/ml. This means the prevalence of vitamin D deficiency is high among T2DM patients in this sample. This finding is almost similar to that reported by Anyanwu *et al.* from Nigeria in which 63% of T2DM patients were deficient in vitamin D [24]. In addition, in line with this result, low levels of serum vitamin D in T2DM patients have been published by Abudawood *et al*. from Saudi Arabia [13]. High prevalence of vitamin D deficiency was also reported in other studies [28, 29].

The present study revealed that vitamin D deficiency was prevalent in both sexes with female preponderance. On the other hand, Oko *et al* from Nigeria reported a significant lower level of vitamin D in diabetic women than men [23]. On the other hand, a study conducted on Iraqi diabetic patients reported that diabetic females had lower vitamin D level than males [22]. It seems that many reasons involved behind the high prevalence of vitamin D deficiency, notably in women. Since Aden city is a known area with usual sunshine days all over the year, the low level of vitamin D in this sample is unexpected. Nonetheless, several reasons can stand behind that. Binkley *et al*, 2007 studied serum 25-hydroxyvitamin D [25(OH)D] concentration in healthy individuals with habitually high sun exposure and suggested that individuals response differently to UVB radiation, causing some individuals to have low vitamin D concentration in spite of abundant sun exposure [30].

Moreover, in areas like Aden city where there is plentiful sunlight, the cultural factors may negatively affect serum vitamin D concentration of women, in terms of body covering which limits skin exposure to the sun. These factors do not apply to men. Another possible reason may be the darker skin color which limits the penetration of UVB light, thereby reducing cutaneous synthesis of vitamin D [31]. A study by Sindi *et al* from Saudi Arabia suggested a possible racial difference of vitamin

D level or genetic predisposition to vitamin deficiency may stand behind the low vitamin level in Saudi Arabia sample population [32]. The above mentioned information might explain the prevalence of vitamin D deficiency in this sample. The study result is also revealed a significance difference between vitamin D deficiency and sex of patients (p-value = 0.006).

Studies have shown that future morbidity and mortality as well as health risks, notably in T2DM, may be predicted by using BMI [1]. In addition, patients with higher BMI might be more likely to experience obesity related health problem. It was indicated that increment in BMI is linked to excess fat cells and an increase in the process of lipolysis and free fatty acids in serum that associated with insulin resistance and hyperglycemia [33]. In the present study, the mean BMI of the patients is 27.00±5.90 kg/m^2 which reflects overweight category. This result is in agreement with the report of Oko *et al.* in which the mean age of T2DM patients was 27.70±0.79 kg/m^2 [24]. Furthermore, the results of classification of BMI groups (overweight and obesity) revealed a higher rate (almost more than half of the study sample) than normal and underweight group which points to a tendency to having high BMI in this sample of T2DM patients. Moreover, two thirds of the sample had duration of diabetes five years and more than five years. Studies have shown that vitamin D deficiency links to overweight/obesity [34] and longer duration of diabetes disease [35]. Therefore, BMI, duration of diabetes and being female might be determinants of lower vitamin D levels in this study sample.

Limitations and Strength of the Study

This study had several limitations. First, the study design was cross-sectional, which limits the ability to establish causality and determine temporal relationships. Second, the study was conducted at a single center, which may affect the generalizability of the findings. Third, dietary and sunlight exposure information, which can influence vitamin D levels, were not assessed. Fourth, due to financial difficulties and higher expense of the tests, glycated hemoglobin, serum insulin concentration, and lipid profile could not be measured. Finally, the study sample size was relatively small, potentially limiting the statistical power to detect significant associations. Despite these limitations, the study provides valuable insights into the prevalence and distribution of vitamin D levels among T2DM patients attending ADC, contributing to the existing knowledge on the status of vitamin D in this population.

Conclusion

Vitamin D deficiency is prevalent in patients with T2DM attending ADC during the study period. Vitamin D deficiency had a significance difference with sex of patients. Deficiency in vitamin D was high in patients with higher BMI and having RBS more than 140 mg/dl. Further studies should examine vitamin D status in a larger population and diabetes related factors to elucidate the role of vitamin D in prevention and treatment of diabetes.

References

1. Malone JI, Hansen BC. Does obesity cause type 2 diabetes mellitus (T2DM)? Or is it the opposite? Pediatr Diabetes. 2019;20(1):5-9.
2. Lotfy M, Adeghate J, Kalasz H, Singh J, Adeghate E. Chronic complications of diabetes mellitus: a mini review. Current diabetes reviews. 2017;13(1):3-10.
3. Nasr MH, Hassan BAR, Othman N, Karuppannan M, Abdulaziz NB, Mohammed AH, et al. Prevalence of vitamin D deficiency between type 2 diabetes mellitus patients and non-diabetics in the Arab Gulf. Diabetes Metab Syndr Obes. 2022;15(null):647-57.
4. Gunaid AA, Assabri AM. Prevalence of type 2 diabetes and other cardiovascular risk factors in a semirural area in Yemen. East Mediterr Health J. 2008;14(1):42-56.
5. Nasser A, Al-saeedi A, Mahmood A. Alpha-Tocopherol on Diabetic Effect of Alpha-Tocopherol on Diabetic Peripheral Neuropathy in Yemeni Patients with Uncontrolled Type 2 Diabetes Mellitus. YJMHR. 2017;6(1-2): https://www.researchgate.net/publication/330687420.
6. Alotaibi A, Perry L, Gholizadeh L, Al-Ganmi A. Incidence and prevalence rates of diabetes mellitus in Saudi Arabia: An overview. J Epidemiol Glob Health. 2017;7(4):211-8.
7. Sadiya A, Ahmed SM, Carlsson M, Tesfa Y, George M, Ali SH, et al. Vitamin D supplementation in obese type 2 diabetes subjects in Ajman, UAE: a randomized controlled double-blinded clinical trial. Eur J Clin Nutr. 2015;69(6):707-11.
8. Shah SM, Ali R, Loney T, Aziz F, ElBarazi I, Al Dhaheri S, et al. Prevalence of Diabetes among Migrant Women and Duration of Residence in the United Arab Emirates: A Cross Sectional Study. PLoS One. 2017;12(1):e0169949.
9. Strings S, Wells C, Bell C, Tomiyama A. The association of body mass index and odds of type 2 diabetes mellitus varies by race/ethnicity. Public Health. 2023;215(null):27-30.
10. Agha M, Agha R. The rising prevalence of obesity: part A: impact on public health. Int J Surg Oncol (N Y). 2017;2(7):e17.
11. Nwaokoro J, Okokon B, Nwaokoro A, Emerole C, Ibe S, Onwuliri V, et al. Problems associated with treatment compliance among type 2 diabetic patients at a tertiary health institution in Nigeria. AJDM. 2014;22(1).
12. Vondra K, Hampl R. Vitamin D and new insights into pathophysiology of type 2 diabetes. Horm Mol Biol Clin Investig. 2021;42(2):203-8.
13. Abudawood M, Tabassum H, Ansar S, Almosa K, Sobki S, Ali MN, et al. Assessment of gender-related differences in vitamin D levels and cardiovascular risk factors in Saudi patients with type 2 diabetes mellitus. Saudi J Biol Sci. 2018;25(1):31-6.
14. World Health Organization. Classification of diabetes mellitus. Geneva, 2019 https://iris.who.int/bitstream/han

dle/10665/325182/9789241515702-eng.pdf.
15. American Diabetes Association. 2. Classification and Diagnosis of Diabetes: Standards of Medical Care in Diabetes-2021. Diabetes Care. 2021;44(Suppl 1):S15-S33 https://doi.org/10.2337/dc21-S002.
16. Thompson SK. Sampling. 2th ed. New York: Wiley; 1945. p 39-48 .https://archive.org/details/sampling0002thom.
17. Alhiassah OKS. Estimation of vitamin D3 25-hydroxycholecalferol and Calcium in Sudanese children with type1 diabetes mellitus (Thesis), Sudan, 2017; 46.
18. Gessler S, Porsch U. A New Digital Point-of-Care Tool With Advanced Blood Glucose Measuring Technology. J Diabetes Sci Technol. 2023;17(5):1321-5.
19. Ramasamy I. Vitamin D Metabolism and Guidelines for Vitamin D Supplementation. Clin Biochem Rev. 2020;41(3):103-26.
20. Nuttall FQ. Body Mass Index: Obesity, BMI, and Health: A Critical Review. Nutr Today. 2015;50(3):117-28.
21. Casadei K, Kiel J. Anthropometric Measurement. StatPearls [Internet]: StatPearls Publishing; 2021 https://www.ncbi.nlm.nih.gov/books/NBK537315/.
22. Jawad IH, Baiee HAL. Vitamin D Level Status and Diabetes Mellitus among Old Adult Iraqi People in Al Hillah City. Medico-Legal Update. 2020;20(2):630.
23. Oko C, Anaja P, Nwaelugo R, Okafor P. Serum Vitamin D Levels Among Type 2 Diabetic Patients in Nigeria: Preliminary Findings. Journal of Medical Laboratory Science. 2022;7(1):38-43.
24. Anyanwu A, Olopade O, Onung S, Odeniyi I, Coker H, Fasanmade O, et al. Serum vitamin D levels in persons with type 2 diabetes mellitus in Lagos, Nigeria. Int J Diabetes Clin Res. 2020;7(133):https://ir.unilag.edu.ng/handle/123456789/9577.
25. Ansari RM, Hosseinzadeh H, Harris MF, Zwar NA. Conceptual model of diabetes self-management for middle-aged population of rural area of Pakistan. International Journal of Diabetes Research. 2017;6(3):68-72.
26. Aljack HA, Abdalla MK, Idris OF, Ismail AM. Vitamin D deficiency increases risk of nephropathy and cardiovascular diseases in Type 2 diabetes mellitus patients. J Res Med Sci. 2019;24(null):47-53.
27. Mustafa TI, Saleh BO, Thaker AA. Association of Serum Levels of 25 Hydroxyvitamin D and Type 2 Diabetes Mellitus: Age and Gender Dependent Study. Iraqi Postgraduate Medical Journal. 2017;16(2):https://www.iasj.net/iasj/download/4175ef6ff6c4e7c6.
28. AlHewishel MA, Bahgat M, Al Huwaiyshil A, Alsubie MA, Alhassan A, Al Huwaiyshil AH. 25 (OH) D serum level in non-diabetic and type II diabetic patients: a Cross-Sectional Study. Cureus. 2020;12(6):e8910.

29. Papadakis G, Villiotou V. Association between 25-hydroxyvitamin D levels and glycemic status. Curr Res Diabetes Obes J. 2017;1:1-4.
30. Binkley N, Novotny R, Krueger D, Kawahara T, Daida YG, Lensmeyer G, et al. Low vitamin D status despite abundant sun exposure. J Clin Endocrinol Metab. 2007;92(6):2130-5.
31. Aloia JF, Patel M, DiMaano R, Li-Ng M, Talwar SA, Mikhail M, et al. Vitamin D intake to attain a desired serum 25-hydroxyvitamin D concentration1–3. Am J Clin Nutr. 2008;87(6):1952-8.
32. Sindi AAA, Albanghali MA, Izhari MA, Alghamdi S, Alghamdi FS, Shanawaz MA, et al. Prevalence of Vitamin D Deficiency and its Association with Age, Sex and Ethnicity in Albaha, Saudi Arabia. J Res Med Dent Sci. 2021;9(12):150-60.
33. Manna P, Jain SK. Obesity, oxidative stress, adipose tissue dysfunction, and the associated health risks: causes and therapeutic strategies. Metab Syndr Relat Disord. 2015;13(10):423-44.
34. Yang K, Liu J, Fu S, Tang X, Ma L, Sun W, et al. Vitamin D status and correlation with glucose and lipid metabolism in Gansu Province, China. Diabetes Metab Syndr Obes. 2020;13(null):1555-63.
35. Bashir F, Khan ZU, Qureshi S, Seetlani NK, Sheikh Z. Prevalence of hypovitaminosis D in type 2 diabetes mellitus and its relationship with glycemic control. J Liaquat Uni Med Health Sci. 2016;15(02):83-9.