

Original Research Article

Differentials in vitamin D deficiencies among individuals with type 2 diabetes in an urban community in India

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ABSTRACT

Background: India's geographical location, spanning from 8.4° N to 37.6° N latitude, suitably receives year-round sunlight. However, we see that studies have reported a high prevalence of vitamin D deficiency, particularly among individuals with type 2 diabetes. Given the critical role of vitamin D in insulin biosynthesis and glucose metabolism, evaluating its status in individuals with type 2 diabetes is of particular clinical relevance. This study aims to examine the patterns and underlying determinants of vitamin D deficiency within this population.

Methods: A retrospective cohort of 545 individuals diagnosed with type 2 diabetes between 2011 and 2021 is analysed. Ordered logistic regression is employed to assess the association between demographic, clinical, and metabolic factors and the likelihood of vitamin D deficiency.

Results: Men had significantly higher odds of Vitamin D deficiency compared to women (OR: 0.66). Younger individuals diagnosed between the ages of 30-44 years were more likely to exhibit deficiency than those diagnosed at older ages (OR: 0.69 for 45-59 years; OR: 0.47 for ≥60 years). Poor glycemic control was strongly associated with increased odds of deficiency: patients with HbA1c levels of 7-8% and >8% had higher odds (OR: 1.46 and OR: 1.92, respectively) compared to those with levels <7%.

Conclusions: The study highlights the need for targeted screening and management strategies to address Vitamin D deficiency, particularly among younger adults, men, and poorly controlled diabetic patients.

Keywords: Vitamin D, Type 2 diabetes, India, Urban population

INTRODUCTION

Vitamin D, a fat-soluble vitamin, is primarily synthesised in the skin upon exposure to sunlight or ultraviolet (UV) radiation.¹ Despite India's geographic advantage, spanning latitudes from 8.4° N to 37.6° N and receiving ample sunlight throughout the year, numerous studies have documented a surprisingly high prevalence of vitamin D deficiency across the country.²⁻⁴ Community-based investigations have revealed that a significant proportion of the Indian population-ranging from 50% to

94%-is deficient in vitamin D. Hospital-based studies echo these findings, reporting deficiency rates between 37% and 99% among patients.^{5,6}

Multiple interrelated factors contribute to the widespread prevalence of vitamin D deficiency across India. Prominent among these are increased skin pigmentation, limited sunlight exposure, obesity, and gastrointestinal malabsorption, all of which hinder adequate synthesis or absorption of vitamin D.²⁻⁴ As Lo et al have highlighted, individuals with darker skin pigmentation, common

across much of the Indian population, require nearly twice the duration of sun exposure compared to lighter-skinned individuals to synthesise sufficient levels of vitamin D.⁷ In addition to biological determinants, evolving lifestyle patterns also play a crucial role. A growing proportion of the population now works in predominantly indoor settings, reducing opportunities for regular sunlight exposure. This is compounded by typical working hours in India, which often span from 11 am to 7 pm, overlapping almost entirely with the window of optimal ultraviolet B (UVB) radiation (11 am to 2 pm), when the skin's capacity to convert 7-dehydrocholesterol to pre-vitamin D₃ is at its peak.³ Moreover, the extreme heat during Indian summers often deters people from spending time outdoors during these midday hours. Collectively, these behavioural and environmental factors significantly limit sun exposure and have become key contributors to the persistently low vitamin D levels observed in the Indian population.⁸

Vitamin D plays a critical role in metabolic health, particularly in context of diabetes. It is essential for insulin biosynthesis, influencing pancreatic β -cell function through activation of calcium-dependent endopeptidases and improving insulin sensitivity in peripheral tissues, thereby enhancing glucose metabolism.⁹⁻¹²

While several cross-sectional studies have examined the prevalence of vitamin D deficiency in the general population, there remains a notable gap in the literature focusing on at-risk subgroups, particularly individuals with type 2 diabetes. Addressing this gap, the present retrospective cohort study explores the patterns of vitamin D management among newly diagnosed type 2 diabetes patients, aiming to contribute to more tailored and effective clinical strategies for this vulnerable group.

METHODS

Study population

This study is based on retrospective diabetes cohort research conducted collaboratively by the international institute for population sciences and the medical division of the Bhabha Atomic Research Centre Hospital.¹³ During 2010-12, approximately 30,463 CHSS beneficiaries were registered with the hospital, and clinical tests revealed that among these, 835 beneficiaries aged 30 years and above were newly diagnosed with diabetes in the years 2011 and 2012. These individuals with diabetes were retrospectively followed up until 2021. All patients in the cohort have comprehensive medical records available, including laboratory records, drug records, and details of outpatient and inpatient visits during the study period. The healthcare services utilised by the patients are contributory, with support from the government employer, thereby minimising disparities due to financial constraints. A detailed characterisation of the study population is available here.¹³

Data

In a cohort of 835 individuals with diabetes, 545 underwent testing for vitamin D levels, which are categorised as follows: less than 20 ng/ml indicating deficiency, 20-30 ng/ml indicating insufficiency, 30-100 ng/ml as sufficient, 100-150 ng/ml as excess, and above 150 ng/ml as toxicity.¹⁴ Additionally, within these 545 individuals, 436 also received HbA1c testing either seven days before or after their vitamin D test. The HbA1c levels were stratified into three groups according to the glycemic management guidelines set by the Indian council of medical research (ICMR) for individuals with diabetes in India: below 7% (Ideal), 7% to less than 8% (Satisfactory), and 8% or higher (Unsatisfactory).¹⁵

Statistical analysis

Descriptive statistics, such as the frequency of vitamin D tests, were analysed over a 10-year period to explore changes in vitamin D status over time. This analysis was divided into two five-year intervals. The study examined the percentage of individuals in each vitamin D category based on their most recent test results during these two periods.

In this study, ordered logistic regression is employed to evaluate the impact of various factors on the likelihood of vitamin D deficiency. The analysis includes two models, model I and model II. Model I consists of 545 diabetes patients who have undergone vitamin D testing out of the 845-study population. Model II consists of 436 out of these 545 cases that also have HbA1c test results. The analysis incorporates the following independent variables: Sex (Men and Women), intake of vitamin D drugs within the last six months (yes or no), age at diabetes diagnosis (30-44, 45-59, and 60+ years), diabetes duration (0 to 5 years, and five years and beyond), and HbA1c levels. Odds ratios and their corresponding 95% confidence intervals are calculated to determine the strength and direction of the associations. Statistical significance is set at $p < 0.05$. All statistical analyses are performed using the software STATA.

When investigating the influence of factors on vitamin D deficiency, the data structure has been adjusted from a longitudinal to a cross-sectional approach. This modification is implemented due to the time-dependent nature of the factors involved. The rationale behind this shift in data structure is to treat each vitamin D lab test as an independent event. Further, to minimise the potential autocorrelation that could occur with more frequent testing, records with a minimum six-month interval between two consecutive vitamin D tests are selected for an individual ID.

RESULTS

To understand how vitamin D status evolves over course of type 2 diabetes, we examined trends in deficiency

prevalence over a ten-year follow-up period. Analysis focused on differences by sex and age at Diabetes diagnosis with distributions presented in Figures 1 and 2. Figures 1 and 2 reveal a notable increase in vitamin D deficiency over the ten-year follow-up period, with

prevalence rising from 39.44% to 54.79% in men and 35.94% to 48.41% in women. The overall deficiency rate increased from 37.19% to 50.96%, with men consistently exhibiting higher rates than women.

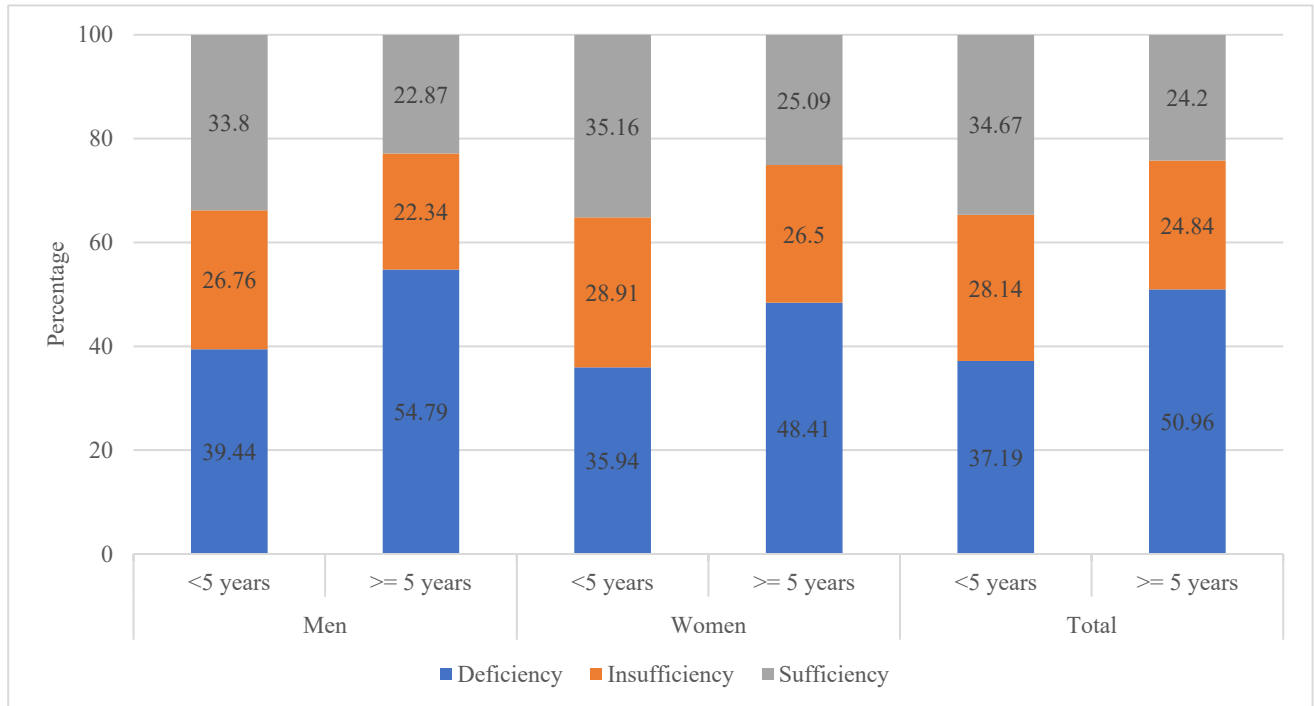


Figure 1: Sex-wise distribution of diabetes patients by vitamin D levels: 0–5 vs. 5+ years of diabetes duration.

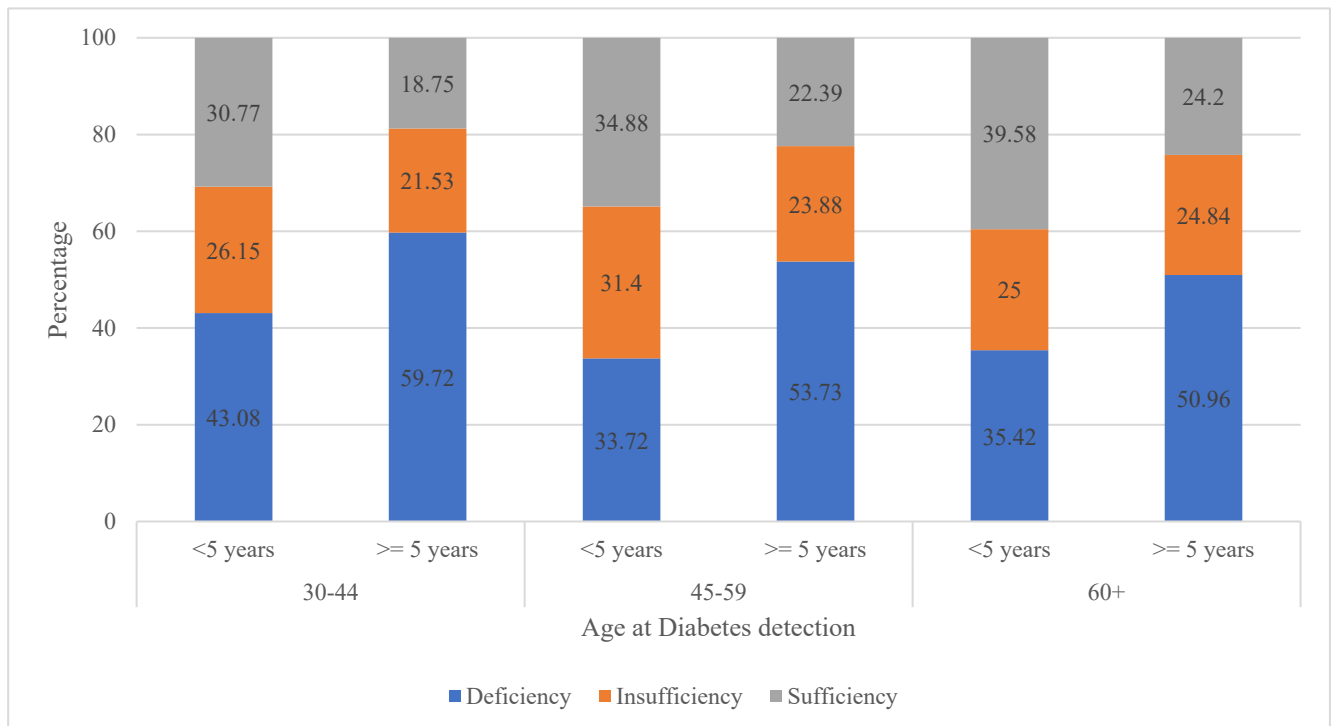


Figure 2: Age at diabetes detection wise distribution of diabetes patients by vitamin D levels: 0–5 vs. 5+ years of diabetes duration.

When stratified by age at diabetes diagnosis, deficiency was more pronounced in those diagnosed at younger ages. For individuals diagnosed at 30-44 years, prevalence rose from 43.08% to 59.72%, and for those diagnosed at 45-59 years, from 33.72% to 53.73%. In contrast, those diagnosed at 60 years or older showed only a marginal increase (35.42% to 36.51%). As presented in Table 1, the number of vitamin D tests conducted among the study

population increased markedly over the 10-year study period, from 272 tests in the first five years to 1,127 tests in the subsequent five years. Despite this rise, the proportion of tests performed following vitamin D supplementation declined with increasing diabetes duration, decreasing from 52.57% in the initial five-year period to 42.41% in the latter half. Across the entire study period, 44.39% of Vitamin D tests were conducted post-supplementation.

Table 1: Descriptive statistics of vitamin D test observations for 545 individuals by HbA1c categories in the study population.

Variables	Ideal (HbA1c <7)	Satisfactory (HbA1c 7-8)	Unsatisfactory (HbA1c ≥8)	No data on HbA1c levels	Total
No. of observations (M:F) total	632 (259:373)	187 (74:113)	146 (70:76)	434 (133:301)	1399 (536:863)
No. of observations (M:F) <5 years diabetes duration	107 (46:61)	27 (11:16)	15 (5:10)	123 (36:87)	272 (98:174)
No. of observations (M:F) ≥5 years diabetes duration	525 (213:312)	160 (63:97)	131 (65:66)	311 (97:214)	1127 (438:689)
No. of observations under vitamin D supp. intake (%) total	249 (42.13%)	84 (39.07%)	61 (38.36%)	227 (52.3%)	621 (44.39%)
No. of observations under vitamin D supp. intake (%) less than 5 diabetes duration	46 (46.00%)	16 (55.17%)	12 (60.00%)	69 (56.1%)	143 (52.57%)
No. of observations under vitamin D supp. intake (%) 5 and above diabetes duration	203 (41.34%)	68 (36.56%)	49 (35.25%)	158 (50.8%)	478 (42.41%)
Mean vitamin D levels (SE) <5 years diabetes duration	26.68(1.76)	29.82(3.52)	20.07(2.11)	35.58(2.57)	30.55 (1.42)
Mean vitamin D levels (SE) ≥ 5 years diabetes duration	24.75 (0.63)	22.42 (0.98)	19.38 (0.90)	26.38 (1.08)	24.15 (0.45)
Total (considering all vitamin D tests)					
Deficiency (%)	244 (41.29%)	109 (50.70%)	95 (59.75%)	162 (37.33%)	610 (43.6%)
Insufficiency (%)	187 (31.64%)	58 (26.98%)	43 (27.04%)	124 (28.57%)	412 (29.45%)
Sufficiency (%)	160 (27.07%)	48 (22.33%)	21 (13.21%)	148 (34.1%)	377 (26.95%)
Less than 5 diabetes duration (considering all vitamin D tests)					
Deficiency (%)	36 (36.00%)	11 (37.93%)	12 (60.00%)	37 (30.08%)	96 (35.29%)
Insufficiency (%)	35 (35.00%)	9 (31.03%)	5 (25.00%)	29 (23.58%)	78 (28.68%)
Sufficiency (%)	29 (29.00%)	9 (31.03%)	3 (15.00%)	57 (46.34%)	98 (36.03%)
5 and above diabetes duration (considering all vitamin D tests)					
Deficiency (%)	208 (42.36%)	98 (52.69%)	83 (59.71%)	125 (40.19%)	514 (45.61%)
Insufficiency (%)	152 (30.96%)	49 (26.34%)	38 (27.34%)	95 (30.55%)	334 (29.64%)
Sufficiency (%)	131 (26.68%)	39 (20.97%)	18 (12.95%)	91 (29.26%)	279 (24.76%)

Mean vitamin D concentrations were consistently lower among participants with poorer glycemic control, regardless of diabetes duration. Among individuals with diabetes duration of less than five years, mean Vitamin D levels were 26.68 ng/ml (SE 1.76) for those with HbA1c <7%, 29.82 ng/ml (SE 3.52) for HbA1c 7-8%, and 20.07 ng/ml (SE 2.11) for HbA1c ≥8%. In participants with diabetes duration of five years or more, the corresponding mean levels were 24.75 ng/ml (SE 0.63), 22.42 ng/mL (SE 0.98), and 19.38 ng/ml (SE 0.90), respectively.

A parallel trend was evident in the prevalence of vitamin D deficiency, which increased with worsening glycemic control. Among individuals with diabetes duration <5 years, deficiency was present in 36.00% of those with

HbA1c <7%, 37.93% with HbA1c 7-8%, and 60.00% with HbA1c ≥8%. For those with diabetes ≥5 years, the prevalence of deficiency was even higher, recorded at 42.36%, 52.69%, and 59.71%, respectively, across the same HbA1c categories.

Further stratification based on vitamin D supplementation within six months prior to testing revealed that post-supplement tests were associated with higher mean vitamin D levels compared to those without supplementation (Table 2). During the first five years, the mean levels were 33.17 ng/ml (SE 1.95) among supplemented individuals versus 27.66 ng/ml (SE 2.04) among non-supplemented ones. In the subsequent five years, these means were 25.52 ng/ml (SE 0.65) and 23.15 ng/ml (SE 0.62), respectively.

Table 2: Descriptive statistics of vitamin D test observations with and without vitamin D supplement intake in the last 6 months for 545 Individuals by HbA1c categories in the study population.

Vitamin D supplementation	Ideal (HbA1c <7)		Satisfactory (HbA1c 7-8)		Unsatisfactory (HbA1c ≥8)		No data on HbA1c levels		Total	
	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
No. of observations (M:F) total	342 (145:197)	249 (99:150)	131 (60:71)	84 (24:60)	98 (46:52)	61 (29:32)	207 (70:137)	227 (63:164)	778 (321:457)	621 (215:406)
No. of observations (M:F) <5 years diabetes duration	54 (28:26)	46 (15:31)	13 (7:6)	16 (5:11)	8 (5:3)	12 (2:10)	54 (23:31)	69 (13:56)	129 (63:66)	143 (35:108)
No. of observations (M:F) ≥5 years diabetes duration	288 (117:171)	203 (84:119)	118 (53:65)	68 (19:49)	90 (41:49)	49 (27:22)	153 (47:106)	158 (50:108)	649 (258:391)	478 (180:298)
Mean vitamin D levels (SE) <5 years diabetes duration	22.93 (2.45)	31.09 (2.37)	27.03 (5.00)	32.08 (4.99)	24.83 (3.22)	16.91 (2.47)	32.95 (3.92)	37.63 (3.40)	27.66 (2.04)	33.17 (1.95)
Mean vitamin D levels (SE) ≥5 years diabetes duration	23.68 (0.85)	26.25 (0.93)	22.10 (1.35)	22.97 (1.31)	18.48 (1.04)	21.05 (1.68)	25.69 (1.69)	27.05 (1.34)	23.15 (0.62)	25.52 (0.65)
Total										
Deficiency (%)	168 (49.12)	76 (30.52)	73 (55.73)	36 (42.86)	59 (60.2)	36 (59.02)	91 (43.96)	71 (31.28)	391 (50.26)	219 (35.27)
Insufficiency (%)	93 (27.19)	94 (37.75)	30 (22.9)	28 (33.33)	29 (29.59)	14 (22.95)	54 (26.09)	70 (30.84)	206 (26.48)	206 (33.17)
Sufficiency (%)	81 (23.68)	79 (31.73)	28 (21.37)	20 (23.81)	10 (10.2)	11 (18.03)	62 (29.95)	86 (37.89)	181 (23.26)	196 (31.56)
Less than 5 diabetes duration										
Deficiency (%)	27 (50)	9 (19.57)	06 (46.15)	5 (31.25)	3 (37.5)	9 (75)	22 (40.74)	15 (21.74)	58 (44.96)	38 (26.57)
Insufficiency (%)	18 (33.33)	17 (36.96)	04 (30.77)	5 (31.25)	3 (37.5)	2 (16.67)	11 (20.37)	18 (26.09)	36 (27.91)	42 (29.37)
Sufficiency (%)	9 (16.67)	20 (43.48)	03 (23.08)	6 (37.5)	2 (25)	1 (8.33)	21 (38.89)	36 (52.17)	35 (27.13)	63 (44.06)
5 and above diabetes duration										
Deficiency (%)	141 (48.96)	67 (33.00)	67 (56.78)	31 (45.59)	56 (62.22)	27 (55.1)	69 (45.10)	56 (35.44)	333 (51.31)	181 (37.87)
Insufficiency (%)	75 (26.04)	77 (37.93)	26 (22.03)	23 (33.82)	26 (28.89)	12 (24.49)	43 (28.10)	52 (32.91)	170 (26.19)	164 (34.31)
Sufficiency (%)	72 (25.00)	59 (29.06)	25 (21.19)	14 (20.59)	8 (8.89)	10 (20.41)	41 (26.80)	50 (31.65)	146 (22.5)	133 (27.82)

Despite supplementation, 35.27% of post-supplement tests still showed vitamin D deficiency. In contrast, deficiency was observed in 50.26% of tests without any supplementation in the preceding six months, suggesting that while supplementation improves vitamin D levels, it may not be sufficient to fully mitigate deficiency, particularly in high-risk groups.

Table 3 summarises the ordered logistic regression analysis identifying determinants of vitamin D deficiency among patients with diabetes. Two models were examined to assess the robustness of associations.

Women had significantly lower odds of vitamin D deficiency compared with men, with odds ratios (OR) of 0.67 in model I and 0.66 in model II. Age at diabetes diagnosis also showed a strong inverse relationship with vitamin D deficiency. Relative to individuals diagnosed between 30-44 years, those diagnosed at 45-59 years had lower odds (OR=0.72 in model I; 0.69 in model II), while those diagnosed at ≥60 years had markedly reduced odds (OR=0.48 and 0.47, respectively), corresponding to a 52-55% lower likelihood of deficiency. Given that we are tracking participants for 10 years from the baseline, which is the date of diabetes diagnosis, this observation also indicates that younger individuals have a higher risk of vitamin D deficiency.

Table 3: Ordered logistic regression analysis of factors influencing vitamin D deficiency in diabetes patients.

Variables	Model I				Model II			
	OR	SE	P>z	95% CI	OR	SE	P>z	95% CI
Sex								
Men	1 (ref)				1 (ref)			
Women	0.67	0.07	0	(0.55-0.83)	0.66	0.08	0.01	(0.52-0.85)
Age group based on age at the time of diabetes diagnosis (in years)								
30-44	1 (ref)				1 (ref)			
45-59	0.72	0.09	0.01	(0.57-0.91)	0.69	0.1	0.01	(0.51-0.94)
60+	0.48	0.07	0	(0.37-0.63)	0.47	0.08	0	(0.34-0.66)
Diabetes duration								
Less than 5 years	1 (ref)				1 (ref)			
5 years and beyond	1.55	0.2	0	(1.2-2.01)	1.2	0.2	0.27	(0.87-1.67)
Vitamin D supplement Intake in last 6 months								
No	1 (ref)				1(ref)			
Yes	0.64	0.06	0	(0.52-0.78)	0.64	0.08	0	(0.50-0.82)
HbA1c level								
<7 (Ideal)					1 (ref)			
7-8 (Satisfactory)					1.46	0.22	0.01	(1.08-1.96)
≥8 (Unsatisfactory)					1.92	0.35	0	(1.34-2.74)

DISCUSSION

Our study found a rising trend in vitamin D deficiency among individuals with type 2 diabetes, with the prevalence increasing from 37.19% in the first five years following diagnosis to 50.96% in the subsequent five years.

While this trend indicates a worsening deficiency over time, the observed rates remain comparatively lower than those reported in previous cross-sectional studies across India. For instance, Palazhy et al documented a prevalence of 71.4% in South India among individuals with type 2 diabetes, while a pan-India study reported an even higher rate of 84.2%.^{16,17} Regional studies from Pune, as well as from other areas, have noted prevalence rates ranging from 74.14% to 85.8%.¹⁸⁻²⁰ One plausible explanation for the comparatively lower prevalence in our study is the methodological difference in assessing deficiency. Previous studies included patients across varying stages of diabetes, potentially inflating the overall prevalence. In contrast, our study focused on the most recent test results and analysed trends over two distinct periods. Additionally, the relatively lower prevalence in our sample may reflect improved awareness, access to testing, and preventive health behaviour facilitated by employer-sponsored healthcare services.

Sex-based analysis in our study revealed that men had consistently higher rates of vitamin D deficiency than women, a finding consistent with results from the Asian Indian diabetic heart study (AIDHS) and the Sikh diabetes study (SDS).¹⁹⁻²² A possible explanation may be the occupational profiles of male participants, many were engaged in indoor, sedentary work, reducing sunlight exposure, a key source of endogenous vitamin D synthesis.²³ Interestingly, studies focusing on postmenopausal women with diabetes suggest that older women may be less affected by vitamin D deficiency,

possibly due to greater health-seeking behaviours or supplementation awareness.²⁴⁻²⁶ Nevertheless, this trend is not universal.^{27,28} Several studies from India have reported higher deficiency rates among women.^{29,30}

We also found that younger adults (30-44 years) exhibited higher odds of vitamin D deficiency than older individuals. This finding echoes patterns observed in Korean populations.^{23,31} Greater health awareness and utilisation of healthcare services among the elderly and women may partly explain this trend. Prior studies have noted that Indian men tend to delay seeking healthcare compared to women, which could contribute to underdiagnosis and unmanaged deficiency in younger male patients.^{32,33} Moreover, the role of structured and subsidised healthcare in our population may have facilitated better monitoring and supplementation among older individuals, mitigating their risk.

Previous research has yielded mixed findings on the relationship between vitamin D status and glycemic control. For instance, a study conducted between April 2012 and July 2014 among predominantly sedentary individuals, comprising office workers and housewives, reported alarmingly high rates of Vitamin D deficiency in both diabetic (91%) and non-diabetic (93%) participants. However, linear regression analysis in this study found no significant association between Vitamin D levels and HbA1c.⁸ Similarly, a study from South India observed a tendency toward increased glycemic intolerance among individuals with vitamin D deficiency, but the association did not reach statistical significance.²⁹

In contrast, our study observed a clear association between elevated HbA1c levels and increased risk of vitamin D deficiency, aligning with findings from several South Asian studies. For example, Iqbal et al reported that 58.7% of individuals with poor glycemic control had vitamin D deficiency, compared to 30.6% of those with

good control.¹¹ Similarly, Bhattacharya et al found that severe deficiency was more common in uncontrolled diabetics, with only 8% exhibiting normal vitamin D levels, compared to 24% in the controlled group.⁹ An additional study from Kanpur identified an inverse correlation between vitamin D levels and glycosylated haemoglobin.¹⁰ These consistent findings across diverse populations lend support to the hypothesis that poor glycemic control may contribute to or be exacerbated by low vitamin D levels.

We also explored the role of diabetes duration in shaping vitamin D status. Although individuals with a diabetes duration of ≥ 5 years had higher odds of deficiency, the association did not remain statistically significant in our adjusted model. This aligns partially with findings from Joergensen et al who reported a similar trend but could not establish a significant link.³⁴ Other studies have observed a negative correlation between diabetes duration and vitamin D levels, suggesting that prolonged hyperglycemia and associated metabolic changes may impair vitamin D metabolism.^{35,36} However, these associations are not consistently reported across the literature, with several cross-sectional studies finding no significant relationship.³⁶⁻³⁸ These inconsistencies hint at the complex interplay of metabolic, behavioural, and healthcare factors influencing Vitamin D status in individuals with diabetes.

In summary, our study adds to the growing body of evidence that sex, age, glycemic control, and potentially diabetes duration are important determinants of vitamin D deficiency among people with type 2 diabetes. While causality cannot be inferred, the findings emphasise the need for targeted screening and supplementation strategies, particularly for younger adults, men, and poorly controlled diabetic patients. Further longitudinal studies and interventional research are required to clarify the causal pathways.

Strengths and limitations

The study is based on the data from electronic health records. The use of electronic health records minimises concerns regarding missing or incomplete data. Furthermore, the universal contributory nature of health services ensures the mitigation of any potential disparities arising from financial constraints.

However, a limitation of our study is that the inclusion criteria of having at least one family member employed in a government institute may introduce selection bias. This limits the generalizability of the findings, especially to populations with the lowest socioeconomic backgrounds.

CONCLUSION

Our findings indicate that men and individuals diagnosed with diabetes at a younger age are more susceptible to vitamin D deficiency. Additionally, longer duration of

diabetes and poorer glycemic control, as reflected by higher HbA1c levels, are significantly associated with increased risk of deficiency.

These insights underscore the need to integrate vitamin D screening and management into routine care for diabetes patients, particularly for high-risk groups. Targeted interventions and further research are warranted to address these disparities and support optimal metabolic and bone health in this population.

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