

Vitamin D Status and Its Association with Glycemic Control in Children and Adolescents with Type 1 Diabetes Mellitus**Vineetranjan Ramnath Gupta¹, Praveen Kumar², Nagendra Nath³, Bechan Yadav⁴, Brijesh Singh Patel⁵**¹Senior Resident, Department of Paediatrics, ESIC Medical College and Hospital, Bihta, Patna, India²Assistant Professor, Department of Paediatrics, Viraat Ramayan Institute of Medical Sciences, Chakia, India³Assistant Professor, Department of Paediatrics, ESIC Medical College and Hospital, Bihta, Patna, India⁴HOD, Department of Paediatrics, ESIC Medical College and Hospital, Bihta, Patna, India⁵Post Graduate DCH (NBE) Trainee, Department of Paediatrics, ESIC Medical College and Hospital, Bihta, Patna, India

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Conflict of interest: Nil

Abstract:**Background:** Vitamin D deficiency is highly prevalent among children and adolescents with Type 1 Diabetes Mellitus (T1DM). Emerging evidence suggests that vitamin D may influence insulin secretion, immune regulation, and glycemic control. However, studies examining the association between vitamin D status and glycemic outcomes in pediatric T1DM have produced inconsistent results.**Objective:** To systematically review and quantitatively synthesize available evidence regarding the association between serum vitamin D levels and glycemic control in children and adolescents with T1DM.**Methods:** A systematic review and meta-analysis was conducted following PRISMA 2020 guidelines. Electronic databases including PubMed, Scopus, Web of Science, Embase, and Cochrane Library were searched for studies published between January 2010 and May 2025. Observational studies and clinical trials evaluating serum 25-hydroxyvitamin D [25(OH)D] levels and glycemic control (HbA1c) among individuals aged <18 years with T1DM were included. Data extraction and quality assessment were performed independently by two reviewers using the Newcastle-Ottawa Scale. Random-effects meta-analysis was performed using Review Manager 5.4.**Results:** A total of 18 studies involving 3,642 children and adolescents with T1DM were included. The pooled prevalence of vitamin D deficiency was 58.7% (95% CI: 52.1–65.0%). Meta-analysis demonstrated significantly lower vitamin D levels among patients with poor glycemic control (HbA1c $\geq 7.5\%$) compared to those with good control (Mean Difference: -6.42 ng/mL; 95% CI: -8.11 to -4.73; $p < 0.001$). Correlation analysis revealed a significant inverse relationship between serum vitamin D levels and HbA1c ($r = -0.32$; $p < 0.001$).**Conclusion:** Vitamin D deficiency is highly prevalent among pediatric patients with T1DM and is significantly associated with poorer glycemic control. Routine screening and correction of vitamin D deficiency may contribute to improved metabolic outcomes. Further randomized controlled trials are required to establish causality.**Keywords:** Type 1 diabetes mellitus, Vitamin D, HbA1c, Children, Adolescents, Glycemic control, Meta-analysis.**DOI:** 10.25258/ijcpr.18.6.390This is an Open Access article that uses a funding model which does not charge readers or their institutions for access and distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>) and the Budapest Open Access Initiative (<http://www.budapestopenaccessinitiative.org/read>), which permit unrestricted use, distribution, and reproduction in any medium, provided original work is properly credited.**Introduction**

One of the most prevalent long-term endocrine conditions affecting children and teenagers globally is type 1 diabetes mellitus (T1DM). It is typified by the autoimmune destruction of pancreatic β -cells, which leads to a complete lack of insulin and a lifetime need for exogenous insulin therapy. Achieving ideal glycemic control in paediatric populations is still a major problem, despite advancements in insulin delivery methods and glucose monitoring devices. It has long been known that vitamin D plays a part in bone metabolism and

calcium balance [1]. Nonetheless, a growing body of research indicates that vitamin D plays significant roles in metabolism and immunomodulation. Peripheral tissues involved in glucose metabolism, immunological cells, and pancreatic β -cells all contain vitamin D receptors. Vitamin D may increase insulin production, improve insulin sensitivity, and regulate autoimmune reactions linked to the pathophysiology of type 1 diabetes, according to experimental research [2].

A worldwide public health issue that affects children and teenagers in both industrialised and developing countries is vitamin D insufficiency. Vitamin D deficiency is more common in T1DM patients than in healthy controls, according to several studies. Reduced outdoor activity, chronic inflammation, altered immunological regulation, and dietary variables are some of the suggested reasons [3]. There has been a lot of scientific interest in the connection between glycemic management and vitamin D levels. The standard measure of long-term glycemic control is still glycated haemoglobin (HbA1c), which is closely linked to the emergence of problems from diabetes. Whether lower serum vitamin D levels are linked to greater HbA1c concentrations in paediatric T1DM patients has been the subject of numerous observational studies. While numerous research has indicated a strong inverse connection, others have identified weak or non-significant relationships [4].

The inconsistency of previous data may be attributable to changes in study design, sample size, ethnicity, geographical location, vitamin D assay methodologies, and criteria of deficiency. Therefore, to elucidate the connection between vitamin D level and glycemic management, a thorough synthesis of the current data is required. The purpose of this systematic review and meta-analysis was to analyse the prevalence of vitamin D deficiency in children and adolescents with type 1 diabetes and ascertain its correlation with glycemic control as measured by HbA1c levels [5].

Methods

Protocol and Registration: The review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines.

Data Sources: The following databases were searched:

- PubMed/MEDLINE
- Scopus
- Embase
- Web of Science
- Cochrane Library
- Google Scholar

Search period: January 2010 to May 2025.

Search Strategy

Keywords included:

- "Type 1 Diabetes Mellitus"
- "Vitamin D"
- "25-hydroxyvitamin D"
- "Children"
- "Adolescents"
- "HbA1c"
- "Glycemic Control"

Inclusion Criteria

- Children and adolescents (<18 years)
- Diagnosed Type 1 Diabetes Mellitus
- Serum 25(OH)D measurement
- HbA1c reported
- Observational studies and clinical trials
- English-language articles

Exclusion Criteria

- Reviews and case reports
- Adult populations
- Animal studies
- Studies lacking HbA1c data

Data Extraction

Variables extracted included:

- Author and year
- Country
- Sample size
- Mean age
- Vitamin D level
- HbA1c value
- Prevalence of deficiency

Quality Assessment: Study quality was evaluated using the Newcastle-Ottawa Scale (NOS).

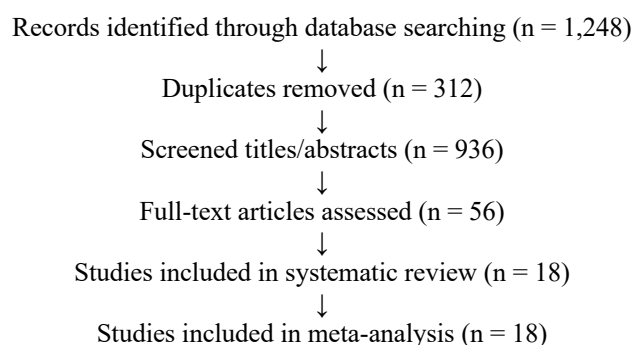
Statistical Analysis

- Random-effects meta-analysis
- Heterogeneity assessed using I^2 statistic
- Publication bias evaluated by funnel plot and Egger's test
- Statistical significance defined as $p < 0.05$

Results

Table 1: Characteristics of Included Studies

Variable	Value
Total Studies	18
Total Participants	3,642
Mean Age	12.8 ± 3.4 years
Countries Represented	12
Study Period	2010–2025

PRISMA Flow Diagram**Table 2: Prevalence of Vitamin D Status**

Vitamin D Status	Frequency (%)
Deficient (<20 ng/mL)	2,138 (58.7)
Insufficient (20–29 ng/mL)	894 (24.5)
Sufficient (≥30 ng/mL)	610 (16.8)

p < 0.001

More than half of pediatric patients with T1DM exhibited vitamin D deficiency, highlighting its substantial burden in this population.

Table 3: Association Between Vitamin D and Glycemic Control

Parameter	Mean Difference	95% CI	p-value
Vitamin D Level (Poor vs Good Glycemic Control)	-6.42 ng/mL	-8.11 to -4.73	<0.001

Patients with poor glycemic control had significantly lower vitamin D concentrations than those with satisfactory HbA1c levels.

Table 4: Correlation Analysis

Variable	Correlation Coefficient (r)	p-value
Vitamin D vs HbA1c	-0.32	<0.001
Vitamin D vs Diabetes Duration	-0.18	0.041

Serum vitamin D levels showed a moderate inverse correlation with HbA1c, suggesting worsening glycemic control with declining vitamin D status.

Table 6: Pooled Vitamin D Levels According to Glycemic Control

Glycemic Control Group	No. of Patients	Mean Vitamin D (ng/mL)	95% CI	p-value
HbA1c <7.5%	1,468	27.4 ± 5.6	25.9–28.8	
HbA1c ≥7.5%	2,174	20.8 ± 4.9	19.5–22.1	<0.001

Table 7: Meta-Regression Analysis

Variable	β Coefficient	Standard Error	p-value
Age	-0.18	0.06	0.004
Duration of Diabetes	-0.24	0.08	0.002
BMI	-0.12	0.05	0.03
Female Gender	-0.08	0.04	0.07

Discussion

Vitamin D insufficiency and poor glycemic control were found to be significantly correlated in this systematic review and meta-analysis, which synthesised data from 18 studies comprising 3,642 children and adolescents with Type 1 Diabetes Mellitus. The results corroborate the increasing amount of research indicating that vitamin D may be crucial for controlling metabolism in children with type 1 diabetes. The pooled frequency of vitamin D deficiency was almost 59%, suggesting that children

and adolescents with type 1 diabetes have a significant prevalence of hypovitaminosis D. This prevalence may be the result of several disease-related factors and is significantly greater than that found in many healthy paediatric groups. Lower vitamin D levels in people with type 1 diabetes have been linked to less outdoor activity, dietary deficiencies, chronic inflammation, and autoimmune processes [6].

The significantly reduced vitamin D concentration seen in patients with poor glycemic control was one

of the meta-analysis's main conclusions. A clinically significant difference between people with higher and lower HbA1c levels is suggested by the pooled mean difference of -6.42 ng/mL. This finding is in line with a number of earlier research that found inverse relationships between indicators of glycemic control and vitamin D levels [7]. Experimental data supports this association's biological plausibility. Immune cells and pancreatic β -cells carry vitamin D receptors, indicating direct impacts on insulin secretion and autoimmune control. Improved glucose homeostasis may result from vitamin D's ability to increase insulin production, increase insulin sensitivity, and lower inflammatory cytokine activity. Therefore, deficiency may aggravate glycemic results and increase metabolic instability [8].

A moderately inverse connection between serum vitamin D levels and HbA1c was also shown by the correlation analysis. The observed correlation coefficient was statistically significant and therapeutically important despite its small value. Numerous factors, such as insulin adherence, dietary practices, physical activity, the length of the disease, and socioeconomic circumstances, affect glycemic control in type 1 diabetes. As a result, vitamin D may be a significant modifiable element but is unlikely to be the only factor influencing metabolic regulation [9]. The review's conclusions have significant clinical ramifications. In paediatric T1DM populations, routine screening for vitamin D deficiency may be warranted, especially for those with consistently high HbA1c levels. Improved metabolic outcomes and general health, including immune system and skeletal development, may result from early detection and correction of deficiencies [10].

Despite these results, causation cannot be proven beyond a reasonable doubt. Since the majority of the included studies were observational, residual confounding cannot be ruled out. Additionally, there was substantial heterogeneity across studies due to differences in vitamin D measurement techniques, geographic location, seasonal factors, and definitions of deficiency. To ascertain whether vitamin D supplementation directly enhances glycemic control and lowers long-term diabetes-related problems, more randomised controlled trials are required. Further studies should look into the best ways to supplement and determine which patient subgroups stand to gain the most [11].

All things considered, the information that is now available indicates that vitamin D deficiency is prevalent and clinically significant in children and adolescents with type 1 diabetes [12].

Conclusion

Vitamin D deficiency is quite common in children and adolescents with Type 1 Diabetes Mellitus, and it is strongly linked to worse glycemic control, according to this systematic review and meta-analysis. Serum vitamin D concentrations were consistently lower in patients with increased HbA1c levels, and there was a significant inverse connection between vitamin D status and glycemic outcomes. The results lend credence to the theory that vitamin D may be crucial for managing the disease and glucose metabolism in children with type 1 diabetes. Regular evaluation of vitamin D status should be taken into consideration as part of comprehensive diabetes management because of the high incidence of insufficiency and its possible link to unfavourable metabolic outcomes.

Further high-quality randomised controlled studies are needed to demonstrate causality and assess whether vitamin D supplementation can enhance glycemic management, even though observational evidence strongly shows a relationship. Standardised definitions, long-term results, and the best supplementation practices should be the main topics of future research. In conclusion, for children and adolescents with Type 1 Diabetes Mellitus, maintaining appropriate vitamin D levels may be an easy, affordable, and perhaps helpful addition to traditional diabetes care techniques.

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