

Association Between Diabetes Mellitus and Anemia in Adolescents: Prevalence and Clinical Implications

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Abstract

Background: Vitamin D plays essential roles in calcium homeostasis, immune modulation, and inflammatory regulation, suggesting potential implications for periodontal health. Adolescence represents a critical period for both skeletal development and establishment of periodontal health patterns, yet research examining vitamin D–periodontal relationships in this population remains limited. **Objective:** This study aimed to investigate the correlation between serum vitamin D levels and periodontal health parameters among adolescents, exploring potential associations with gingivitis severity and clinical attachment status. **Methods:** A cross-sectional analytical study was conducted among 486 adolescents aged 12–17 years. Serum 25-hydroxyvitamin D [25(OH)D] concentrations were measured using chemiluminescent immunoassay. Periodontal assessment included plaque index (PI), gingival index (GI), bleeding on probing (BOP), probing depth (PD), and clinical attachment level (CAL). Participants were categorized by vitamin D status: deficient (<20 ng/mL), insufficient (20–29 ng/mL), and sufficient (≥30 ng/mL). Pearson correlation, ANOVA, and multivariable regression analyses evaluated associations. **Results:** Mean serum 25(OH)D was 24.67 ± 9.84 ng/mL, with 31.5% classified as deficient, 38.9% as insufficient, and 29.6% as sufficient. Vitamin D-deficient adolescents demonstrated significantly higher mean GI (1.67 ± 0.48) compared to sufficient participants (1.12 ± 0.39 ; $p < 0.001$). Significant negative correlations were observed between 25(OH)D and GI ($r = -0.412$, $p < 0.001$), BOP ($r = -0.387$, $p < 0.001$), and PI ($r = -0.298$, $p < 0.001$). Multivariable regression confirmed vitamin D deficiency as independently associated with gingivitis (OR=2.34; 95% CI: 1.56–3.51; $p < 0.001$) after adjusting for confounders. **Conclusion:** Vitamin D levels demonstrate a significant inverse correlation with periodontal inflammation markers in adolescents. Vitamin D deficiency is independently associated with increased gingivitis severity, suggesting potential benefits of adequate vitamin D status for adolescent periodontal health.

Keywords: Diabetes mellitus, anemia, adolescents, comorbidity, glycemic control, clinical outcomes, functional status

1. Introduction

Anemia is a common public health problem worldwide and represents a significant cause of morbidity, particularly among adolescents. It is characterized by a reduction in hemoglobin concentration or red blood cell count, leading to decreased oxygen-carrying capacity of the blood. Globally, anemia affects a substantial proportion of the adolescent population, with a higher prevalence in low- and middle-income countries due to nutritional deficiencies, infections, and other health conditions [1]. The burden of anemia during adolescence is of particular concern, as it can impair physical growth, cognitive development, and overall quality of life [2]. Diabetes mellitus is a chronic metabolic disorder characterized by persistent hyperglycemia and is increasingly being diagnosed among adolescents worldwide. The global prevalence of diabetes has risen markedly in recent decades, driven by lifestyle changes, obesity, and genetic predisposition [3]. In adolescents, diabetes—particularly type 1 and type 2—can have profound systemic effects, including alterations in metabolism, inflammation, and organ function [4]. Emerging evidence suggests that diabetes may also influence hematological parameters, potentially contributing to the development of anemia through mechanisms such as chronic inflammation, renal impairment, and reduced erythropoietin production [5]. In adolescents with diabetes mellitus, anemia is increasingly recognized as a potential comorbid condition that may adversely affect clinical outcomes. Chronic hyperglycemia can lead to microvascular complications, including diabetic nephropathy, which plays a

significant role in the development of anemia [6]. Additionally, nutritional deficiencies, poor glycemic control, and increased oxidative stress may further contribute to reduced hemoglobin levels in this population [7]. The coexistence of anemia and diabetes may exacerbate fatigue, reduce physical capacity, and negatively affect daily functioning and disease management [8]. Adolescence is a critical developmental period marked by rapid growth, hormonal changes, and increased nutritional demands. The presence of chronic conditions such as diabetes, combined with anemia, may significantly affect both physical and psychological well-being. Adolescents may experience decreased academic performance, reduced exercise tolerance, and emotional distress, all of which can hinder optimal development and quality of life [9]. Poor metabolic control may further aggravate anemia and its associated complications, creating a cycle that affects overall health status [10]. Effective management of adolescents with diabetes requires a comprehensive approach that considers not only glycemic control but also associated comorbidities such as anemia. Early detection and appropriate management of anemia are essential to prevent complications and improve overall health outcomes. Clinical strategies increasingly emphasize the importance of routine screening for hematological abnormalities in diabetic patients to ensure timely intervention [11]. Addressing both metabolic and hematological aspects of care may enhance treatment effectiveness and patient well-being [12]. Previous studies have indicated that individuals with diabetes may have a higher prevalence of anemia compared with non-diabetic populations, and this association may be particularly significant in younger age groups [13]. However, despite growing interest in this area, limited data remain regarding the prevalence and clinical implications of anemia among adolescents with diabetes in different populations and healthcare settings [14]. Therefore, this study aims to evaluate the prevalence of anemia among adolescents with diabetes mellitus and to assess its association with clinical characteristics and potential health outcomes. This research seeks to provide further insight into the interplay between diabetes and anemia in this age group, thereby contributing to improved clinical management and healthcare strategies.

2 Methodology

2.1 Study Design and Registration

This study was a hospital-based cross-sectional analytical study designed to evaluate the prevalence of anemia and its clinical implications among adolescents with diabetes mellitus. The study followed standard reporting guidelines for observational studies, namely the STROBE checklist. The study was conducted over a period of three years, from January 2022 to December 2024.

2.2 Study Setting

The study was carried out at a tertiary care teaching hospital providing specialized pediatric and endocrine services. The hospital is a governmental institution that manages a large number of adolescent patients with chronic conditions annually. Adolescents diagnosed with diabetes mellitus are followed through outpatient clinics and may require admission for evaluation and management. The study was implemented in both pediatric wards and outpatient endocrine clinics.

2.3 Study Sample

The study included 212 adolescents diagnosed with diabetes mellitus during the study period. Patients were selected using a consecutive sampling technique, whereby all eligible adolescents meeting the inclusion criteria were enrolled. This approach ensured representation of real-world clinical cases and minimized selection bias.

2.4 Sample Size Determination

The sample size was determined based on prevalence estimation using standard statistical methods. Considering an expected prevalence of anemia among adolescents with diabetes mellitus of approximately 25–30%, a confidence level of 95%, and a margin of error of 5%, the required sample size was calculated to be approximately 200 participants. To enhance the power of the study and account for incomplete data, the sample size was increased to 212 adolescents.

2.5 Criteria for Selection of Study Sample

2.5.1 Inclusion Criteria.

Adolescents aged 10–19 years

Confirmed diagnosis of diabetes mellitus, either type 1 or type 2, based on clinical and laboratory findings

Both male and female participants

Patients attending outpatient clinics or admitted for diabetes management

2.5.2 Exclusion Criteria.

Adolescents with known hematological disorders unrelated to anemia, such as hemoglobinopathies

History of acute bleeding or recent blood transfusion

Patients with chronic diseases affecting hemoglobin levels, such as advanced renal or hepatic failure

Incomplete clinical or laboratory data

2.6 Data Collection Tools

The study instrument consisted of two main parts:

Part One: Sociodemographic and Clinical Data Form

This part was developed by the researcher based on previous literature [15, 16]. It included the following variables: age, gender, body mass index (BMI), and medical history. It also included clinical parameters such as type and duration of diabetes, glycemic control, and associated comorbidities.

Part Two: Laboratory and Outcome Assessment

This section included laboratory investigations such as hemoglobin level, hematocrit, and red blood cell indices to assess anemia status. Additional tests included fasting blood sugar (FBS), random blood sugar (RBS), and glycated hemoglobin (HbA1c). Clinical assessment focused on symptoms related to anemia, such as fatigue and pallor, and general health status.

2.7 Operational Definitions

Diabetes Mellitus: Defined as a prior diagnosis of diabetes or HbA1c \geq 6.5% [17]

Anemia: Defined according to age- and sex-specific hemoglobin levels based on World Health Organization criteria [18]

Obesity: Defined as BMI \geq 30 kg/m² [19]

2.8 Study Instrument Validity and Reliability

The data collection tool was reviewed by a panel of experts in pediatrics and internal medicine to ensure content validity. Necessary modifications were made based on expert recommendations. Standard laboratory methods were used for biochemical and hematological measurements to ensure reliability and accuracy.

2.9 Data Collection Procedure

Data collection was conducted throughout the study period from January 2022 to December 2024. After obtaining informed consent from participants and/or their guardians, eligible adolescents were enrolled during clinic visits or hospital admission. Sociodemographic and clinical data were collected through patient interviews and review of medical records. Laboratory values were obtained from hospital records. All data were documented using a structured data collection sheet.

2.10 Data Analysis

Data were analyzed using the Statistical Package for Social Sciences (SPSS) version 27. Continuous variables were expressed as mean \pm standard deviation (SD). Categorical variables were presented as frequencies and percentages. The Shapiro–Wilk test was used to assess normality. The chi-square (χ^2) test was used to evaluate associations between categorical variables. A p -value < 0.05 was considered statistically significant.

2.11 Ethical Considerations

Ethical approval was obtained from the Scientific Research Committee of the relevant institution prior to data collection. Informed consent was obtained from all participants and/or their legal guardians. Confidentiality and anonymity of participant data were strictly maintained throughout the study.

3 Results

Table 1 shows the baseline demographic and clinical characteristics of the adolescent study population. The mean age and BMI fall within the expected ranges for adolescents, while hemoglobin levels indicate a tendency toward mild anemia. Glycemic parameters suggest suboptimal metabolic control among the participants. Statistical analysis demonstrated significant deviations in hemoglobin and glycemic indices compared with standard reference values ($t = 4.86$ for Hb, $t = 6.75$ for HbA1c, $p < 0.001$).

Table 1: Baseline Characteristics of the Study Population (n=212)

Variable	Value
Mean Age (years)	15.2 \pm 2.6
Weight (kg)	56.8 \pm 12.4
Height (m)	1.58 \pm 0.12
BMI (kg/m ²)	22.7 \pm 4.1
Hemoglobin (g/dl)	11.2 \pm 1.6
FBS (mg/dl)	142.6 \pm 18.3
RBS (mg/dl)	210.4 \pm 22.5
HbA1c (%)	7.8 \pm 1.1

Table 2 presents the prevalence of anemia and other clinical conditions among adolescents with diabetes mellitus. Anemia was observed in a considerable proportion of participants. Chi-square analysis revealed a statistically significant distribution of these conditions across the population ($\chi^2 = 16.48$, $p < 0.01$).

Table 2: Prevalence of Anemia and Other Clinical Conditions

Condition	Frequency (%)
Anemia	84 (39.6%)
Poor Glycemic Control (HbA1c \geq 7%)	126 (59.4%)
Overweight/Obesity	48 (22.6%)
Nutritional Deficiency Indicators	52 (24.5%)

Table 3 illustrates the age-wise distribution of anemic and non-anemic adolescents. A higher proportion of anemia was observed in the older adolescent group (15–19 years). Chi-square testing confirmed a statistically significant association between age group and anemia status ($\chi^2 = 5.72, p = 0.017$), indicating that increasing age within adolescence may be associated with a higher prevalence of anemia.

Table 3: Age-wise Distribution of Anemic and Non-Anemic Adolescents

Age Group (years)	Anemic (n=84)	Non-Anemic (n=128)
10–14	36 (42.9%)	68 (53.1%)
15–19	48 (57.1%)	60 (46.9%)

Table 4 shows the association between key clinical factors and anemia status. Poor glycemic control, overweight/obesity, and longer duration of diabetes were significantly more common among anemic adolescents. Chi-square analysis demonstrated significant associations (poor glycemic control: $\chi^2 = 8.94, p < 0.01$; obesity: $\chi^2 = 6.12, p < 0.05$; duration of diabetes: $\chi^2 = 10.35, p < 0.01$), indicating that anemia is associated with poorer metabolic and clinical profiles.

Table 4: Association of Clinical Factors with Anemia Status

Risk Factor	Anemic (n=84)	Non-Anemic (n=128)	p-value
Poor Glycemic Control	60 (71.4%)	66 (51.6%)	<0.05
Overweight/Obesity	26 (31.0%)	22 (17.2%)	<0.05
Duration of Diabetes (>5 years)	40 (47.6%)	32 (25.0%)	<0.01

Table 5 compares clinical symptoms and functional status between anemic and non-anemic adolescents. Anemic participants reported higher rates of fatigue, reduced physical activity, and impaired academic performance. They also demonstrated greater functional limitations. Chi-square analysis revealed significant differences in symptom distribution and functional status ($\chi^2 = 12.67, p < 0.01$), indicating that anemia has a notable impact on daily functioning and quality of life in adolescents with diabetes.

4 Discussion

Anemia in adolescents is a multifactorial condition influenced by nutritional, metabolic, and chronic health factors. Among these, diabetes mellitus may play an important role in affecting hematological status and overall health outcomes. Glycemic control, disease duration, and associated metabolic disturbances all contribute to the development and progression of anemia in adolescents with diabetes [20]. The present study examined the prevalence of anemia and its clinical implications among adolescents with diabetes mellitus.

Table 5: Clinical Symptoms and Functional Status by Anemia Stat

Variable	Anemic (n=84)	Non-Anemic (n=128)
Symptoms		
Fatigue	58 (69.0%)	40 (31.2%)
Reduced Physical Activity	46 (54.8%)	38 (29.7%)
Poor Academic Performance	34 (40.5%)	28 (21.9%)
Functional Status		

Normal Activity	30 (35.7%)	82 (64.1%)
Mild Limitation	38 (45.2%)	34 (26.6%)
Significant Limitation	16 (19.0%)	12 (9.3%)

The findings confirmed that there were no major inconsistencies in baseline characteristics within the study population, with participants showing relatively similar demographic and clinical profiles. The mean age, body mass index, and other baseline variables reflected a representative adolescent cohort with metabolic challenges. Similar observations have been reported in previous studies where adolescent populations with chronic diseases demonstrated comparable baseline characteristics across groups [21]. Establishing such uniformity is important for accurately assessing the effect of comorbid conditions such as anemia on clinical outcomes [22]. This baseline consistency strengthens confidence that the differences observed are primarily related to anemia status rather than confounding variables. Although adolescence is characterized by rapid growth and increased physiological demands, previous studies suggest that factors such as nutritional status and metabolic control can significantly influence hematological parameters [23]. In this study, these factors were proportionally distributed, allowing clearer evaluation of the independent role of anemia. Regarding prevalence, the results showed that anemia was present in 39.6% of adolescents with diabetes mellitus. This finding is consistent with previous studies reporting a higher prevalence of anemia among diabetic populations compared with non-diabetic peers [24]. The relatively high prevalence observed in this study reinforces the potential role of diabetes as a contributing factor to anemia. Age-wise distribution revealed that anemia was more common among older adolescents (15–19 years), while younger adolescents showed comparatively lower rates. Similar patterns have been reported in earlier studies where anemia prevalence increased with age during adolescence [25]. This may be attributed to increased nutritional demands, hormonal changes, and longer duration of diabetes exposure, emphasizing the importance of early monitoring and intervention [26]. The association between anemia and key clinical factors was particularly evident in this study. Poor glycemic control, overweight/obesity, and longer duration of diabetes were significantly more prevalent among anemic adolescents. These findings are consistent with studies demonstrating that metabolic dysregulation contributes to impaired erythropoiesis and reduced hemoglobin levels [27]. Chronic hyperglycemia has been associated with inflammation, oxidative stress, and renal changes, all of which may contribute to anemia development [28]. This clustering of metabolic disturbances suggests that diabetes may act synergistically with other factors to worsen hematological status. In terms of clinical impact, the results showed that anemic adolescents experienced more pronounced symptoms, including fatigue, reduced physical activity, and decreased academic performance. A higher proportion of anemic participants also demonstrated functional limitations compared with non-anemic individuals. These findings are consistent with studies indicating that anemia negatively affects physical capacity, cognitive function, and quality of life in adolescents [29]. Reduced hemoglobin levels can impair oxygen delivery to tissues, leading to decreased energy levels and overall functional performance [30]. From the researcher's perspective, anemia may significantly compromise the daily functioning and disease management of adolescents with diabetes. The within-group observations further supported these findings, showing that adolescents with anemia consistently exhibited poorer functional status compared with their non-anemic counterparts. This suggests that routine diabetes management alone may not be sufficient to ensure optimal health outcomes. Previous research has emphasized the importance of early detection and management of anemia in improving overall well-being [3]. Regular screening and timely intervention may help mitigate the adverse effects associated with anemia [31]. From the researcher's perspective, integrating hematological assessment into diabetes care is essential for improving patient outcomes. Between-group comparisons revealed statistically significant differences in clinical symptoms and functional status, favoring non-anemic adolescents. These differences indicate that anemia has a sustained and negative effect on adolescent health. Similar conclusions have been drawn in studies highlighting the impact of anemia on physical and cognitive development [7]. Evidence suggests that untreated anemia may lead to long-term developmental consequences [9]. These consistent differences observed reinforce the need for comprehensive care strategies. The impact of diabetes on anemia can be explained by several physiological mechanisms. Chronic hyperglycemia may lead to reduced erythropoietin production, increased inflammatory cytokines, and impaired iron metabolism [11]. It may also contribute to early renal dysfunction, which plays a key role in anemia development [13]. These mechanisms collectively contribute to reduced hemoglobin levels and impaired oxygen transport [32]. From the researcher's perspective, understanding these mechanisms helps explain the higher prevalence of anemia observed in adolescents with diabetes. Another contributing factor may be nutritional deficiencies, which are common during

adolescence and may be exacerbated by chronic illness. The coexistence of metabolic and nutritional factors further complicates disease management [17]. Studies have shown that adolescents with multiple risk factors have poorer health outcomes compared with those with isolated conditions [20]. This highlights the importance of addressing all contributing factors rather than focusing on a single condition. Based on these findings, the alternative hypothesis is accepted, as adolescents with diabetes mellitus who had anemia demonstrated significantly poorer clinical symptoms and functional status compared with non-anemic individuals. Anemia represents an important comorbid condition that adversely affects health outcomes in adolescents with diabetes. Early detection, effective glycemic control, and integrated management strategies are essential to improve overall well-being and reduce the burden of complications [32].

5 Limitations

This study has some limitations. It was conducted in a single tertiary care center, which may limit the generalizability of the findings to other populations and healthcare settings. The study design was cross-sectional, which restricts the ability to establish causal relationships between diabetes mellitus and anemia in adolescents. The study primarily focused on clinical and laboratory findings at the time of assessment, and long-term outcomes and follow-up were not evaluated. Variability in patient compliance, nutritional status, and treatment regimens may have influenced the results. Additionally, detailed assessment of micronutrient deficiencies, such as iron, vitamin B12, and folate, and renal function parameters was not extensively performed, although these factors may significantly contribute to anemia in this population.

6 Implications for Practice

The findings of this study highlight the importance of early identification and effective management of anemia in adolescents with diabetes mellitus. Integrating routine screening for hemoglobin levels and hematological parameters into diabetes care protocols may improve overall health outcomes. Emphasis should also be placed on optimizing glycemic control, nutritional assessment, and appropriate supplementation when necessary. Multidisciplinary approaches involving physicians, nurses, dietitians, and educators are essential for comprehensive adolescent care. These results support the incorporation of combined metabolic and hematological management strategies within standard diabetes care pathways and emphasize the critical role of healthcare providers in improving quality of life and preventing complications.

7 Conclusion

Adolescents with anemia demonstrated higher rates of fatigue, decreased physical activity, and functional limitations compared with non-anemic individuals. These findings underscore the importance of early detection, optimal glycemic control, and comprehensive management strategies, including nutritional support, to improve health outcomes and reduce the burden of complications in this population.

Abbreviations

BMI – Body Mass Index

FBS – Fasting Blood Sugar

RBS – Random Blood Sugar

HbA1c – Glycated Hemoglobin

Hb – Hemoglobin

SD – Standard Deviation

WHO – World Health Organization

ANOVA – Analysis of Variance

Conflict of Interest

The author declares no conflicts of interest related to this study.

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