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Research Article

Lipid Profile Abnormalities and Their Association with Glycemic Control in Children with Type 1 Diabetes Mellitus: A Case-Control Study

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ABSTRACT
Background: Type 1 diabetes mellitus (T1DM) in children is associated with metabolic alterations that predispose to early cardiovascular disease. Dyslipidemia is an important modifiable risk factor and is strongly influenced by glycemic control.
Objectives: To compare the lipid profile of children with T1DM and healthy controls, and to evaluate the association between glycosylated hemoglobin (HbA1c) and dyslipidemia among diabetic children.
Methods: This prospective, hospital-based case–control study was conducted at a tertiary pediatric center from April 2020 to December 2021. Forty children with T1DM (aged 1–18 years, duration >1 year) were compared with forty age- and sex-matched healthy controls. After overnight fasting, venous samples were analyzed for blood glucose, HbA1c (in cases), and complete lipid profile including total cholesterol (TC), triglycerides (TG), HDL, LDL, VLDL, and TC/HDL ratio. Dyslipidemia was defined according to ADA criteria. Statistical significance was set at $p < 0.01$.
Results: Diabetic children had significantly higher mean levels of TC, TG, LDL, and VLDL compared to controls ($p < 0.001$), while HDL was lower but not statistically significant. Dyslipidemia was present in 67.5% of cases versus 22.5% of controls. Hypertriglyceridemia (52.5%) and elevated LDL (42.5%) were the most common abnormalities. Poor glycemic control (HbA1c ≥9%) was strongly associated with dyslipidemia (76.5% vs. 16.7%; $p < 0.001$).
Conclusion: Dyslipidemia is highly prevalent in children with T1DM and is strongly linked to poor glycemic control. Early screening and optimization of metabolic control may reduce long-term cardiovascular risk in this population.

Keywords: Type 1 Diabetes Mellitus, Dyslipidemia, Lipid Profile, Hba1c, Pediatric Endocrinology, Cardiovascular Risk.

INTRODUCTION

Type 1 diabetes mellitus (T1DM) is a chronic autoimmune disorder characterized by absolute insulin deficiency resulting from immune-mediated destruction of pancreatic β-cells [1]. It accounts for approximately 10% of all diabetes cases worldwide and is one of the most common endocrine–metabolic disorders of childhood [2]. The incidence of T1DM has shown a rising global trend, with substantial increases reported in developing countries, including India [3, 4]. Recent data suggest that India contributes significantly to the global burden, with growing numbers of children living with T1DM [5].

Insulin deficiency leads not only to hyperglycemia but also to profound alterations in lipid metabolism. Insulin normally suppresses lipolysis, enhances lipoprotein lipase activity, and facilitates clearance of triglyceride-rich lipoproteins. In its absence, increased free fatty acid flux and impaired lipid clearance result in characteristic dyslipidemia involving elevated total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), triglycerides (TG), and reduced high-density lipoprotein cholesterol (HDL-C) [6]. These abnormalities accelerate atherosclerosis and significantly increase cardiovascular disease (CVD) risk, even from childhood [7].

Children with T1DM have a two- to four-fold higher risk of premature cardiovascular complications compared to the general population [8]. Evidence of vascular dysfunction, including endothelial impairment, has been demonstrated as early as five years after diagnosis [9]. Given the lifelong duration of diabetes in affected children, early-onset dyslipidemia represents a critical modifiable factor in preventing future CVD.

Monitoring glycemic control using glycated hemoglobin (HbA1c) is central to diabetes management. HbA1c not only reflects mean blood glucose over the previous two to three months but also correlates strongly with long-term complications [10]. Poor glycemic control is associated with adverse changes in lipid parameters in both type 1 and type 2 diabetes [11]. Children with HbA1c ≥9% are more prone to hypertriglyceridemia, elevated LDL-C, and increased atherogenic ratios, reflecting a direct link between metabolic control and cardiovascular risk [12, 13].

Several studies globally have reported high rates of dyslipidemia among children with T1DM. Al-Naama et al. observed significantly elevated TC, LDL, and TG in diabetic children compared to controls [14]. Similar findings were reported by Mona et al., who found dyslipidemia in 65% of diabetic children [15]. South Asian studies also highlight a considerable burden of lipid abnormalities associated with poor glycemic control [12, 13].

MATERIALS AND METHODS

Study Design and Setting: A prospective, hospital-based case–control study was conducted in the Department of Pediatric Medicine, Sir Padmapat Institute of Neonatology and Pediatric Health (SPINPH), SMS Medical College, Jaipur, from April 2020 to December 2021.

Study Population

Eighty children aged 1–18 years were enrolled, including:

- 40 diagnosed cases of Type 1 Diabetes Mellitus (T1DM) with disease duration >1 year
- 40 age- and sex-matched healthy controls

Eligibility Criteria

Inclusion Criteria

Cases

- Children 1–18 years
- T1DM for >1 year
- Regular follow-up at SPINPH

Controls

- Healthy children without diabetes
- No chronic illnesses affecting lipid metabolism

Exclusion Criteria (Both Groups)

- Cardiovascular, renal, hepatic, thyroid disease
- Nephrotic syndrome
- Use of antihypertensive or lipid-lowering drugs
- Refusal of consent

Ethical Approval and Consent

Written informed consent was obtained from parents/guardians. Ethical standards were maintained throughout.

Sample Size

Based on detecting a 5 mg/dL difference in HDL levels with 80% power and 95% confidence, a minimum of 32 participants per group was required. To improve validity, 40 subjects were included in each group.

Data Collection

Demographic details (age, sex, duration of diabetes, family history) and clinical information were recorded using a structured proforma. Anthropometric measurements and systemic examination were performed.

Laboratory Measurements

After overnight fasting (8–10 hours), venous blood samples were collected.

Tests Performed

- **Fasting Blood Glucose:** glucose oxidase method
- **Lipid Profile:** total cholesterol, triglycerides, HDL, LDL, VLDL, TC/HDL ratio (automated analyzer)
- **LDL Calculation:** Friedewald's Formula
  $$LDL = TC - HDL - (TG/5)$$
- **VLDL Calculation:** VLDL = TG/5
- **HbA1c (cases only):** measured by High-Performance Liquid Chromatography (HPLC)

Definition of Dyslipidemia

According to ADA criteria, dyslipidemia was defined as the presence of any of the following:

- Total Cholesterol ≥200 mg/dL
- LDL ≥100 mg/dL
- HDL <40 mg/dL
- Triglycerides ≥150 mg/dL

Children with ≥1 abnormal value were classified as having dyslipidemia.

Glycemic Control Categories (Cases Only)

- **Optimal Control:** HbA1c <9%
- **Poor Control:** HbA1c ≥9%

Statistical Analysis

Data were analyzed using appropriate statistical software. Quantitative variables were expressed as mean ± standard deviation (SD), while qualitative variables were presented as frequencies and percentages. Comparisons between cases and controls were performed using the Student's t-test for continuous variables and the Chi-square test or Fisher's exact test for categorical variables. A p-value of <0.01 was considered statistically significant.

RESULTS

A total of 80 children were enrolled, including 40 with Type 1 Diabetes Mellitus (T1DM) and 40 healthy controls. Both groups were comparable in baseline demographic

characteristics. The results are presented below using five key publication-quality tables.

Table 1. Baseline Characteristics of Study Participants

Characteristic	Cases (n=40)	Controls (n=40)	p-value
Age (years), Mean ± SD	10.18 ± 3.44	10.48 ± 3.57	1.000
Age Groups			
<5 years	3 (7.5%)	3 (7.5%)	
5–10 years	13 (32.5%)	12 (30%)	
10–15 years	20 (50%)	20 (50%)	
15–19 years	4 (10%)	5 (12.5%)	
Gender			
Male	22 (55%)	23 (57.5%)	1.000
Female	18 (45%)	17 (42.5%)	

Table 2. Glycemic Status of Diabetic Children (HbA1c %)

HbA1c Category (%)	Cases (n=40)
6.5–8	4 (10%)
8–10	4 (10%)
10–12	9 (22.5%)
12–14	18 (45%)
>14	5 (12.5%)
Mean ± SD	**11.76 ± 2.33**

Table 3. Comparison of Lipid Profile between Cases and Controls

Parameter	Cases (Mean ± SD)	Controls (Mean ± SD)	p-value
Total Cholesterol (mg/dL)	172.9 ± 36	146.3 ± 24.33	<0.001
Triglycerides (mg/dL)	149 ± 45.36	101.67 ± 41.83	<0.001
HDL (mg/dL)	51.78 ± 8.08	54.62 ± 10.95	0.190
LDL (mg/dL)	90.50 ± 31.28	69.61 ± 23.21	0.001
VLDL (mg/dL)	30.66 ± 8.79	19.94 ± 8.72	<0.001
TC/HDL Ratio	3.33 ± 0.77	2.76 ± 0.69	0.001

Table 4. Prevalence of Dyslipidemia in Cases vs Controls

Dyslipidemia	Cases (n=40)	Controls (n=40)	p-value
Present	27 (67.5%)	9 (22.5%)	<0.001
Absent	13 (32.5%)	31 (77.5%)	

Table 5. Association of Dyslipidemia with Glycemic Control (HbA1c) in Cases

Dyslipidemia	HbA1c <9% (n=6)	HbA1c ≥9% (n=34)	p-value
Present	1 (16.7%)	26 (76.5%)	0.010
Absent	5 (83.3%)	8 (23.5%)	

DISCUSSION

This study assessed lipid abnormalities in children with Type 1 Diabetes Mellitus (T1DM) and compared them with healthy controls, along with evaluating the influence of glycemic control on dyslipidemia. The findings demonstrated a significantly higher prevalence of dyslipidemia among diabetic children and a strong relationship between poor glycemic control and adverse lipid patterns. These observations align with the established metabolic disturbances caused by absolute insulin deficiency in T1DM.

T1DM results from autoimmune destruction of pancreatic β-cells, leading to profound insulin deficiency and subsequent abnormalities in carbohydrate and lipid metabolism [1]. Insulin plays a critical role in regulating lipid homeostasis; in its absence, lipolysis becomes uncontrolled, free fatty acid flux to the liver increases, and lipoprotein lipase activity decreases. These mechanisms contribute to elevated triglyceride-rich lipoproteins, higher

total cholesterol and LDL levels, and reduced HDL clearance, forming the classical dyslipidemia of T1DM [6]. This pathophysiological basis helps explain the significantly higher TC, TG, LDL, VLDL, and TC/HDL ratio observed among diabetic children in our study compared to controls.

The demographic comparability between groups strengthens the interpretation of biochemical differences. The mean age of participants was around 10 years, corresponding to a known peak onset period for T1DM observed globally and within India [4,5]. A slight male predominance in our sample mirrors earlier Indian pediatric reports, though the gender distribution in T1DM varies worldwide [5]. These similarities suggest that the metabolic differences found in this study are disease-related rather than demographically influenced.

One of the most significant observations was the substantial proportion of children with poor glycemic control. The mean HbA1c level among cases was 11.76%, far higher than recommended targets. HbA1c is a strong marker of metabolic control and long-term complications, reflecting average blood glucose over a two- to three-month period [10]. Poor glycemic control has been consistently associated with worsened lipid parameters in children and adolescents with T1DM [11]. In this study, dyslipidemia was significantly more prevalent in children with HbA1c ≥9% compared to those with better metabolic control, highlighting the close interplay between hyperglycemia and lipid metabolism.

The prevalence of dyslipidemia among cases (67.5%) is comparable to findings from several international studies. Mona et al. reported dyslipidemia in 65% of Egyptian children with T1DM, and Zabeen et al. noted a prevalence of 64% in Bangladeshi children [10,12]. These parallels underscore the widespread burden of dyslipidemia among diabetic youth in low- and middle-income settings. Our findings also mirror those of Al-Naama et al., who reported significantly elevated TC, LDL, and triglycerides in diabetic children compared to controls [14]. Conversely, some studies have reported lower prevalence rates, such as Bulut et al. (26.2%), likely reflecting better glycemic control or different patient demographics [10].

The most frequent lipid abnormality in our study was hypertriglyceridemia (52.5%), followed by elevated LDL (42.5%). These patterns have been noted in studies from Bangladesh, Iran, and Brazil, where hypertriglyceridemia and high LDL were strongly associated with poor metabolic control [12,13,15]. Elevated LDL, in particular, is clinically significant as it plays a central role in the development of early atherosclerotic changes. Although HDL levels in our cohort were slightly lower in diabetic children, the difference was not statistically significant, a finding shared by several prior studies. Variability in HDL responses across studies may be due to differences in diet, physical activity, and glycemic control profiles.

The strong association between dyslipidemia and poor glycemic control observed in this study highlights the modifiable nature of lipid abnormalities in T1DM. Hyperglycemia exacerbates lipid derangements by increasing hepatic triglyceride synthesis, reducing lipid clearance, and altering apolipoprotein function [11]. Studies by Mostofizadeh et al. and Parveen et al. have demonstrated similar findings, showing significantly worse lipid profiles among children with HbA1c ≥9% [12,13]. These findings support the need for aggressive metabolic control to reduce cardiovascular risk.

The clinical implications of these results are substantial. Early dyslipidemia in T1DM increases the lifetime risk of cardiovascular disease. ISPAD and ADA recommend periodic lipid screening in all diabetic children, especially those with poor glycemic control [2,7].

CONCLUSION

Dyslipidemia is significantly more common in children with Type 1 Diabetes Mellitus compared to healthy controls. Hypertriglyceridemia and elevated LDL were the predominant abnormalities. Poor glycemic control (HbA1c ≥9%) was strongly associated with the presence of dyslipidemia, highlighting the importance of strict metabolic management. Early screening and timely intervention may help reduce long-term cardiovascular risks in these children.

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