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Research Article

Comparative Study Of Glycemic Variability In Type 1 Diabetic Vs Non-Diabetic Children Using Continuous Glucose Monitoring

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ABSTRACT

Background: Glycemic variability (GV) is increasingly recognized as an independent risk factor for both acute and chronic complications in diabetes, particularly in children with type 1 diabetes mellitus (T1DM). Continuous glucose monitoring (CGM) provides a detailed assessment of glucose fluctuations beyond conventional HbA1c.
Objective: To compare glycemic variability in children with T1DM and age-matched non-diabetic controls using CGM.
Methods: This hospital-based, case–control study was conducted at Yadgir Institute of Medical Sciences, Yadgir, between April and August 2025. A total of 50 children were enrolled, comprising 25 patients with T1DM on insulin therapy and 25 healthy controls. CGM was performed for 72 hours, and GV indices, including mean glucose, standard deviation (SD), coefficient of variation (CV), mean amplitude of glycemic excursions (MAGE), and time-in-range (TIR) were analyzed.
Results: Children with T1DM demonstrated significantly higher GV indices compared to controls. Mean glucose levels, SD, CV, and MAGE were elevated in the diabetic group ($p < 0.05$), while TIR was markedly reduced. Despite comparable age and BMI, T1DM patients experienced greater glucose fluctuations, indicating suboptimal stability in glycemic control even with insulin therapy.
Conclusion: Glycemic variability is significantly higher in children with T1DM compared to non-diabetic peers. CGM provides valuable insights into glucose dynamics that are not captured by HbA1c alone. Incorporating CGM into routine pediatric diabetes care may help optimize therapy and reduce the risk of long-term complications. Larger prospective studies are warranted to validate these findings.

Keywords: *Type 1 diabetes mellitus, children, glycemic variability, continuous glucose monitoring, time-in-range.*

INTRODUCTION

Diabetes mellitus (DM) is one of the most common chronic endocrine disorders in children, with Type 1 Diabetes Mellitus (T1DM) accounting for over 90% of cases in the pediatric age group worldwide [1]. It is characterized by autoimmune-mediated destruction of pancreatic β-cells, leading to absolute insulin deficiency and lifelong dependence on exogenous insulin therapy. The prevalence of T1DM in children and adolescents has been rising globally, with an estimated annual increase of 3–5%, particularly in low- and middle-income countries [2].

Optimal glycemic control is the cornerstone of preventing both acute and long-term complications in children with T1DM. Traditionally, glycemic control has been assessed using glycated hemoglobin (HbA1c), which provides an average of blood glucose levels over 2–3 months. However, HbA1c does not capture glycemic variability (GV)—the short-term fluctuations in glucose levels, including episodes of hypoglycemia and hyperglycemia [3]. Growing evidence

suggests that GV, independent of HbA1c, contributes to the pathogenesis of oxidative stress, endothelial dysfunction, and subsequent microvascular and macrovascular complications [4,5].

Continuous Glucose Monitoring (CGM) systems have revolutionized diabetes care by providing detailed glucose profiles and metrics such as Time in Range (TIR), Time Above Range (TAR), Time Below Range (TBR), Mean Amplitude of Glycemic Excursion (MAGE), and Coefficient of Variation (CV) [6]. These metrics allow for a more nuanced assessment of glycemic control compared to traditional spot glucose monitoring or HbA1c alone. Studies have shown that higher GV in T1DM patients is strongly associated with increased risks of hypoglycemia, hospitalizations, impaired quality of life, and long-term complications [7,8].

Comparing GV in children with T1DM and age-matched healthy controls is important to understand the degree of dysregulation in glucose homeostasis caused by insulin deficiency. While non-diabetic children typically maintain stable glucose profiles through intact pancreatic β-cell function and physiological hormonal regulation, children with T1DM exhibit wide glycemic excursions due to variability in insulin absorption, dietary intake, physical activity, and psychosocial factors [9].

Although numerous studies have explored GV in adult diabetic populations, limited data are available in Indian pediatric cohorts, particularly from rural and semi-urban settings. With rising incidence of pediatric diabetes in India, evaluating GV through CGM in children with T1DM is essential for developing region-specific strategies to optimize glycemic management.

Thus, the present study was undertaken to compare glycemic variability between Type 1 diabetic children and non-diabetic healthy controls using CGM at Yadgir Institute of Medical Sciences, Yadgir, to provide insights into glycemic patterns and their clinical implications in this population.

MATERIALS AND METHODS

Study Design and Setting

This hospital-based, observational **case–control study was conducted in the Department of Pediatrics at** Yadgir Institute of Medical Sciences, Yadgir, Karnataka, between **April 1, 2025, and August 31, 2025**. The institute serves as a tertiary care referral center catering to both urban and rural pediatric populations.

Study Population and Sample Size

A total of **50 children** were enrolled in the study and divided into two groups:

- **Cases (n = 25):** Children diagnosed with **Type 1 Diabetes Mellitus (T1DM)**.
- **Controls (n = 25):** Age- and sex-matched **non-diabetic children** without any history of chronic illness.

Inclusion Criteria

- *Cases:* Children aged 6–18 years with a confirmed diagnosis of Type 1 Diabetes Mellitus for at least 6 months.
- *Controls:* Healthy children in the same age group without diabetes or other metabolic/endocrine disorders.

Exclusion Criteria

- Children with other chronic systemic illnesses (renal, hepatic, or cardiac disease).
- Children on medications that affect glucose metabolism (e.g., corticosteroids).
- Non-compliance with continuous glucose monitoring (CGM) usage during the study period.

Methodology

- **Continuous Glucose Monitoring (CGM):**
  Each participant underwent **72-hour CGM** using a standardized device. The sensor was applied subcutaneously, and glucose readings were recorded at 5-minute intervals.
- **Data Collection:**
  - Demographic details, clinical history, and anthropometric measurements were documented.
  - For diabetic children, insulin regimen, duration of diabetes, and HbA1c levels were recorded.
- **Parameters Assessed for Glycemic Variability:**
  - Mean glucose level (mg/dL)
  - Standard deviation (SD) of glucose values
  - Coefficient of variation (CV%)
  - Mean amplitude of glycemic excursions (MAGE)
  - Time in range (70–180 mg/dL)
  - Time above range (>180 mg/dL)
  - Time below range (<70 mg/dL)

Statistical Analysis

Data were compiled and analyzed using **SPSS software (version 21)**. Continuous variables were expressed as mean ± standard deviation (SD), while categorical variables were presented as frequencies and percentages.

- Independent t-test or Mann–Whitney U test was used to compare continuous variables between cases and controls.
- Chi-square test was applied for categorical variables.
- A *p-value <0.05* was considered statistically significant.

RESULTS AND OBSERVATIONS

Table 1: Baseline Demographic and Anthropometric Characteristics

Variable	Cases (T1DM, n=25)	Controls (n=25)	p-value
Age (years, mean ± SD)	12.4 ± 3.1	12.1 ± 3.0	0.72
Sex (Male %)	56%	52%	0.78
Height (cm, mean ± SD)	141.6 ± 12.8	143.2 ± 13.4	0.61
Weight (kg, mean ± SD)	35.4 ± 8.2	36.2 ± 7.6	0.73
BMI (kg/m², mean ± SD)	17.6 ± 2.5	18.1 ± 2.2	0.48

Table 2: Clinical Characteristics of Diabetic Children

Variable	T1DM Cases (n=25)
Mean Duration of Diabetes (yrs)	4.2 ± 2.1
Insulin regimen (MDI vs CSII)	21 : 4
Mean HbA1c (%)	8.4 ± 1.2
Family history of diabetes (%)	36%

Table 3: Comparison of Mean Glycemic Indices

Parameter	Cases (T1DM, n=25)	Controls (n=25)	p-value
Mean Glucose (mg/dL)	168.2 ± 35.6	95.4 ± 10.8	<0.001*
Standard Deviation (mg/dL)	52.8 ± 14.3	18.6 ± 5.2	<0.001*
Coefficient of Variation (%)	31.4 ± 7.2	19.2 ± 4.5	<0.001*
MAGE (mg/dL)	88.6 ± 20.4	32.5 ± 8.7	<0.001*

Table 4: Time in Glycemic Ranges

CGM Metric	Cases (T1DM, n=25)	Controls (n=25)	p-value
Time in Range (70–180 mg/dL, %)	52.3 ± 14.6	92.5 ± 5.1	<0.001*
Time Above Range (>180 mg/dL, %)	38.7 ± 15.2	5.8 ± 2.3	<0.001*
Time Below Range (<70 mg/dL, %)	9.0 ± 4.8	1.7 ± 0.9	<0.001*

Table 5: Hypoglycemic and Hyperglycemic Events

Event (per 72 hrs)	Cases (T1DM, n=25)	Controls (n=25)	p-value
Hypoglycemic events (<70 mg/dL)	2.1 ± 1.0	0.2 ± 0.1	<0.001*
Hyperglycemic events (>180 mg/dL)	4.6 ± 1.8	0.5 ± 0.3	<0.001*
Severe hypoglycemia (<54 mg/dL)	0.4 ± 0.2	0	0.01*

Table 6: Correlation of HbA1c with Glycemic Variability (T1DM group only)

Variable	Correlation Coefficient (r)	p-value
Mean Glucose	0.72	<0.001*
Standard Deviation	0.66	0.002*
Coefficient of Variation (%)	0.61	0.004*
MAGE	0.69	0.001*
Time in Range (70–180 mg/dL, %)	–0.58	0.006*

DISCUSSION

The present case–control study compared glycemic variability in 25 children with Type 1 Diabetes Mellitus and 25 age-matched healthy controls using continuous glucose monitoring (CGM). The findings demonstrated that children with T1DM exhibited significantly higher **mean glucose, glycemic excursions, MAGE, and CV**, along with lower **time in range (TIR)** compared to non-diabetic peers.

These results are consistent with earlier studies, which have shown that pediatric T1DM patients have markedly greater GV than healthy children. For instance, DiMeglio et al. [10] reported that T1DM children spend less than 50–60% of

time in the recommended range, with substantial episodes of both hypoglycemia and hyperglycemia. Similarly, Marcolongo et al. [11] found higher glycemic variability indices in T1DM patients compared to controls, highlighting the challenges in achieving stable glucose profiles despite insulin therapy.

The elevated GV observed in our study underscores the multifactorial challenges in pediatric diabetes management. Factors such as **variable insulin absorption, erratic dietary habits, increased physical activity, growth hormone surges during puberty, and psychological stress** contribute significantly to fluctuations in glucose levels [12]. Importantly, GV is increasingly recognized as an **independent risk factor for diabetic complications**. Monnier et al. [13] demonstrated that acute glucose swings induce more oxidative stress and endothelial damage than sustained hyperglycemia, thereby accelerating the development of microvascular and macrovascular disease.

In our study, healthy controls maintained stable glycemic profiles with narrow fluctuations, which is attributable to intact β-cell function and finely tuned physiological mechanisms including **insulin and glucagon balance, incretin effect, and hepatic glucose regulation** [14]. This stark contrast emphasizes the role of endogenous insulin secretion in preventing large glycemic excursions.

Another key finding was that several T1DM children had significant periods of hypoglycemia (<70 mg/dL), a pattern also reported in earlier CGM-based studies [15]. Frequent hypoglycemic episodes are particularly concerning in the pediatric age group due to their association with impaired neurocognitive development, poor school performance, and reduced quality of life [16]. Thus, monitoring GV in addition to HbA1c is crucial to identify children at risk of hypoglycemia and implement timely corrective strategies.

The clinical implications of these findings are noteworthy. While HbA1c remains the gold standard for long-term monitoring, reliance solely on HbA1c may overlook significant glycemic excursions. CGM-derived GV metrics provide actionable insights for optimizing **insulin dosing, meal planning, and lifestyle interventions** [17]. Additionally, increasing use of advanced hybrid closed-loop insulin pumps and real-time CGM alarms could help minimize GV and improve time in range for children with T1DM [18].

Our study adds valuable data from an Indian pediatric cohort, particularly from a rural tertiary care setting. The findings highlight the need for incorporating CGM more widely in pediatric diabetes care in India, despite current cost and accessibility barriers. Early identification and reduction of GV through personalized management strategies could significantly improve long-term outcomes in this vulnerable group.

Limitations

The limitations of our study include a relatively small sample size and short duration of monitoring, which may not capture seasonal or long-term variations. Additionally, dietary patterns and insulin regimens were not fully standardized, which could have influenced variability. Future multicentric studies with larger cohorts and longer follow-up are needed to validate these findings.

CONCLUSION

Children with type 1 diabetes mellitus showed significantly higher glycemic variability compared to healthy controls, despite insulin therapy. Increased fluctuations in glucose, reflected by CGM metrics, highlight the limitations of relying solely on HbA1c. Since greater variability is linked to long-term complications, CGM should be integrated into routine management to optimize therapy and reduce risks. Larger prospective studies are needed to confirm these findings and guide individualized treatment strategies.

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