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Factors Affecting Glycemic Control Among Children and Adolescents with Type 1 Diabetes Mellitus Attending Benghazi Children's Hospital, Libya: Cross-Sectional Study

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Abstract

Background: Poor glycemic control in children with type 1 diabetes leads to serious complications affecting growth, development, and quality of life. In Libya, data are limited. Our study assesses glycemic control and identifies risk factors associated with poor control, to guide better management and prevent long-term complications in young patients.

Methodology: A cross-sectional study was conducted at Benghazi Children's Hospital, involving 120 children and adolescents aged (<18 years) with type 1 diabetes mellitus for over a year. Glycemic control was assessed using glycated haemoglobin and categorized as good (HbA1c <7.5%) or poor (HbA1c ≥7.5%). Logistic regression analysis was performed to identify significant risk factors associated with poor glycemic control.

Results: The study found that 93.3% of participants had poor glycemic control, with a mean HbA1c of 10.2%. Adolescents and prolonged use of insulin pen needles for more than one day were identified as risk factors for poor glycemic outcomes, with p-values of 0.030 and 0.014, respectively.

Conclusion: Poor glycemic control was highly prevalent among children and adolescents with type 1 diabetes mellitus attending Benghazi Children's Hospital. Adolescence (11–18 years) and reuse of insulin pen needles were associated with poor glycemic control. These findings highlight the need for targeted interventions and strengthened diabetes management strategies.

Key Words: Adolescent, Child, Diabetes Mellitus, Type 1, Glycemic Control, Glycated Haemoglobin, Risk Factor

Background

Diabetes mellitus is a serious chronic condition characterized by high blood glucose levels.[1] Among its forms, type 1 and type 2 diabetes are the most prevalent globally.[2] In 2021, an estimated 541 million people had impaired glucose tolerance, and over 6.7 million individuals aged 20-79 died from diabetes or its complications.[3]

Type 1 diabetes mellitus poses a global health concern, being the most common chronic illness and the most prevalent type of diabetes in children worldwide. In 2021, the International Diabetes Federation reported that 1.52 million (17.0%) of the total population with type 1 diabetes were under 20 years old. In Libya, the estimated prevalence among patients under 20 years of age is 5,413 out of 24,556 patients in 2022.[4]

Once diagnosed, patients start insulin therapy, with optimal management achieved through an individualized self-care plan tailored to each child and their family.[5] The American Diabetes Association recommends assessing glycated hemoglobin (HbA1c) levels every three months to evaluate long-term glycemic control, with a target HbA1c of <7% (53 mmol/mol) recommended for patients with comprehensive diabetes care.[5,6]

Strict glycemic control delays the onset and slows the progression of diabetes complications. However, this goal must be balanced against the risk of hypoglycemia.[6]

Children with poor glycemic control may experience problems, including poor linear growth, poor weight gain, and delayed skeletal and pubertal development.[7] Early detection and appropriate management are crucial for preventing acute and chronic complications, enabling patients to lead more active and fulfilling lives.

Despite ongoing improvements, most children and adolescents with type 1 diabetes mellitus do not achieve adequate glycemic control. A T1DX-QI-based cohort study found that roughly 21% of children and adolescents with type 1 diabetes met their ideal glycemic target.[8]

This challenge is particularly evident in low-income countries, where limited resources and inadequate governmental support restrict access to essential treatments and innovations needed to achieve optimal glycemic control and improve quality of life.

Studies from Ethiopia, Saudi Arabia, and Sudan report that most children and adolescents with type 1 diabetes fail to achieve their glycemic targets.[9–12] Contributing factors include low socioeconomic status, longer disease duration, not applying carbohydrate counting, lipodystrophy at injection sites, limited caregiver involvement in insulin administration, and poor adherence to glucose monitoring.[9–12]

To our knowledge, no studies from Libya have evaluated glycemic control and associated risk factors of poor outcomes among children and adolescents with type 1 diabetes. This study assesses current glycemic control and factors associated with poor diabetes management among patients attending the diabetes clinic at Benghazi Children's Hospital. Addressing these factors can aid in targeting better management strategies and reducing the risk of long-term devastating diabetes complications.

Materials and Methods

Study design

A cross-sectional study was conducted among children and adolescents diagnosed with type 1 diabetes mellitus who attended the pediatric diabetes clinic at Benghazi Children's Hospital.

Children (2-10 years) and adolescents (11-18 years), who were diagnosed with type 1 diabetes mellitus for over one year and on a basal-bolus insulin regimen, were targeted. Patients newly diagnosed or on an insulin pump were excluded.

Period of Data Collection

Data collection took place from April 15, 2024, to September 15, 2024.

Sampling

Convenience sampling was applied during patients' follow-up visits to the diabetes clinic, resulting in the enrollment of 120 participants.

Data Collection

Patients and caregivers were interviewed during follow-up visits after written parental/guardian consent using a self-developed 31-item questionnaire covering sociodemographic data, clinical status, diabetes management, diet, physical activity, and school-related restrictions (defined as the absence of qualified nursing staff to administer insulin and/or the lack of a designated private suitable place for children with diabetes to self-administer insulin within the school setting). Height and weight were assessed using the Centers for Disease Control and Prevention (CDC) growth calculators for ages 2–20 years. The questionnaire was reviewed by two pediatric endocrinologists/diabetologists and to assess the clarity and feasibility of the questionnaire, a pilot study involving 20 patients was conducted.

Data Analysis

Data were analyzed using SPSS, version 21. Continuous variables were summarized as mean ± SD, and categorical variables as frequencies and percentages. Glycemic control was defined based on the American Diabetes Association (ADA) Standards of Care in Diabetes—Children and Adolescents (2023), that allows less stringent HbA1c targets in pediatric patients lacking access to continuous glucose monitoring (CGM) or advanced insulin delivery technology. Accordingly, glycemic control, in this cohort, was classified as "good" if the HbA1c level was <7.5%, and poor if the HbA1c level was ≥7.5%.[5]

Chi-square and Fisher's Exact tests were used to assess the association between poor glycemic control and its possible associated factors. A binary logistic regression model determined the association between each independent variable and the outcome. The goodness-of-fit assessment of the logistic regression model was assessed using the Hosmer-Lemeshow test. Variables with $p \leq 0.25$ in the bivariate logistic regression were entered into the final multivariable analysis to control for confounders. The adjusted odds ratio (aOR) with 95% confidence intervals (CI) and a p-value < 0.05 was considered statistically significant.

Ethical Consideration

This study was performed in line with the principles of the Declaration of Helsinki; approval was granted by the Ethics Committee of Libyan International Medical University (Research Project No. MHS-2-G-00439).

Results

Sociodemographic Characteristics:

Sociodemographic characteristics with the level of HbA1c of participants are presented in (table 1). 68 patients (56.7%) were adolescents, 43.3% were between two and 10 years of age. The majority were females (63, 52.5%), with a mean age of 11 ± 3.34 years. Two families with a positive type 1 diabetes history had siblings diagnosed with the same illness. In one of these families, all three children were diagnosed with type 1 diabetes mellitus (Table 1).

Table 1: Sociodemographic Characteristics with the Level of HbA1c of Participants

Variable	Category	Frequency n =120 n (%)	Good G.C. n=8 n	Poor G.C. n=112 n	p-value
Sex	Male	57 (47.5)	5	52	0.475
	Female	63 (52.5)	3	60	
Age group	2-10	52 (43.3)	6	46	0.076
	11-18	68 (56.7)	2	66	
Puberty	Yes	59 (49.2)	1	58	**0.032**
	No	61 (50.8)	7	54	
T1DM family history	Yes	31 (25.8)	1	30	0.678
	No	89 (74.2)	7	82	
Marital status of parents	Married	110 (91.7)	8	102	0.621
	Divorced	5 (4.2)	-	5	
	Widowed	5 (4.2)	-	5	
Family income	Enough	99 (82.5)	6	93	0.628
	Not enough	21 (17.5)	2	19	

G.C, Glycemic Control; T1DM, type 1 diabetes mellitus. Chi-square and Fisher's exact test, p-value ≤ 0.05 considered significant.

Both age groups showed a high prevalence of poor glycemic control, more pronounced among adolescents (11-18 years) (Figure 1).

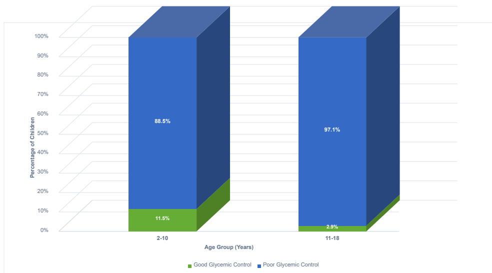

Figure 1: The distribution of glycemic control status among participants by age group.

The Proportion of Children with Glycemic Control

Most participants (112, 93.3%) had poor glycemic control (HbA1c ≥ 7.5%) and only eight children had good glycemic levels. The overall average HbA1c was 10.2% with a standard deviation of 1.9 (Table 2A).

Clinical Characteristics and Management Practices

Glucose monitoring varied, with 78.3% utilizing carb counting, while 40.9% missed insulin doses. 63.3% of participants did not apply proper injection site rotation. 68 participants had lipodystrophy. Over half of the participants understood sick-day rules, yet 64.2% had a DKA admission in the past year (Table 2A and Table 2B).

Table 2A: Clinical Characteristics of Participants by Glycemic Control Status

Variable	Category	Frequency n= 120 n (%)	Good G. C. n= (8)	Poor G. C. n= (112)	p-value
Age at Diagnosis (Years)	< 12	106 (88.8)	8	98	0.594
	≥ 12	14 (11.6)	-	14	
Disease Duration (Years)	< 5	80 (66.7)	5	75	> 0.999
	5-10	32 (26.6)	3	29	
	> 10	8 (6.7)	0	8	
Lipodystrophic Changes	Yes	68 (56.7)	6	62	0.463
	No	52 (43.3)	2	50	
DKA Admission (2023-2024)	Yes	77 (64.2)	6	71	0.710
	No	42 (35.8)	2	43	
Comorbidity	Hypothyroidism	3 (2.5)	-	3	0.428
	Celiac Disease	7 (5.8)	1	6	
	Celiac Disease & Hypothyroidism	1 (0.8)	-	1	

DKA, Diabetic Ketoacidosis; G.C, Glycemic Control. Chi-square and Fisher's Exact test: p-value ≤ 0.05 considered significant.

Table 2B: Diabetes Management Practices of Participants by Glycemic Control Status

Variable	Category	Frequency n= 120 n (%)	Good G. C. n= (8)	Poor G. C. n= (112)	p-value
Insulin Dose/kg	< 0.8 IU/kg	40 (31.6)	3	35	0.615
	0.8-1.2 IU/kg	73 (60.9)	5	68	
	> 1.2 IU/kg	9 (7.5)	-	9	
Daily Glucose Monitoring	< 4 times/day	53 (44.2)	2	51	0.352
	4-6 times/day	55 (45.8)	5	50	
	> 6 times/day	10 (8.3)	1	9	
	Does not monitor	2 (1.7)	-	2	
Missing Doses	Yes	49 (40.9)	2	47	0.470
	No	71 (59.1)	6	65	
On Carb Counting	Yes	94 (78.3)	5	89	0.368
	No	26 (21.7)	3	23	
Parental Supervision	Self-Dependent	53 (44.2)	2	51	0.565
	Parent-Dependent	67 (55.8)	6	61	
Regular Follow-Up	Yes	73 (60.8)	6	67	0.479
	No	47 (39.2)	2	45	
Attended Educational Sessions	Yes	66 (55)	5	61	0.660
	No	54 (45)	3	51	
Proper Injection Site Rotation	Yes	44 (36.7)	2	42	0.712
	No	73 (63.3)	6	70	
Post-prandial Insulin Correction Dose	Yes	117 (97.5)	8	109	0.641
	No	3 (2.5)	-	3	
Return the Insulin to the Fridge	Yes	94 (78.3)	4	90	0.066
	No	26 (21.7)	4	22	
Changing the Insulin Pen Needle	After every use*	10 (8.3)	2	8	**0.019**
	One day of use	37 (30.8)	4	33	
	More than one day	73 (60.8)	2	71	
Know and Apply Sick-Day Management Rules	Yes	67 (55.8)	6	61	0.30
	No	53 (44.2)	2	51	
School Restriction to Inject Insulin †	Yes	67 (55.8)	2	65	0.070
	No	53 (44.2)	6	47	

*Interpret with caution because of the small sample size in this category.
†School restriction refers to absence of qualified nursing staff to administer insulin and/or lack of a designated private place for children with diabetes to self-administer insulin at school.
Chi-square and Fisher's Exact test: p-value ≤ 0.05 considered significant.

Nutritional and Body Status of Participants

Of the total participants, 16 (13.3%) were underweight and 23 (19.2%) were stunted. Most participants (82.5%) lacked regular dietitian visits for diabetes nutrition. However, 80% ate vegetables and fruits regularly, and about half of the participants (51.7%) did not exercise regularly.

Factors Associated with Poor Glycemic Control

Simple binary logistic regression was performed to identify variables associated with glycemic control. Variables with p-value < 0.25—including age, puberty, insulin back to fridge, needle time of use, regular exercise, and school restriction to inject insulin—were considered eligible for inclusion in the multivariable model (Table 3).

Table 3. Factors Associated with Poor Glycemic Control Among Participants.

Variable	Mean HbA1c ± SD	cOR	CI (95%)	P-value
Age (Years)				
2-10	9.6 ±1.9	1	(0.38-22.28)	0.082*
11-18	10.7±1.8	4.304		
Puberty				
At Puberty	10.5±1.8	1	(0.016-1.117)	0.063*
Not at puberty	9.8±2	0.133		
Return Insulin to Fridge				
Yes	10.3±1.8	1	(0.057-1.055)	0.059*
No	9.7±2.2	0.244		
Pen Needle Time of Use				
One for Every Use	9.8±2.6		(1.139 – 8.083)	0.026*
One Day of Use	9.7±1.7	3.034		
More than one day of use	10.5±1.9			
Regularly Exercising				
Yes	10.3±1.9	0.333	(0.064 - 1.723)	0.190*
No	10±1.9			
School Restriction to Inject Insulin				
Yes	10.3 ±1.7	0.250	(0.048-1.293)	0.098*
No	10 ±2.2			

CI, Confidence Interval; cOR, crude odds ratio; Glycated Hemoglobin, HbA1c; SD, Standard Deviation. *: P-value < 0.25 eligible for multivariate regression.

Multiple Logistic Regression Analysis of Risk Factors Associated with Poor Glycemic Control

The final model included factors with a p-value < 0.05 from the bivariate regression, controlling for confounders and modifiable effects (Table 4).

Table 4. Multivariate logistic regression of the risk factors associated with poor glycemic control.

Variable	cOR	aOR	CI (95%)	P-value
Pen Needle Time of Use	3.034	4.74	1.28 - 10.97	0.014*
Age	4.304	5.83	1.02 - 33.38	0.030*

cOR, crude odds ratio; aOR, adjusted odds ratio; CI, confidence interval. *: P-value ≤ 0.05.

Discussion

We found that 93.3% of participants had poor glycemic control, with a mean HbA1c of 10.2%. Adolescents (11-18 years) and patients who used the insulin pen needle for more than one day were major factors associated with poor glycemic control.

In comparison with previous studies our findings align with those reported in Saudi Arabia, where 171 children had poor glycemic control (mean HbA1c: 10.39%, + 1.86).[10] Other studies in Ethiopia and Sudan also found that most children with type 1 diabetes were not meeting their glycemic targets.[9–13]

In this study, we found that type 1 diabetes mellitus patients aged 11-18 years were by far poorly managed compared to younger children, which is in line with the findings of Habteyohans et al., emphasizing the parallels in behavior and associated factors across distinct populations.[13] These outcomes may reflect the impact of parental supervision in younger children, while adolescents face hormonal, psychosocial, and disease-acceptance challenges that reduce adherence to injections and glucose monitoring.[14, 15]

Another factor to consider is socioeconomic status; in our study, families who were financially challenged and struggled to secure insulin did not correlate with poor glycemic control, contrary to the finding of others may be due to the fact that insulin is often given free of charge to diabetics across the country.[9,11] Long-term use of insulin pen needles was associated with poor glycemic control in our study. Reusing insulin pen needles causes deformation of the needle tip, which predisposes to lipodystrophic changes at injection sites. The deformed tip further impairs insulin delivery, resulting in inconsistent insulin absorption, postprandial hyperglycemia, and ultimately poor glycemic outcomes.[16]

Most parents were aware that insulin pen needles are intended for single use only. However, inconsistent provision of an adequate supply of needles remains the primary driver of needle reuse. Sustainable governmental funding to supply not only insulin but also pen needles would represent a meaningful step forward. Furthermore, with advances in diabetes technology, wider access to continuous glucose monitoring (CGM) would greatly support patients in achieving better glycemic control and overall diabetes management.

Notably, 63.3% of participants did not rotate injection sites and 56.7% had lipodystrophy, rates that are clinically concerning and warrant attention. Lipodystrophy is well established to alter insulin absorption, leading to unpredictable hyperglycemia and suboptimal control.[17]

However, no direct association was found between lipodystrophic changes and poor glycemic control. This may be due to the reliance on self-reported lipodystrophy rather than physical examination, which may have resulted in an underestimation of its true prevalence and attenuated the association. These findings nonetheless underscore the importance of routine clinical assessment of injection sites and reinforcement of proper rotation technique as modifiable targets in the management of pediatric type 1 diabetes.

The frequency of DKA in this study was high, with 35.8% of patients experiencing at least one admission for diabetic ketoacidosis. Similar findings have been reported across the MENA region. A prospective study in Egypt involving 240 children (aged 9 months to 12 years) found a comparably high prevalence, with all participants experiencing at least one DKA episode during the study period.[19] Similarly, a retrospective study in Saudi Arabia reported that 68.3% of 180 reviewed cases had recurring DKA admissions.[20] In contrast, data from The Royal College of Paediatrics and Child Health (RCPCH) in the United Kingdom recorded a markedly lower DKA admission prevalence of 2.7% among children with type 1 diabetes in 2017–2018, reflecting a more robust support system for this population.[21]

Limitations

The study's single-center design and non-probability sampling method may limit the generalizability of the results. The study's power to identify risk factors associated with poor glycemic control was restricted due to the small sample size, the homogeneity of poor glycemic control across participants, as well as social desirability bias related to self-reported behaviors.

The marked imbalance in glycemic control outcomes (93.3% poor vs. 6.7% good) may affect the stability of the logistic regression model. Although the Hosmer-Lemeshow test suggested adequate model fit, findings from the regression analysis should be interpreted with caution. Although multivariable logistic regression was performed to adjust for potential confounders, only a limited number of variables were available for inclusion in the final model. Several clinically relevant factors known to influence glycemic control were collected but did not meet the threshold and therefore were not carried forward into the multivariable analysis. Consequently, residual confounding cannot be fully excluded.

Age and pubertal status are related variables that raise the potential for collinearity. The association between prolonged insulin pen needle use and poor glycemic outcomes should be interpreted cautiously. This practice may represent overall suboptimal diabetes management, but the categorization of needle change frequency resulted in one group with a notably small sample size (n=10), which may have limited the statistical reliability of comparisons involving this category.

Conclusion

Poor glycemic control was a common presentation for nearly all children and adolescents with type 1 diabetes mellitus attending Benghazi Children's Hospital. The risk factors associated with poor glycemic control included adolescents (11-18 years of age) and the use of insulin pen needles for more than one day. These findings are preliminary and hypothesis-generating. The imbalanced outcome distribution limited the statistical reliability of the regression model, and the identified risk factors should be confirmed in larger, multi-center studies before informing clinical guidelines.

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CRediT authorship contribution statement

Fatima Abdalmohsen Boud: Conceptualization, Data curation, Investigation, Methodology, Project administration, Supervision, Visualization, Validation, Writing – Original draft, Writing – review & editing.
Aya Faroug Elmughrabi: Investigation, Validation, Writing – Original draft, Writing – review & editing.
Najah Husayn Bisat: Formal analysis, Methodology, Validation, Writing – Original draft, Writing – review & editing.
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Maryam Abdullah Abourqeeah: Investigation, Validation, Writing – review & editing.
Shirin Idriss Alougly: Validation, Writing – review & editing.

Patient consent for publication

Written informed consent was obtained from the caregivers of all participants.

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