RESEARCH ARTICLE

Predictors of glycaemic control in children and adolescents with type 1 diabetes mellitus

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Abstract

Objective: To identify the predictors of glycaemic control in children and adolescents with type-1 diabetes mellitus.

Method: The analytical, cross-sectional study was conducted at the Paediatric Endocrinology Department of the National Institute of Child Health, Karachi, from June to November 2024, and comprised children of both genders aged 2-18 years having definite diagnosis of type-1 diabetes mellitus with a disease duration >1 year. Glycated haemoglobin ≥7.5% was labelled as poor glycaemic control. Association of glycaemic control with various socio-demographic, clinical and management-related characteristics was explored. Data was analysed using SPSS 26.

Results: Of the 163 children, 83(50.9%) were girls. The overall median age at the time of presentation was 12.0 years (interquartile range: 9.0-14.0 years). The median glycated haemoglobin was 8.4% (interquartile range: 7.2-10.6). Good and poor glycaemic control was noted in 58(35.6%) and 105(74.4%) subjects, respectively. Primary caregiver being the father was independently associated with higher odds of poor glycaemic control (p=0.039). Insulin non-adherence (p=0.019) and irregular blood glucose monitoring (p<0.001) were significant independent predictors of poor glycaemic control. Patients with a check-up interval >2 months had higher odds of poor glycaemic control (p=0.010).

Conclusion: The prevalence of poor glycaemic control was high among children and adolescents with type-1 diabetes mellitus. Key glycaemic control indicators included adherence to insulin and blood glucose monitoring, caregiver involvement, and regular healthcare visits.

Key Words: Adolescent, Caregivers, Child, Glycaemic control, Insulin, Type-1 diabetes mellitus.

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Introduction

Type-1 diabetes mellitus (T1DM) presents a significant challenge globally, characterised by the autoimmune destruction of pancreatic beta cells, leading to insulin deficiency.[1] The global incidence of T1DM is around 29.2/100,000/year.[2,3] Local data indicates the incidence of T1DM among children between 0.3-1.1/100,000/year.[4] While developed nations report increasing rates, regions with limited healthcare resources, such as Pakistan, face challenges in accurately assessing the burden due to scant published data.

Genetic predisposition, environmental triggers and socio-demographic factors are some of the crucial contributors behind the development of T1DM.[5,6] Management of T1DM necessitates meticulous glycaemic control to mitigate the risk of both short-term and long-term complications. Treatment modalities include exogenous insulin administration, dietary management, regular monitoring of blood glucose levels, and education for self-management.[7] The American Diabetes Association (ADA) generally recommends target glycated haemoglobin (HbA1c) <7.5% for all age groups.[8] A study in Cameroon reported that only 24% of children with T1DM had good glycaemic control (GGC).[9] Regional data reports relatively older age to be a significant predictor of poor glycaemic control (PGC) as 88.2% of children aged at least 10 years had PGC (p=0.01).[10] Overall, 72.5% of T1DM children had PGC.[10] A study in Saudi Arabia evaluating children and adolescents with T1DM found that 94.7% children had PGC.[11] Abrahim et al. in Ethiopia described that poor involvement of caregivers in insulin administration was noted among 88.4% T1DM children having PGC.[12] Numerous factors influence glycaemic control in paediatric T1DM patients, including demographic, clinical.

To the best of our knowledge, not much local data exists regarding the predictors of PGC among children with T1DM. The current study was planned to fill the gap in literature by identifying the predictors of glycaemic control in Pakistani children and adolescents with T1DM in an urban tertiary care setting.

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Patients and Methods

The analytical, observational, cross-sectional study was conducted at the outpatient department (OPD) and inpatient/ward of Paediatric Endocrinology, National Institute of Child Health, Karachi, from June 1 to November 30, 2024. After approval from the institutional ethics review board, the sample size was calculated using Open Epi calculator and formula n = z2*p(1-p)/e2,[13] where p was the frequency of primary caregiver as guardian among T1DM children (88%).[12] The calculation was done with 95% confidence level and 5% margin of error.

The sample was raised using non-probability consecutive sampling technique till the sample size target was achieved. Those included were individuals of either gender aged 2-18 years having definite diagnosis of T1DM with disease duration >12 months. Those excluded were children with any type of diabetes other than T1DM, and children with congenital heart disease, chronic kidney disease, chronic lung disease, coeliac disease or haematological disorders, hypothyroidism and hypoadrenalism (as per medical history, record and clinical evaluation). Written consent was taken from both parents/guardians and the participating children. T1DM was defined as the presence of classic symptoms of hyperglycaemia (e.g., polyuria, polydipsia, unexplained weight-loss) and/or random plasma glucose (RPG) concentration ≥200mg/dL (11.1mmol/L), or fasting plasma glucose (FPG) ≥126mg/dL (7.0mmol/L) or 2-hour plasma glucose ≥200mg/dL (11.1mmol/L) during an oral glucose tolerance test (OGTT) in a patient with symptoms of hyperglycaemia.[14]

At the time of enrolment, socio-demographic characteristics, like gender, age, area of residence, maternal education level (father or caregiver if the mother is not alive) and monthly family income, were noted. HbA1c evaluation was performed through the institutional laboratory free of cost. Residential status was named as urban if living in a city above or equal to the district level, or rural if a city/town/village below the district level. Family living arrangement was noted as living with both parents, living with a single parent, sibling, relatives or orphan. The education level of the primary caregiver (either mother/father or guardian) was noted. Primary caregiver was termed either the mother, father, or anyone else mostly involved in the care of the diabetic child. Duration of T1DM was noted from the date of diagnosis. HbA1c <7.5% was considered GGC. HbA1c ≥7.5% was taken as PGC.[15] Socio-economic status was be categorised on the basis of the monthly family income as low (monthly family income <PKR18,000), middle (PKR18,000-40,000) and high (>PKR40,000).[16]

Type of insulin regimen was named as split/twice daily dose regimen (Neutral Protamine Hagedorn [NPH] and Regular), basal bolus/multiple daily injections regimen (combination of short/rapid-acting insulin, and long-acting insulin [glargine, detemir]. Adherence to insulin was labelled as yes if the patient did not miss any doses in the preceding one week. Adherence to blood glucose monitoring (BGM) was named yes if the patient checked blood glucose at least three times in a day. Caregiver involvement was categorised as to whether the caregiver supervised or helped in the preparation and administration of insulin, or the patients injected insulin by themselves. Caregiver's involvement in BGM was termed yes if the caregiver supervised or helped in testing blood glucose levels and maintaining the record in the diary, and no if the patients checked blood glucose levels and maintained the record in the diary by themselves.

Data were analysed using SPSS 26. Qualitative data, like gender, residence, monthly family income, type of insulin and glycaemic control, was presented as frequencies and percentages. Quantitative data, like age, body mass index (BMI), age at onset of T1DM, frequency of insulin injections (weekly), frequency of BGM (weekly), yearly attendance for check-ups to healthcare facility, number of hospitalisations (yearly) and HbA1c, was presented as mean +/- standard deviation (SD), if normally distributed, or median with interquartile range (IQR), if not normally distributed. Data normality was checked using the Shapiro-Wilk test. Socio-demographic and disease-related characteristics were compared with respect to glycaemic control (good/poor). Chi-square or Fisher exact test was employed to compare qualitative data. Independent sample t-test or Mann-U Whitney test was used to compare mean and median, respectively, for quantitative data. Variables demonstrating an association with glycaemic control at $p<0.10$ on univariate analysis were entered into a multivariate binary logistic regression model to identify independent predictors of poor glycaemic control. Adjusted odds ratios (aORs) with 95% confidence intervals (CIs) were calculated. $P<0.05$ was taken as significant.

Results

Of the 163 children, 83(50.9%) were girls. The overall median age at the time of presentation was 12.0 years (IQR: 9.0-14.0 years). The median age at the onset of diabetes was 6.0 years (IQR: 3.0-8.0 years). The media duration of T1DM was 5.0 years (IQR: 2.9-7.0 years). Monthly family income was middle in 105(64.4%) cases. The median HbA1c was 8.4% (IQR: 7.2-10.6). GGC and PGC was noted in 58(35.6%) and 105(74.4%) subjects, respectively. PGC was significantly associated with

Table-1: Association of glycaemic control with baseline characteristics.

Characteristics		Total (N=163)	Glycaemic control		P-value
			Good (n=58)	Poor (n=105)	
Gender	Boys	80 (49.1%)	26 (44.8%)	54 (51.4%)	0.420^
	Girls	83 (50.9%)	32 (55.2%)	51 (48.6%)	
Age in years, median (IQR)	12.0 (9.0-14.0)	12.0 (10.0-16.0)	12.0 (8.3-13.0)	0.153*	
Age in years at the onset of T1DM diagnosis, median (IQR)	6.0 (3.0-8.0)	5.0 (3.0-8.8)	6.0 (3.1-8.0)	0.555*	
Duration of T1DM in years, median (IQR)*	5.0 (2.9-7.0)	5.5 (2.0-9.1)	5.0 (3.0-7.0)	0.517	
Residence	Rural	52 (31.9%)	13 (22.4%)	39 (37.1%)	0.053^
	Urban	111 (68.1%)	45 (77.6%)	66 (62.9%)	
Primary caregiver	Father	27 (16.6%)	1 (1.7%)	26 (24.8%)	0.004^
	Mother	117 (71.8%)	49 (84.5%)	68 (64.8%)	
	Uncle	1 (0.6%)	-	1 (1.0%)	
	Self	12 (7.4%)	5 (8.6%)	7 (6.7%)	
	Sister	6 (3.7%)	3 (5.2%)	3 (2.9%)	
Caregiver's education	Illiterate	61 (37.4%)	17 (29.3%)	44 (41.9%)	0.089^
	Primary	29 (17.8%)	10 (17.2%)	19 (18.1%)	
	Secondary to matriculation	41 (25.2%)	14 (24.1%)	27 (25.7%)	
	Intermediate	23 (14.1%)	14 (24.1%)	9 (8.6%)	
	Graduation or above	9 (5.5%)	3 (5.2%)	6 (5.7%)	
Monthly family income	Low	51 (31.3%)	13 (22.4%)	38 (36.2%)	0.064^
	Middle	105 (64.4%)	44 (75.9%)	61 (58.1%)	
	High	7 (4.3%)	1 (1.7%)	6 (5.7%)	
Family living arrangement	Both parents	139 (85.3%)	52 (89.7%)	87 (82.9%)	0.436^
	Single parent	23 (14.1%)	6 (10.3%)	17 (16.2%)	
	Orphan	1 (0.6%)	-	1 (1.0%)	
HbA1c (%) as median (IQR)	8.4 (7.2-10.6)	6.8 (6.0-7.2)	9.90 (8.6-11.9)	<0.001*	

^Chi-square test applied; *Mann-U Whitney test applied; IQR: Interquartile range, T1DM: Type-1 diabetes mellitus, HbA1c: Glycated haemoglobin.

Table-2: Association of glycaemic control with T1DM management-related variables.

Characteristics		Total (N=163)	Glycaemic control		P-value
			Good (n=58)	Poor (n=105)	
Type of insulin	Basal bolus	97 (59.5%)	37 (63.8%)	60 (57.1%)	0.408^
	Split/twice daily	66 (40.5%)	21 (36.2%)	45 (42.9%)	
Adherence to insulin	125 (76.7%)	57 (98.3%)	68 (64.8%)	<0.001^	
Adherence to blood glucose monitoring	77 (47.2%)	53 (91.4%)	24 (22.9%)	<0.001^	
Caregiver's involvement in insulin administration	111 (68.1%)	58 (100%)	53 (50.5%)	<0.001^	
Caregiver's involvement in blood glucose monitoring	95 (58.3%)	58 (100%)	37 (35.2%)	<0.001^	
Attendance for check-ups	Monthly	93 (57.1%)	54 (93.1%)	39 (37.1%)	<0.001^
	After every 2-months	13 (8.0%)	2 (3.4%)	11 (10.5%)	
	After every 3 months	30 (18.4%)	2 (3.4%)	28 (26.7%)	
	After every 4 months	1 (0.6%)	-	1 (1.0%)	
	After every 6 months or above	26 (24.8%)	-	26 (24.8%)	

^Chi-square applied, T1DM: Type-1 diabetes mellitus.

Table 3: Mutivariable binary logistic regression analysis for the predictors of poor glycaemic control.

Predictors	Reference category	Adjusted odds ratio (95% CI)	P-value
Residence (rural)	Urban	1.7 (0.7-4.0)	0.212
Primary caregiver (father)	Mother	6.9 (1.1-42.7)	0.039
Caregiver's education (illiterate)	Intermediate or above	1.8 (0.7-4.8)	0.265
Monthly family income (low)	Middle/high	1.5 (0.7-3.5)	0.453
Insulinnon-adherence	Adherence to insulin	6.1 (1.4-27.7)	0.019
Blood glucose monitoring non-adherence to	Adherence to blood glucose monitoring	11.9 (4.1-34.7)	<0.001
Check-up interval > 2 months	Check-up inerval ≤ 2 months	4.2 (1.4-12.6)	0.010

CI: Confidence interval.

primary caregiver status as father (p=0.004) (Table 1).

GGC had a significant association with adherence to insulin, adherence to BGM, caregiver's involvement in insulin administration, and monthly check-ups (Table 2).

Multivariate binary logistic regression analysis showed that primary caregiver being the father was independently associated with higher odds of PGC (p=0.039). Insulin non-adherence (p=0.019) and irregular BGM (p<0.001) were significant independent predictors of PGC. Patients with a check-up interval >2 months had higher odds of PGC (p=0.010) (Table 3).

Discussion

The current study revealed that the prevalence of PGC (HbA1c ≥7.5%) among children and adolescents with T1DM was 64.4%. Habteyohans et al.[17] reported a prevalence of PGC at 71.9% in Ethiopia. Al-Qahtani et al.[11] found an even higher prevalence of PGC (94.7%) in Saudi Arabia. These numbers underscore the universal challenge of achieving glycaemic targets in paediatric T1DM populations, particularly in resource-limited settings. In interpreting glycaemic control in the current study, it is important to contextualise HbA1c thresholds against contemporary guideline targets. The ADA Standards of Care indicate that an HbA1c <7.0% is appropriate for many children and adolescents with diabetes, while less stringent goals (e.g., <7.5%) may be reasonable in selected patients based on hypoglycaemia risk, psychosocial burden and feasibility of intensive management.[18] International Society for Pediatric and Adolescent Diabetes (ISPAD) consensus guidance recommends an HbA1c target around ≤7.0% for most youth, with consideration of lower targets (≈6.5%) where safely achievable, particularly in settings with robust education/support and access to advanced diabetes technologies, targets can be individualised as per age, developmental considerations and treatment resources.[19] Therefore, while the current study dichotomised glycaemic control into good versus poor based on HbA1c, these results should be interpreted in the light of guideline-endorsed, individualised HbA1c targets that may vary by age group and clinical context.

PGC was significantly associated in the current study with the primary caregiver being the father ((p=0.039). Shibeshi et al.[20] identified non-maternal caregivers as a predictor of poor control, likely due to limited engagement in daily diabetes management tasks. In Tanzania, McLarty et al.[21] highlighted that lower caregiver education levels were associated with suboptimal glycaemic outcomes.

Adherence to insulin and BGM emerged as strong predictors of glycaemic control in the current study. These findings mirror those of Al-Qahtani et al.[11] in Saudi Arabia, and Dumrisilp et al.[22] in Thailand, who emphasised the pivotal role of self BGM and adherence to insulin in achieving glycaemic targets. Clinically, this underscores the necessity of reinforcing these behaviours through structured education programmes tailored for patients and caregivers.[23,24]

Regular healthcare visits were another significant predictor of poor glycaemic control in the present study. This finding is supported by Kidie et al.[25] who noted that frequent healthcare interactions provide opportunities for intervention, monitoring and reinforcement of diabetes management practices. The direction of this association warrants caution because reverse causality is also possible in a cross-sectional design. Children with persistently elevated HbA1c, recurrent symptoms or intercurrent illness are scheduled more frequently or self-present more often, thereby may be increasing the observed frequency of clinic contact. PGC may also contribute to reduced follow-up through diabetes distress, treatment fatigue, fear of blame, financial constraints, or repeated negative healthcare experiences, leading to missed appointments and longer check-up intervals. Low monthly family income status showed a relatively weaker association with poor glycaemic control,

but income did not emerge as a consistently significant predictor in the adjusted model in the current study. This contrasts with findings from Kidie et al.,[25] according to which, affordability of insulin and related resources was a critical determinant of glycaemic control. The difference may be attributed to better public healthcare support in the current setting. Ali et al. in Sudan[18] found that 97.8% of adolescents failed to achieve glycaemic targets, but the current study did not find any significant association of age with PGC. Hormonal fluctuations, psychosocial factors and reduced adherence during adolescence may explain these outcomes.[26] There might be a need for age-specific strategies to address barriers in this demographic group.

The current study has limitations because self-reported data is prone to recall bias. Socio-economic and caregiver educational data was categorised broadly, potentially limiting nuanced analysis. Several clinically relevant determinants of glycaemic control were not systematically assessed, including dietary patterns and carbohydrate counting practices, structured physical activity assessment, and frequency/severity of hypoglycaemia. Future research should explore longitudinal approaches and context-specific strategies to improve diabetes management in resource-constrained settings.

Conclusion

PGC prevalence was found to be high among children and adolescents with T1DM. Key associations of good glycaemic control included adherence to insulin and BGM, caregiver involvement, and regular healthcare visits. Interventions should prioritise caregiver education, structured diabetes counselling, and access to healthcare to mitigate the high PGC burden.

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AUTHORS' CONTRIBUTIONS:
HNR, MNI, SC, VRR, MY & RP: Concept, design, data acquisition, analysis, interpretation, drafting, revision, final approval and agreement to be accountable for all aspects of the work.