ORIGINAL ARTICLE

CONTENTS

Determinants of glycemic control in children and adolescents with type 1 diabetes (T1D) in three care centers of the changing diabetes in children (CDIC) program in the northern regions of Cameroon

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ABSTRACT

Aim: Type 1 diabetes mellitus (T1DM) is the most common endocrine disorder affecting children and adolescents worldwide. Glycemic control is the ultimate goal of diabetes management, and poor glycemic control is associated with serious short- and long-term complications. Only a few studies have addressed this problem in Cameroon. This study aimed to identify the determinants of glycemic control of T1DM in children and adolescents living in the three northern regions of Cameroon.

Materials and Methods: This was a descriptive and analytical cross-sectional study conducted on 100 children and adolescents with type 1 diabetes followed up in the three T1DM management centers of the CDiC program in the northern regions of Cameroon, from November 2016 to March 2017. Glycemic control was assessed on the basis of glycosylated hemoglobin (HbA1c) levels, according to the current ADA Standards of Care in Diabetes—2025 and ISPAD Clinical Practice Consensus Guidelines 2022, both of which recommend a universal target of HbA1c ≤7.0% (≤53 mmol/mol) for all children and adolescents with type 1 diabetes, regardless of age group. Data were entered into CDC Epi-info™ version 7.2 software, then exported to IBM SPSS Statistics™ version 20.0 for analysis. Descriptive and inferential statistics were used. Bivariate analysis was followed by binary logistic regression to calculate adjusted odds ratios (AORs) for determinants of glycemic control, and a p-value <0.05 was considered statistically significant.

Results: The 100 participants were predominantly male (73%), with a mean age of 16.59 ± 2.54 years. The median HbA1c value was 10.08% [8.7–11.63], reflecting very poor overall glycemic control. Applying the current unified ADA/ISPAD target of ≤7.0% (53 mmol/mol), only 19% of participants achieved their glycemic targets — a proportion markedly lower than figures reported in high-income countries such as the United States (approximately 21–25% in the T1D Exchange Registry). In bivariate analysis, variables significantly associated with glycemic control included: being followed in the Adamaoua region (OR=0.21 [0.07–0.62]; p=0.003), living within 20 km of the diabetes clinic (OR=4.4 [0.94–20.84]; p=0.04), and duration of diabetes less than 2 years (OR=2.90 [1.06–8.30]; p=0.03). In multivariate logistic regression, belonging to the Adamaoua region, a treatment regimen of more than 2 injections per day, living less than 20 km from the management clinic, fewer than three episodes of severe hypoglycemia in the last 6 months, duration of diabetes less than 2 years, and participation in more than three therapeutic education sessions were associated with achieving glycemic targets.

Conclusions: The majority of children and adolescents with T1DM in the northern regions of Cameroon had poor glycemic control, with only 19% achieving the current unified target of HbA1c ≤7.0% (≤53 mmol/mol). Belonging to the Adamaoua region, intensive insulin therapy (>2 injections/day), proximity to the care center (<20 km), fewer severe hypoglycemic episodes, shorter disease duration (<2 years), and regular therapeutic education were identified as factors associated with good glycemic control. Although global innovations such as hybrid closed-loop insulin delivery systems and teplizumab represent transformative advances in T1D management, these technologies remain inaccessible in the study setting. Intensification of therapeutic education, creation of satellite CDiC centers, and progressive adoption of affordable monitoring technologies are urgently needed.

KEYWORDS: type 1 diabetes, glycemic control, children and adolescents, northern regions of Cameroon, HbA1c

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INTRODUCTION

Diabetes is a group of metabolic diseases characterized by chronic hyperglycemia related to a deficit in insulin secretion and/or action [1]. Type 1 diabetes (T1DM) results from a mostly autoimmune destruction of the beta cells of the pancreas [2]. According to the International Diabetes Federation (IDF) Diabetes Atlas, 10th edition (2021), there are now approximately 8.4 million people living with type 1 diabetes worldwide, with over 150,000 new cases diagnosed annually in individuals under 20 years of age [5]. The vast majority (over 90%) reside in low- and middle-income countries [6]. In sub-Saharan Africa, a systematic review by Katte et al. (2023) reported a pooled incidence of 2–10 per 100,000 per year across the region [20]. In Cameroon, approximately 500 to 800 children are estimated to live with T1DM, a figure likely to be an underestimate given the limited diagnostic infrastructure and high rates of misdiagnosis [21]. Including patients over 18 years of age, the total figure may reach 800 to 900 patients [5].

Unlike type 2 diabetes, T1DM results from an autoimmune process and is not lifestyle-related; until recently, there was no known way to prevent or delay its onset. However, a landmark clinical trial demonstrated that teplizumab, an anti-CD3 monoclonal antibody, significantly delayed the onset of clinical T1DM by a median of approximately 3 years in high-risk antibody-positive relatives [29]. Teplizumab (Tzield™) received FDA approval in November 2022, representing the first disease-modifying therapy for T1DM. Nevertheless, such innovations remain inaccessible in sub-Saharan Africa. People with T1DM cannot survive without daily doses of insulin and must adhere to a precise treatment regimen. This is not always easy, and explains the occurrence of serious complications and early mortality, estimated at approximately 10% annually among diabetic children in Cameroon [6]. This is partly attributable to parents' and guardians' lack of awareness of specialized clinics offering free treatment, poor diagnosis by healthcare staff, and patients' non-adherence to treatment [6].

In 2010, a project called Changing Diabetes in Children (CDiC) was implemented to train healthcare professionals, educate patients and their parents, and provide free insulin, with the aim of reducing diabetes-related mortality in children [7].

Numerous factors have been identified as determinants of glycemic control in children and adolescents with T1DM [8, 9]. Multiple studies have examined sociodemographic aspects (age, gender, ethnicity, socioeconomic status, family structure), therapeutic factors (insulin dose, treatment regimen, insulin delivery technology), and behavioral factors (dietary adherence, physical activity, glycemic self-monitoring). In high-income countries, the adoption of advanced diabetes technologies — including continuous glucose monitoring (CGM) systems, insulin pumps (continuous subcutaneous insulin infusion, CSII), and hybrid closed-loop systems such as Medtronic SmartGuard™ and Tandem Control-IQ™ - has dramatically improved glycemic outcomes, with time-in-range exceeding 70% achieved in clinical trials [28]. However, these technologies remain largely unavailable in sub-Saharan Africa, including Cameroon, creating a critical equity gap in diabetes care [19].

In 2013, Djonou et al. identified, in Cameroon, that the duration of diabetes, high insulin doses, and the presence of severe hypoglycemia were associated with poor glycemic control [10]. In the northern regions of Cameroon, characterized by a low level of qualified personnel, a precarious socioeconomic context, and a climate of insecurity, optimal management of T1DM patients remains limited, despite the free supply of insulin.

AIM

To further improve the care of children and adolescents in this part of the country, we set out to identify the factors associated with glycemic control of type 1 diabetes in children and adolescents in the northern regions of Cameroon.

MATERIALS AND METHODS

TYPE, SITE AND STUDY PERIOD

This was a descriptive and analytical cross-sectional study conducted in the regional hospitals of Ngaoundéré, Garoua and Maroua. These hospitals are home to centers for the management of diabetes in children and adolescents, as part of the Changing Diabetes in Children (CDiC) program. This global program, developed by Novo Nordisk, aims to facilitate access to type 1 diabetes treatment for children in low-income countries. Free services encompass both inpatient and outpatient treatment, covering emergencies, outpatient consultations, and regular medical follow-up. Children and adolescents with T1DM benefit from regular pediatric follow-up, including assessments by healthcare professionals, medication refills, and diabetes education sessions. This study was conducted over a period spanning November 2016 to March 2017.

STUDY POPULATION

SOURCE POPULATION

All children and adolescents living with type 1 diabetes in the northern regions of Cameroon.

TARGET POPULATION

All children and adolescents treated at the Changing Diabetes in Children (CDiC) type 1 diabetes centers in the regional hospitals of Ngaoundéré, Garoua and Maroua.

INCLUSION CRITERIA

Patients aged between 6 and 19 years at the time of interview were included. In addition, they were required to have type 1 diabetes and to have been enrolled in the CDiC program for at least 6 months. Children and adolescents were required to give their assent to participate in the study, and parental or guardian written authorization was obtained.

EXCLUSION CRITERIA

Participants with only one HbA1c test in the last six months were excluded. Also excluded were those who withdrew informed consent during the study, failed to complete the interview, or had secondary diabetes (chronic pancreatitis), monogenic diabetes (lipoatrophic), MODY, or neonatal diabetes.

STUDY VARIABLES

The dependent variable was the level of glycemic control. Independent variables were divided into two categories. Socio-demographic factors included age, gender, educational level, parental marital status, displacement status, cohabitation with parents, cultural background, place of residence, and relationship of key caregivers to the child or adolescent. Diabetes-related factors included diabetes history, medical history, insulin treatment modalities, glycemic self-monitoring, geographic accessibility to care, and therapeutic education.

ETHICAL APPROVAL

This study was reviewed and approved by the Institutional Ethics Committee of the Faculty of Medicine and Biomedical Sciences of the University of Yaoundé I (Reference Number: 293/UY1/FMSB/VDRC/CSD). Written informed consent was obtained from all participants prior to inclusion. For minors, parental or guardian written authorization was obtained, and child assent was secured. Study procedures adhered to the ethical principles outlined in the Declaration of Helsinki (Fortaleza revision, 2013).

OPERATIONAL DEFINITIONS

Glycemic control was assessed using HbA1c, in accordance with the ADA Standards of Care in Diabetes - 2025 and the ISPAD Clinical Practice Consensus Guidelines 2022, both of which recommend a universal HbA1c target of ≤7.0% (≤53 mmol/mol) for all children and adolescents with T1DM, regardless of age group [9, 14]. This replaces the former age-stratified ADA thresholds (HbA1c <8% for ages 6–12 years and <7.5% for ages 13–19 years) used at the time of data collection (2016–2017). For historical transparency, the former thresholds are noted where appropriate in the Results; however, all discussion and conclusions are aligned with the current unified target. Participants were accordingly classified as: (a) achieving glycemic control (HbA1c ≤7.0%) or (b) not achieving glycemic control (HbA1c >7.0%).

Intensive insulin therapy is defined as a regimen comprising 3 or more insulin injections per day, or the use of an insulin pump (continuous subcutaneous insulin infusion, CSII). Conventional insulin therapy is defined as 2 injections per day. In the present study, no participant used an insulin pump due to unavailability in the study setting.

Severe hypoglycemia is defined by the presence of at least one of the following: alteration of the child's state of consciousness or coma, or need for parenteral treatment (glucagon or IV glucose). Geographical accessibility refers to the distance between the patient's place of residence and the nearest CDiC care center. Therapeutic education encompasses all measures designed to help patients better manage their lives with diabetes.

DATA PROCESSING AND ANALYSIS

Data were entered into CDC Epi-info™ version 7.2, then exported to IBM SPSS Statistics™ version 20.0 for analysis. Excel was used for graphical representations. Headcounts and percentages were calculated for qualitative variables; means, standard deviations, maxima and minima for quantitative variables. Variables were tested for normality using the Shapiro-Wilk test. Association between quantitative variables was assessed by Pearson's correlation coefficient. The Pearson Chi-square test was used for categorical variables; odds ratios (ORs) with 95% confidence intervals (CIs) were calculated for dichotomous variables. The threshold of statistical significance was set at $p < 0.05$. Candidate variables with a p-value ≤ 0.25 in bivariate analysis were entered into a binary logistic regression model to calculate adjusted odds ratios (AORs) and identify significant independent predictors of poor glycemic control.

RESULTS

DESCRIPTIVE STUDY

SOCIO-DEMOGRAPHIC CHARACTERISTICS

During our study, we included 100 patients out of 103 in the three northern regions of Cameroon (three were excluded for age >19 years). Among participants, 51% were from the Far North region, 27% from the North, and 22% from Adamaoua. Male participants represented 73% (sex ratio 3:1). The mean age was 16.59 ± 2.54 years, and the most represented age group was [15–20]. The main occupation was education (61%), with 28% in junior secondary school. Seventy-six percent attended school. There were 3% foreign

Table 1. Distribution of participants according to socio-demographic data

Variables	Percentage [%]
Regions	
Far North	51
North	27
Adamaoua	22
Gender	
Male	73
Female	27
Age (in years)	
[15-20]	73
[10-15]	24
[5-10]	03
Average age	16.57 ±2.54
Nationality	
Cameroonian	97
Other	03
Internal refugees	
Yes	06
No	94
Participant's occupation	
Pupil/Student	61
Learning a trade	11
Worker	15
Unoccupied	13
Participant's school level	
No schooling	24
Primary	21
Secondary (6e-3e)	28
Secondary (2nd-Tle)	25
University	02
Parents' marital status	
Married	95
Common-law union	01
Separated or divorced	03
Widow(er)	01
Cultural area	
Sudan-Sahel	98
Grass Field	02

Source: Authors' own work

nationals and 6% internally displaced persons. Socio-demographic characteristics are summarized in Table 1.

Regarding education level, lower secondary: 28%, upper secondary: 25%, primary: 21%, tertiary: 2%. Additionally, 24% had no formal Western education (Fig. 1)

GEOGRAPHIC ACCESSIBILITY AND THERAPEUTIC EDUCATION

Sixty-one percent of participants lived less than 5 km from their care center. However, 30% lived more than 20 km away, with an average distance of 101.34 ± 61.66 km separating them from the CDiC center. More than half attended at least one therapeutic education session per month. All participants were able to test their blood glucose correctly and independently (Table 2).

INSULIN TREATMENT MODALITIES

Nearly 89% of participants received three insulin doses per day. The mean daily dose was 0.80 ± 0.20 IU/kg/day. The main insulin regimen was Actrapid-Mixtard (95%). Only 5% were strictly compliant with their prescribed treatment (Table 3).

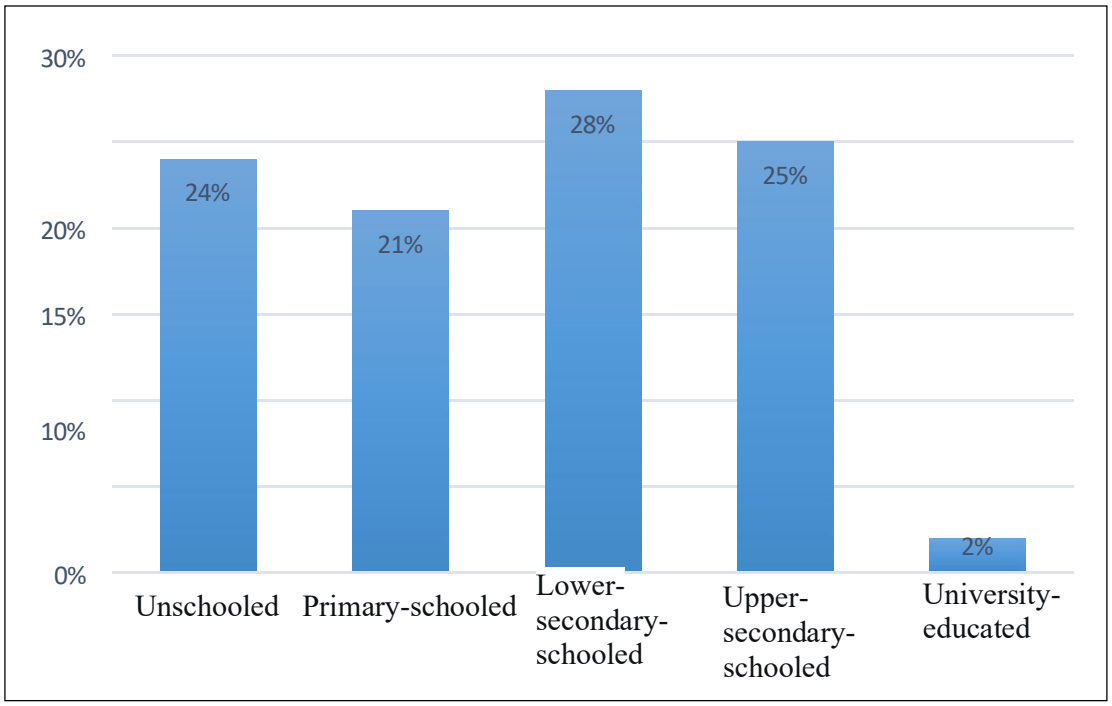

Fig. 1. Participants' level of education
Source: Authors' own work

Table 2. Distance to care center, therapeutic education attendance, and blood glucose testing ability

Variables	Percentage [%]
Distance to care center	
Less than 5 km	61
Between 5 km and 10 km	03
Between 10 km and 20 km	06
Over 20 km	30
Assistance with therapeutic education in the last six months	
Once	03
Twice	15
Three times	20
Four times	01
Five times	03
Six times	58
Ability to test blood sugar correctly	100

Source: Authors' own work

SELF-MONITORING OF BLOOD GLUCOSE

Ninety-eight percent of participants possessed a glucometer and urine test strips. The daily frequency of glycemic self-monitoring was three times per day in 93% of cases (Table 4).

ACUTE COMPLICATIONS

The most frequent acute complication was severe hypoglycemia (93% of cases), followed by infection (7%). No episode of diabetic ketoacidosis was recorded (Table 5).

GLYCEMIC BALANCE AND PARACLINICAL ASSESSMENTS

Only 19% of participants were considered well-controlled (Fig. 2). Mean fasting blood glucose was 192.86 ± 65 mg/dL, and mean glycated hemoglobin was 10.08 ± 2.34% (Table 6). Applying the current unified ADA/ISPAD target of HbA1c ≤7.0% (≤53 mmol/mol), the proportion achieving glycemic control was 19% - far below the target and substantially lower than figures reported in high-income countries (approximately 21–25% in the T1D Exchange Registry, USA [30]).

Table 3. Insulin treatment modalities

Variables	Percentage [%]
Average number of injections per day	
1 injection/day	0
2 injections/day	11
3 injections/day	89
Average daily insulin dose as a function of weight (IU/Kg/day)	0.80 ± 0.20
Insulin therapy regimen	
Actrapid-Insulatard	5
Actrapid-Mixtard	95
Strict compliance with insulin therapy	5

Source: Authors' own work

Table 4. Self-monitoring of blood glucose

Variables	Percentage [%]
Possession of a glucometer	98
Possession of urine dipsticks	98
Daily frequency of glycemic control	
Twice a day	07
Three times a day	93
Therapeutic regimen	
Two injections a day	11
Three injections a day	89

Source: Authors' own work

Table 5. Acute diabetic complications in participants

Variables	Percentage [%]
Ketoacidosis	0
Severe hypoglycemia	93
Infections	07

Source: Authors' own work

Table 6. Paraclinical tests

Variables	
Fasting blood glucose [mg/dl]	192.86 ± 65
Glycated hemoglobin [%]	10.08 ± 2.34

Source: Authors' own work

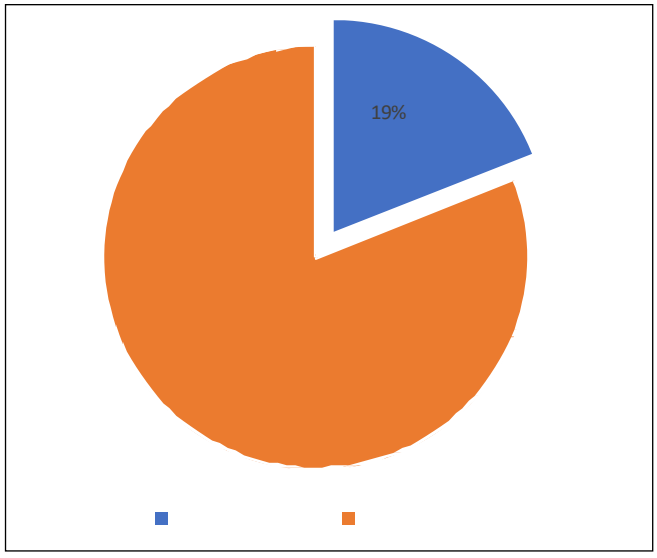

Fig. 2. Participants' glycemic balance
Source: Authors' own work

ANALYTICAL STUDY

SOCIO-DEMOGRAPHIC FACTORS AND GLYCEMIC CONTROL

A statistically significant association was found between glycemic control and being followed in the Adamaoua region (p=0.003; OR=0.21 [0.07–0.62]). No statistically significant association was found between glycemic control and age (p=0.35), gender (p=0.09), occupation (p>0.50), level of education, or family structure (Table 7).

GEOGRAPHIC ACCESSIBILITY AND GLYCEMIC CONTROL

Among the 30% of patients living more than 20 km from their CDiC center, only 2% had a controlled HbA1c. Ninety percent of controlled patients lived less than 20 km from their center (Table 8). In univariate analysis, a significant association was found between distance and glycemic control (p=0.04; OR=4.4 [0.96–20.84]) (Table 9).

Table 7. Association between sociodemographic characteristics and glycemic target attainment

Variables	Glycemic balance		
	Chi²	p	Odd ratio [95% CI]
Age			
Between [6 - 12] years	0.85	0.35	0.44 [0.07 – 2.61]
From [13 - 19] years old	0.85	0.35	2.2 [0.38 – 13.38]
Female gender	2.71	0.09	0.42 [0.148 – 1.199]
Occupation of participants			
Pupils/students	0.04	0.83	0.89 [0.31 – 2.51]
Apprenticeship	0.005	0.94	1.06 [0.21 – 5.37]
Unoccupied	0.12	0.72	1.33 [0.27 – 6.59]
Worker	0.01	0.91	0.92 [0.23 – 3.67]
Participant's level of education			
No	0.06	0.79	0.85 [0.27 – 2.69]
1er secondary school	0.14	0.69	0.80 [0.27 – 2.38]
2nd secondary cycle	1.04	0.30	1.98 [0.52 – 7.49]
Primary	0.00	0.99	0.99 [0.29 – 3.38]
University	1.27	0.25	0.22 [0.01 – 3.76]
Participant's region			
Adamaoua	8.79	0.003	0.21 [0.07 – 0.62]
Far North	3.54	0.06	2.70 [0.94 – 7.83]
North	0.42	0.52	1.50 [0.45 – 4.96]
Family structure			
Living with your mother	1.5	0.21	3.05[0.47– 9.73]
Living with your father	0.85	0.35	2.26 [0.38 – 13.38]

Source: Authors' own work

Table 8. Access to care and glycemic control

Variables	HbA1c normal or not		
	Normal HbA1c	High HbA1c	Total
Distance less than 20 km	17	53	70
Distance over 20 km	2	28	30
Total	19	81	100

Source: Authors' own work

Table 9. Relationship between geographical accessibility to care and glycemic control

	Glycemic balance		
	Chi²	*p-value*	Odd ratio [95% CI]
Distance between home and PEC center (less than 20 km)	4.23	0.04	44 [0.96 – 20.84]

Source: Authors' own work

THERAPEUTIC EDUCATION AND GLYCEMIC CONTROL

No statistically significant association was found between glycemic control and participation in therapeutic education sessions (p=0.59). However, participation in at least one session per month was associated with a 1.3-fold increased likelihood of achieving glycemic targets (OR=1.3 [0.48–3.57]). Possession of a glucometer multiplied by approximately 5 the likelihood of reaching glycemic targets (OR=4.44 [0.26–74.45]) (Table 10).

CURRENT DIABETES MANAGEMENT AND GLYCEMIC CONTROL

A statistically significant association was found between glycemic control and diabetes duration of less than 2

Table 10. Glycemic control and therapeutic education

Variables	Glycemic balance		
	Chi²	*p-value*	Odd ratio [95% CI]
Participation in therapeuticeducation / month	0.27	0.59	1.3 [0.48 – 3.57]
Glucometer ownership	1.27	0.25	4.44 [0.26 – 74.45]
Possession of urine dipsticks	0.47	0.48	1.24 [1.12 – 1.38]

Source: Authors' own work

Table 11. Current diabetes management

Variables	Glycemic balance		
	Chi²	*p-value*	Odd ratio [95% CI]
Insulin			
Therapeutic regimen	0.003	0.95	0.94 [0.09 – 8.88]
Number of injections/day	2.89	0.09	1.27 [1.14 – 1.41]
Duration of diabetes			
[≤ 2 years]	4.59	0.03	2.90 [1.06 – 8.30]
[3- 4 years]	2.33	0.12	0.32 [0.67 – 1.47]
[> 4 years]	0.49	0.49	0.69 [0.24 – 1.94]

Source: Authors' own work

Table 12. Association between glycemic control and the number of severe hypoglycemias

	Glycemic balance		
	Chi²	*p-value*	Odd ratio [95% CI]
Number of severe hypoglycemias in the last 6 months	0.40	0.52	1.19 [0.23 – 16.7]

Source: Authors' own work

years (p=0.03; OR=2.90 [1.06–8.30]). A multiple daily injection regimen (>2 injections/day) was associated with a 1.27-fold increased likelihood of achieving glycemic targets (OR=1.27 [1.14–1.41]) (Table 11).

SEVERE HYPOGLYCEMIA AND GLYCEMIC CONTROL

Approximately 95% of controlled participants had presented with at least 3 episodes of severe hypoglycemia in the last six months. The number of severe hypoglycemic episodes was associated with a 1.19-fold increased risk of poor glycemic control (OR=1.19 [0.23–16.79]; p=0.52) (Table 12).

DISCUSSION

In order to identify the factors associated with glycemic control of type 1 diabetes in children and adolescents in the northern regions of Cameroon, we conducted a study across all CDiC centers in the Far North, North, and Adamaoua regions. Our sample comprised the entire population of T1DM patients in these centers, which enabled us to obtain results reflecting the characteristics of this population. After recruiting 100 patients, we found that the majority were adolescent males enrolled in the first cycle of secondary school, receiving an appropriate insulin dose (0.80±0.20 IU/kg/day) divided into three daily doses, and conducting adequate treatment self-monitoring. The most frequent acute complication was severe hypoglycemia. The mean HbA1c was 10.08±2.34%. The main factors associated with glycemic control were: (1) belonging to the Adamaoua region (OR=0.21 [0.07–0.62]; p=0.003); (2) living less than 20 km from the treatment center (OR=4.4 [0.96–20.84]; p=0.04); (3) having diabetes for less than 2 years (OR=2.90 [1.06–8.30]; p=0.03); and (4) a treatment regimen of more than 2 injections per day (OR=1.27 [1.14–1.41]). These objectives were fully achieved, although the study had limitations. Insecurity in certain regions meant that some patients could not be seen in person. The sample size was also small; a larger sample could have revealed additional significant correlations. Nevertheless, our cross-sectional design has made available original data from the northern regions of Cameroon, a population that is largely under-studied.

SOCIO-DEMOGRAPHIC FACTORS AND GLYCEMIC CONTROL

A large proportion of our study population did not achieve their glycemic targets (81%), with a mean HbA1c of 10.08±2.34%, far exceeding the current unified target of

≤7.0% (≤53 mmol/mol) now recommended for all children and adolescents with T1DM, regardless of age group, by both the ADA Standards of Care 2025 and the ISPAD Clinical Practice Consensus Guidelines 2022 [9, 14]. Under this unified benchmark, only 19% of our participants achieved good glycemic control. This proportion is alarmingly low, and is comparable to — or lower than — figures reported in other low-resource settings. Data from the T1D Exchange Registry (USA) show that approximately 21–25% of youth with T1D achieve HbA1c ≤7.0% [30, 31]. Noorani et al. in Tanzania reported a mean HbA1c of 11.05±2.1% [50], consistent with our results and reflective of shared structural challenges in sub-Saharan Africa. By contrast, Craig et al. in Australia and Petitti et al. in the USA found mean HbA1c values of 8.2% and 8.18% respectively [34], underscoring the profound inequality in global glycemic outcomes. Previous studies have consistently found adolescence to be associated with poor glycemic control [48], partly due to higher insulin elimination and lower insulin sensitivity compared with younger children, as well as psychosocial factors associated with puberty.

In our study, patients followed up in the Adamaoua region demonstrated significantly better glycemic control (p=0.003) than those in the North and Far North regions. This may be explained by a lower patient-to-provider ratio at the Adamaoua CDiC center, greater relational continuity between the center coordinator and patients, and a more stable humanitarian situation compared with the Far North. These observations are consistent with evidence that patient-centered care and lower case loads improve metabolic outcomes [11]. We also note that the older the patient, the 2.2-fold greater the risk of being poorly controlled (OR=2.2 [0.38–13.38]), reflecting diminishing parental supervision with advancing age. Female sex appeared to be better associated with glycemic control (OR=0.42 [0.148–1.199]), in contrast to findings from Germany where female sex was associated with poorer control [51]. Higher educational level and cohabitation with both parents were also associated with improved control, consistent with Argentinian data showing that single-parent family structure and lower maternal education are predictors of poor glycemic control [29].

GEOGRAPHIC ACCESSIBILITY AND GLYCEMIC CONTROL

We found a statistically significant association between the distance separating the patient's place of residence and the CDiC center, and glycemic control (p=0.04; OR=4.4 [0.95% CI: 0.96–20.84]). Living more than 20 km from the CDiC center increased the risk of poor glycemic control by approximately 4.5-fold. This finding is consistent with broader evidence on geographic barriers in chronic disease management. The Atun et al. Lancet Diabetes & Endocrinology commission identified geographic barriers as among the most critical determinants of care quality and diabetes outcomes in sub-Saharan Africa [19]. In our context - where public transport is costly, roads are often unpaved, and humanitarian insecurity limits mobility in the Far North - the burden of distance is amplified. These findings provide empirical justification for the creation of additional satellite CDiC centers or mobile care units in the northern regions of Cameroon.

THERAPEUTIC EDUCATION AND GLYCEMIC CONTROL

While no statistically significant association was found between participation in therapeutic education and glycemic control in bivariate analysis (p=0.59), a clinically meaningful trend was observed: participation in at least one session per month was associated with a 1.3-fold increased likelihood of achieving glycemic targets (OR=1.3 [0.48–3.57]). This finding is consistent with the growing body of evidence supporting structured diabetes self-management education (DSME) as a cornerstone of T1DM care. The ISPAD 2022 Clinical Practice Consensus Guidelines on diabetes education emphasize that structured, ongoing, multidisciplinary education is associated with improved HbA1c, reduced acute complications, and better quality of life in youth with T1DM [12]. The non-significant finding in our study may reflect the limited number of sessions attended and the structural barriers - including low literacy, language diversity, and cultural factors — that reduce the effectiveness of standard educational approaches in the northern regions of Cameroon.

Regarding insulin regimen, participants with more than two injections per day were more likely to achieve their glycemic targets, consistent with ISPAD 2022 recommendations for intensive insulin therapy as the standard of care in T1DM [13]. This result aligns with Ziegler et al., who found that the number of daily insulin injections was proportional to HbA1c improvement [18]. Possession of a glucometer was associated with a 5-fold increase in the likelihood of achieving glycemic targets (OR=4.44 [0.26–74.45]), underscoring the fundamental role of self-monitoring. The lack of a significant association between self-monitoring frequency and glycemic control may reflect the fact that none of our participants achieved the ADA recommendation of at least 4 blood glucose tests per day.

A statistically significant association was found between diabetes duration of less than 2 years and better glycemic control (p=0.03; OR=2.90 [1.06–8.30]). This is consistent with the known phenomenon of residual beta-cell function ("honeymoon period") in the early years after T1DM onset, which facilitates glycemic control. As diabetes duration increases, total insulin deficiency becomes complete, making glycemic management more challenging and reinforcing the importance of early intensive education and follow-up.

Hypoglycemia remains a major limiting factor in improving glycemic control. The fear of hypoglycemia often leads

patients to tolerate higher blood glucose levels [25]. In our cohort, the number of severe hypoglycemic episodes was associated with a 1.19-fold increased risk of poor glycemic control (OR=1.19 [0.23–16.79]; p=0.52), consistent with the finding of Svoren et al. [11]. This could reflect both poorer adherence following a hypoglycemic episode and the effects of excessive correction of hypoglycemia, leading to rebound hyperglycemia.

GLOBAL ADVANCES IN T1D MANAGEMENT AND THEIR RELEVANCE TO OUR SETTING

Over the past decade, the management of T1DM has been transformed by a series of technological innovations that have substantially improved glycemic outcomes in high-income settings. The widespread adoption of continuous glucose monitoring (CGM) systems - particularly real-time devices such as the Dexcom G7 and Abbott FreeStyle Libre 3 - has enabled patients to monitor interstitial glucose continuously, dramatically improving time-in-range (TIR) and reducing hypoglycemic episodes [26]. The integration of CGM with insulin pump therapy (CSII) through hybrid closed-loop systems represents the most significant advancement in T1D management. Systems such as the Medtronic MiniMed 780G with SmartGuard™ technology and the Tandem Control-IQ™ use machine-learning algorithms to continuously adjust basal insulin delivery in response to CGM data, achieving TIR exceeding 70% and significantly reducing HbA1c levels in randomized controlled trials [28]. The ISPAD 2022 guidelines actively recommend these systems for children and adolescents where available [27].

In parallel, the approval of teplizumab (Tzield™), an anti-CD3 monoclonal antibody that delays the onset of clinical T1DM by a median of 32 months in high-risk relatives, has opened a new era of disease modification and secondary prevention [29]. These advances are not currently accessible in Cameroon or sub-Saharan Africa more broadly, due to prohibitive costs, lack of infrastructure, limited healthcare professional training, and absence of supply chains for consumables [19]. The mean HbA1c of 10.08% observed in our cohort stands in stark contrast to the sub-7.0% targets achievable with these technologies in well-resourced settings, and reflects the profound inequity in global diabetes care.

These observations carry concrete implications for advocacy and policy. The continued exclusion of children in low-income countries from evidence-based technological advancements perpetuates the cycle of poor glycemic control, accelerated complications, and premature mortality. Intermediate solutions - such as time-limited, subsidized access to flash glucose monitoring - have been piloted in some African settings and may represent a feasible, cost-effective first step toward improving glycemic monitoring in the northern regions of Cameroon.

CONCLUSIONS

Great strides have been made in the management of T1DM in children and adolescents in Cameroon, notably in improving access to insulin through the CDiC program. The aim of this study was to identify factors associated with glycemic control in a population of children and adolescents with type 1 diabetes living in the northern regions of Cameroon, who have free access to care and medication.

At the conclusion of this work, we state the following: the glycemic control of children and adolescents with T1DM in the northern regions of Cameroon is not optimal, despite free access to care: only 19% achieved the current unified HbA1c target of ≤7.0% (≤53 mmol/mol) as recommended by the ADA Standards of Care 2025 and ISPAD 2022 guidelines [9, 14]. This proportion is alarmingly low and calls for urgent, multifaceted interventions.

Factors associated with good glycemic control included: (1) belonging to the Adamaoua region; (2) a treatment regimen of more than 2 injections per day; (3) living less than 20 km from the care clinic; (4) fewer than three episodes of severe hypoglycemia in the last 6 months; (5) diabetes duration of less than 2 years; and (6) participation in more than three therapeutic education sessions per 6 months.

RECOMMENDATIONS

Based on these findings, we recommend the following priority interventions:

(1) Intensification of structured therapeutic education programs, including culturally adapted content and peer-support diabetes camps;

(2) Creation of additional CDiC satellite centers or mobile care units to reduce geographic barriers;

(3) Strengthening of continuous supply chains for insulin and glucometers;

(4) Advocacy for progressive adoption of affordable glucose monitoring technologies (e.g., flash glucose monitoring) through national health financing mechanisms;

(5) Development of a regional epidemiological registry to generate longitudinal data and monitor outcomes.

In light of global innovations - including hybrid closed-loop insulin delivery systems (SmartGuard™, Control-IQ™) and teplizumab - long-term strategic investments must be made to progressively reduce the technology gap between high-income countries and resource-limited settings such as the northern regions of Cameroon.

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CONFLICT OF INTEREST

The Authors declare no conflict of interest

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