Original Research

Adherence as a Predictor of Glycemic Control Among Adolescents With Type 1 Diabetes: A Retrospective Study Using Real-world Evidence

Sohayla A. Ibrahim, MSc[1]; Maguy Saffouh El Hajj, PharmD[1]; Yaw B. Owusu, MSc[1]; Maryam Al-Khaja, PharmD[2]; Amel Khalifa, MD[2]; Dalia Ahmed, PharmD[2]; and Ahmed Awaisu, PhD[1]

[1]*College of Pharmacy, QU Health, Qatar University, Doha, Qatar; and* [2]*SIDRA Medicine, Doha, Qatar*

ABSTRACT

Purpose: Metabolic control among adolescents with type 1 diabetes mellitus (T1DM) is generally poor. Nonadherence is a contributor to this poor glycemic control, leading to adverse outcomes. The findings of studies reporting the association between adherence and glycemic control are conflicting. This study aimed to assess the level of adherence among adolescents with T1DM and its relationship with glycemic control.

Methods: This was a retrospective, cross-sectional study that was conducted at Sidra Medicine, a state-of-the-art tertiary health care facility for women and children in Qatar. Mean blood or interstitial glucose monitoring frequency (BGMF) was used to assess adherence level among adolescents with T1DM, whereas glycemic control was assessed via documented glycated hemoglobin A_{1c} (HbA_{1c}). Adolescents who had a mean BGMF of ≥4 checks per day were considered adherent, and those who had an HbA_{1c} level of <7% were considered as having controlled diabetes. Correlational and logistic regression analyses were performed to assess the relationship between adherence and glycemic control, incorporating other covariates into the model.

Findings: The rate of adherence among adolescents with T1DM in Qatar was 40.9%. Adherent adolescents had significantly lower median HbA_{1c} levels compared with nonadherent adolescents (9.0% vs. 9.7%; $P = 0.002$). A significant negative correlation was found between BGMF and HbA_{1c} level (correlation coefficient $r_s = -0.325$; $P < .001$). Approximately 97% of nonadherent adolescents compared with 87% of adherent adolescents had suboptimal diabetes control ($HbA_{1c} \geq 7\%$) ($P = .016$). Furthermore, nonadherent adolescents were 78% less likely to have controlled diabetes compared with adherent adolescents (adjusted odds ratio = 0.221; 95% CI, 0.063–0.778; $P = 0.019$). The combined effect of the determinants of glycemic control among adolescents with T1DM that were included in the multiple regression model was able to explain approximately 9% of the variances in glycemic control (Cox and Snell $R^2 = 0.092$).

Implications: The current findings suggest that nonadherence was highly prevalent among adolescents with T1DM and was a significant independent predictor of glycemic control, explaining 9% of the variability. This finding warrants further exploration of other possible predictors of poor glycemic control among the adolescent population. Comprehensive interventions, including educational, technological, and health service delivery aspects, aimed at improving adherence and ultimately optimizing glycemic control are warranted in adolescents with T1DM. (*Clin Ther.* 2022;44:1380–1392.) © 2022 The Author(s). Published by Elsevier Inc. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/)

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INTRODUCTION

Type 1 diabetes mellitus (T1DM) or insulin-dependent diabetes mellitus is an autoimmune disease that is usually characterized by absolute deficiency or lack of insulin.[1,2] It is the most prevalent metabolic noncommunicable chronic disease in children, accounting for 5% to 10% of all diabetes cases across all types and increasing at a rate of approximately 3% each year.[3,4] Comparatively, the incidence of T1DM is considered higher in Qatar than other countries in the Middle East and North Africa region.[5,6] The reported incidence in Qatar increased from 23.64 to 28.4 cases per 100,000 children between 2011 and 2019. The management of T1DM is crucial to slow the progression of the disease and to prevent the emergence of acute and chronic complications. Consequently, the management encompasses multiple facets, including adherence to insulin delivery regimens, dietary restrictions, and other pertinent lifestyle recommendations.

In T1DM, recommendations include monitoring blood or interstitial glucose readings frequently, correcting insulin doses relative to the glucose readings, administering doses of insulin, attending scheduled appointments regularly, counting carbohydrates, modifying lifestyle, and obtaining medical supplies.[7–9] However, these tasks are highly demanding in nature and frequency, which adds to the challenge of maintaining optimal adherence and diabetes control. Adolescence is a transitional phase between childhood and adulthood during which a number of changes associated with puberty occur, including hormonal, cognitive, and psychosocial changes.[7,10] Those changes further contribute to the adherence burden, making it particularly more challenging among adolescents.[9] Several methods have been reported for the assessment of adherence among adolescents with T1DM, with each method assessing adherence from a different aspect and having its merits and demerits. The daily frequency of self-monitoring of blood glucose, carbohydrate intake entry, and insulin bolus delivery via pump download are among the commonly used objective adherence behavior methods.[8,11]

Adolescents with T1DM have high rates of nonadherence, reaching up to 93%.[12] Moreover, they also tend to have poorly controlled diabetes, with only approximately 21% meeting their glycosylated hemoglobin (HbA_{1c}) targets of <7%, as set by the American Diabetes Association.[13] This nonadherence can lead to complications and hospitalizations, adding significant burden to the direct and indirect medical costs of managing the disease.[12,14] In the Diabetes Control and Complications Trial (DCCT), adolescents compared with adults clearly had poorer glycemic control measured as higher HbA_{1c} levels.[15] Collectively, during adolescence, adherence is low, glycemic control is typically suboptimal, and the rates of acute complications, including hypoglycemia and diabetic ketoacidosis, are the highest.[8]

The association between glycemic control and adherence among adolescents with T1DM was assessed in many studies that documented conflicting findings. Some studies have found a link between improved adherence (measured as higher blood or interstitial glucose monitoring frequency [BGMF]) and reduced HbA_{1c}.[16–18] Moreover, a meta-analysis of 2492 adolescents with T1DM reported that there was an adherence-glycemic control link with a mean effect size of −0.28 (95% CI, −0.32 to −0.24) across 21 studies.[15] In contrast, some studies have not found a link between BGMF and glycemic control.[19,20] Thus, whether an association exists between adherence and glycemic control among adolescents with T1DM is still controversial. Therefore, the objectives of this study were to assess the level of adherence among adolescents with T1DM in Qatar using the BGMF approach and to investigate the relationship between the level of adherence and glycemic control, measured via HbA_{1c}. In the context of the present study, BGMF via glucometer download was used as a proxy for adherence. Adolescents who had achieved a mean BGMF of ≥ 4 were classified as adherent, based on minimum recommendations for adherence behaviors used in previous comparable research studies[11,21–23] and setting-specific recommendations provided by pediatric endocrinologists in our hospital.

PARTICIPANTS AND METHODS

Study Design

This study used a retrospective, cross-sectional study design. Quantitative data were collected from electronic medical records (Cerner Millennium, North Kansas City, Kansas) to assess the levels of adherence among adolescents with T1DM using the mean BGMF documented through glucometers or other flash glucose monitoring (FGM) devices. Ethical approvals were obtained from the institutional review boards of Sidra Medicine (approval 1500792) and Qatar University (approval QU-IRB 1103-EA/19). Patient consent was not required in this study because it was a retrospective study without any direct patient interaction.

Study Setting

The study was conducted at Sidra Medicine, a semigovernmental institution that provides tertiary health care services to children, adolescents, and women.[24] The institution provides comprehensive multidisciplinary care for children and adolescents with endocrine disorders, such as diabetes mellitus, thyroid disorders, and growth hormone disorders. Sidra Medicine has an Endocrinology and Diabetes Outpatient Clinic where all children and adolescents with T1DM in Qatar receive care. The Endocrinology and Diabetes Outpatient Clinic operates 8 hours on weekdays (Sunday-Thursday) from 7:00 am to 3:00 pm.

Study Participants

Study participants were adolescents with T1DM between the ages of 12 and < 18 years. This specific population was chosen because of the multiple challenges, such as hormonal and psychosocial factors, that arise as they transition from childhood to adulthood.

Individuals were included in the study if they satisfied the following inclusion criteria: (1) 12 to 17 years of age, (2) diagnosed with T1DM, (3) taking insulin via multiple daily injections or continuous subcutaneous insulin infusion (CSII), and (4) duration of diabetes of at least 1 year. Individuals diagnosed with multiple (>1) chronic conditions in addition to T1DM or any mental illnesses were excluded from the study.

Sample Size Determination

An online sample size calculator was used to calculate the sample size using the following parameters: margin of error, 5%; confidence level, 95%; response distribution, 50%; and population size, 500 adolescents with T1DM. The population size was not obtainable as a statistic from the clinic. Therefore, it was estimated based on a study conducted in Sidra Medicine that stated that >900 children (<18 years of age) were treated at their institution.[24] According to the distribution of children to adolescents of 2.5:1 in Qatar in 2019, we overestimated the population size to be 500. The estimated sample size using the parameters and assumptions above was determined as 218 patients. Convenient or opportunity sampling technique was used for inclusion in this study, because the identification of a sampling frame was not feasible.

Outcome Measures

HbA_{1c} is an important clinical indicator of glycemic control and illness management with a target of <7% according to American Diabetes Association guidelines; therefore, it was set as a primary outcome measure in this study. In addition, BGMF was used to assess adherence and as a predictor of HbA_{1c}; thus, it was set as the other primary outcome measure (ie, the other major illness-related variable of interest).

Data Collection

The data collection tool was designed to capture all relevant demographic and clinical data to be extracted from the medical records, including gender, nationality, age, comorbidities, HbA_{1c}, and duration of illness. Moreover, data on adherence were collected through documented BGMF obtained from glucometers or the frequency of sensor scanning of FGM devices.

The list of all patients with T1DM treated at the Endocrinology and Diabetes Outpatient Clinic at Sidra Medicine was obtained. Each patient profile was assessed for eligibility. Clinical and demographic data, including HbA_{1c}, were collected from the electronic medical record (Cerner Millennium) for all the patients identified as eligible for the study. Data on BGMF per day were also collected from the saved reports previously downloaded from glucometers or other FGM devices. Data were collected between September 2020 and December 2020.

The FGM system works by measuring actual interstitial glucose concentration once the patient scans the sensor with the reader device. FGM devices do not have alarm systems, do not require calibration, and do not provide continuous data on glucose level unless the patient scans the sensor every 8 hours, which is contrary to continuous glucose monitoring devices.[25,26] The sensors should be changed every 2 weeks, and these devices produce accurate results compared with glucometers[25] and continuous glucose monitoring devices.[26]

If objective data on BGMF were not available, clinical notes were reviewed and data were extracted based on health care practitioner, adolescent, or caregiver report (if documented). Previous studies have found that adolescent and caregiver report was significantly correlated with BGMF from glucometer downloads with a correlation coefficient of approximately 0.6 ($P < 0.0001$).[27] A mean of 30 days was collected; if not available, a mean of 14 days was used. Thirty days was chosen because available evidence suggests that white coat adherence can influence the reliability of the results, where the frequency of monitoring increases as a scheduled clinical visit approaches.[28] Adolescents who had a mean BGMF of <4 times per day were considered nonadherent, whereas those who achieved a mean BGMF of ≥4 times per day were classified as adherent. This classification was used based on minimum recommendations for adherence behaviors used in previous comparable research studies[11,21–23] and site-specific recommendations provided by health care professionals in Sidra Medicine.

Statistical Analysis

Descriptive statistics were used to summarize the demographic and clinical characteristics of the patients. Numbers and percentages were used to report categorical variables, whereas medians and interquartile ranges (IQRs) were used to summarize continuous variables, because the data were not normally distributed. The Pearson χ^2 and Fisher exact tests were used to identify the effects of demographic and clinical characteristics on adherence (assessed via BGMF) and glycemic control (HbA_{1c}) as categorical variables. In addition, the Mann-Whitney *U* and Kruskal-Wallis tests were used to assess the effect of the demographic and clinical characteristics on adherence (BGMF) and glycemic control (HbA_{1c}) as continuous variables. The Spearman ρ test was used to determine the correlation between adherence and glycemic control among the studied population.

A univariate binary logistic regression test was used to assess the relationship between adherence (BGMF) and glycemic control (HbA_{1c} level). It was also used to assess the relationships between other covariates (eg, insulin delivery methods, nationality, duration of diabetes, and gender) and glycemic control. Multivariate binary logistic regression test was then used to incorporate covariates with statistical significance into a model. Entry of variables derived from the univariate analysis into the model was less restrictive ($P < 0.25$) than for the multivariate regression model ($P < 0.05$). The cutoff for univariate binary logistic regression is often more liberal than the conventional cutoff for statistical significance (eg, $P < 0.25$, instead of the usual $P < 0.05$) because its purpose is to identify potential predictor variables rather than to test a hypothesis. SPSS software, version 25 (IBM Corp, Armonk, New York) was used for data analyses.

RESULTS

Demographic and Clinical Characteristics of the Study Population

A total of 216 adolescents with T1DM were included in the analyses. Their demographic and clinical characteristics are presented in Table I. The median (IQR) age of the adolescents was 14.2 (3.0) years, and most of them (71.8%) were in the age category of 12 to 15 years. The gender distribution was almost equal, with a slightly higher proportion of female patients (52.3%). Most adolescents were Qatari nationals (60.2%), with no documented family history of diabetes mellitus (71.8%). The median (IQR) body mass index (BMI) of the adolescents was 22.2 (7.0) kg/m^2, and most of them (48.6%) were within the normal BMI range of 18.5 to 24.9 kg/m^2 (Table I).

The median (IQR) duration of diabetes was 5.0 (6.0) years, with most adolescents (60.3%) diagnosed with T1DM for the last 1 to 5 years. Furthermore, most patients (75.8%) were using multiple daily injections as the insulin delivery method, and only a few had other comorbidities, with 8.3% having some form of thyroid disorder. The prevalence of diabetes complications was low in the study population, with 8 patients (3.7%) having nephropathy and 2 patients (0.9%) having retinopathy.

The median (IQR) HbA_{1c} was 9.3% (2.8), with most adolescents (92.7%) having suboptimal diabetes control (HbA_{1c} >7%). Other clinical characteristics of the study subjects are represented in Table I.

Adherence Assessment

Data for BGMF were available for 193 patients. The median of the mean BGMF per day was 3.0 (checks per day), and most adolescents (59.1%) monitored their blood glucose <4 times per day (considered as nonadherent). The adherence rate (checking blood

Table I. Demographic and clinical characteristics of adolescents with type 1 diabetes mellitus in Qatar.

Characteristic	Finding*
Age, median (IQR), y (n = 216)	14.2 (3.0)
Age category, y (n = 216)	
12–15	155 (71.8)
16–18	61 (28.2)
Sex (n = 216)	
Male	103 (47.7)
Female	113 (52.3)
Nationality (n = 216)	
National	130 (60.2)
Nonnational	86 (39.8)
Family history of diabetes (n = 216)	
Yes	61 (28.2)
No	155 (71.8)
Weight, median (IQR), kg (n = 216)	58.4 (21.0)
Height, median (IQR), cm (n = 214)	159.0 (12.5)
BMI, median (IQR), kg/m^2 (n = 214)	22.2 (7.0)
BMI category (n = 214)	
Underweight (<18.5 kg/m^2)	44 (20.6)
Normal weight (18.5–24.9 kg/m^2)	104 (48.6)
Overweight (25–29.9 kg/m^2)	44 (20.6)
Obese ($\geq$30 kg/m^2)	22 (10.3)
Duration of diabetes, median (IQR), y (n = 214)	5.0 (6.0)
Duration of diabetes category (n = 214)	
1–5 y	129 (60.3)
6–10 y	63 (29.4)
>10 y	22 (10.3)
Insulin delivery method (n = 215)	
Pump	52 (24.2)
Injections	163 (75.8)
Comorbidities† (n = 216)	
Thyroid disease	18 (8.3)
Mental disorder	2 (0.9)
Epilepsy	2 (0.9)
Pulmonary disease	1 (0.5)
Diabetes complications† (n = 216)	
Nephropathy	8 (3.7)
Neuropathy	0 (0)
Retinopathy	2 (0.9)
Cardiovascular	0 (0)
HbA_{1c} at time of BGMF data collection, median (IQR), % (n = 192)	9.3 (2.8)
HbA_{1c} at time of BGMF data collection category (n = 192)	
<7% (controlled)	14 (7.3)
$\geq$7% (uncontrolled)	178 (92.7)
Mean BGMF per day, median (IQR), checks per day (n = 193)	3.0 (4.5)

(*continued on next page*)

Table I. (*continued*)

Characteristic	Finding*
Mean BGMF per day category (n = 193)	
<4 checks per day (nonadherent)	114 (59.1)
≥4 checks per day (adherent)	79 (40.9)

BGMF = or interstitial glucose monitoring frequency; BMI = body mass index; HbA_{1c} = glycated hemoglobin; IQR = interquartile range.

* Data are presented as number (percentage) of patients unless otherwise indicated.

† Multiple option response.

glucose ≥4 times per day) among the study participants was approximately 40.9% (Table I).

Effect of Demographic and Clinical Characteristics on Adherence

Table II summarizes the effect of demographic and clinical characteristics on adherence. The median of the mean BGMF per day was significantly higher among adolescents between 12 and 15 years of age compared with those between 16 and 18 years of age (3 vs 2 checks per day) (P = 0.033). Trends of higher adherence rates were noticed among girls, adolescents 12 to 15 years of age, and adolescents taking multiple daily injections, although these differences were not statistically significant. Nationality, duration of diabetes, and family history of diabetes had no effect on adherence.

Effect of Demographic and Clinical Characteristics on Glycemic Control

The effects of demographic and clinical characteristics on glycemic control are presented in Table III. Age category and gender had no effect on glycemic control (P = >0.99 and 0.473, respectively). Qatari nationals had a significantly higher median HbA_{1c} level compared with non-Qatari nationals (9.7% vs 8.9%; P = 0.001). Similarly, patients using insulin pumps had significantly lower median HbA_{1c} levels compared with their counterparts using multiple daily insulin injections (8.9% vs 9.6%; P = 0.008). Glycemic control tended to worsen among adolescents with a longer duration of diabetes and higher BMI, although this difference was not significant.

Effect of Adherence on Glycemic Control

The effect of adherence on glycemic control is presented in Table III. Among the studied population, 12.8% of adherent adolescents (≥4 checks per day) had controlled HbA_{1c} levels (<7%) compared with 3.5% of nonadherent adolescents (<4 checks per day) who had controlled HbA_{1c} levels (P = 0.016). Adolescent who were adherent had a significantly lower median HbA_{1c} level compared with those who were nonadherent (9.0% vs 9.7%; P = 0.002). The association between adherence and glycemic control was assessed using the Spearman ρ test, and the correlation coefficient r_s was −0.325 (P < 0.001), indicating a significant negative correlation.

Logistic Regression Results

The results of the univariate binary logistic regression are presented in Table IV. The findings indicate that adherence was the only independent variable that had a significant effect on glycemic control. For instance, nonadherent adolescents (<4 checks per day) were 75% less likely to have controlled diabetes (HbA_{1c} <7%) compared with adherent adolescents (≥4 checks per day) (odds ratio =0.25; 95%CI, 0.075–0.827; P = 0.023). Some other variables, including nationality, family history of diabetes, duration of diabetes, and BMI, also fulfilled the statistical requirements for inclusion into the multiple regression model (ie, P < 0.25).

Similarly, the multivariate binary logistic regression model is presented in Table V. The combined effect of the determinants of glycemic control among adolescents with T1DM that were included in the multiple regression model was able to explain approximately

Table II. Effect of demographic and clinical characteristics on adherence among adolescents with type 1 diabetes mellitus in Qatar.*

Characteristic	Adherent (≥4 Checks per Day), No. (%)	Nonadherent (<4 Checks per Day), No. (%)	P†	Mean BGMF per Day, Median (IQR)	P‡,§
Age category, y (n = 193)					
12–15	60 (43.5)	78 (56.5)	0.255†	3.0 (4.0)	0.033‡
16-18	19 (34.5)	36 (65.5)		2.0 (3.5)	
Sex (n = 193)					
Male	43 (46.7)	49 (53.3)	0.117†	3.0 (5.1)	0.167‡
Female	36 (35.6)	65 (64.4)		2.9 (3.2)	
Nationality (n = 193)					
National	47 (41.2)	67 (58.8)	0.920†	3.0 (4.6)	0.679‡
Nonnational	32 (40.5)	47 (59.5)		2.9 (3.2)	
Family history of diabetes (n = 193)					
Yes	21 (37.5)	35 (62.5)	0.535†	3.0 (3.0)	0.982‡
No	58 (42.3)	79 (57.7)		3.0 (4.6)	
Insulin delivery method (n = 192)					
Pump	17 (36.2)	30 (63.8)	0.425†	3.0 (2.8)	0.856‡
Injections	62 (42.8)	83 (57.2)		3.0 (4.7)	
Duration of diabetes, y (n = 191)					
1–5	45 (40.5)	66 (59.5)	0.947†	3.0 (4.2)	0.982§
6–10	26 (41.9)	36 (58.1)		3.0 (3.5)	
>10	8 (44.4)	10 (55.6)		3.0 (4.5)	
BMI category (n = 191)					
Underweight (<18.5 kg/m^2)	19 (51.4)	18 (48.6)	0.594†	4.0 (6.8)	0.457§
Normal weight (18.5–24.9 kg/m^2)	38 (38.8)	60 (61.2)		3.0 (4.1)	
Overweight (25–29.9 kg/m^2)	14 (38.9)	22 (61.1)		2.6 (3.8)	
Obese (≥30 kg/m^2)	8 (40.0)	12 (60.0)		2.0 (4.0)	

BGMF = blood or interstitial glucose monitoring frequency; BMI = body mass index; IQR = interquartile range.
* Total samples sizes represent participants for whom we have data on their BGMF.
† Pearson χ^2 test was used to compute the *P* value.
‡ Mann-Whitney U test was used to compute the *P* value.
§ Kruskal-Wallis test was used to compute the *P* value.

9% of the variances in glycemic control (Cox and Snell $R^2 = 0.092$). However, adherence was the only variable that had a significant effect on glycemic control such that nonadherent adolescents (<4 checks per day) were 78% less likely to have controlled diabetes (HbA_{1c} <7%) compared with adherent adolescents (≥4 checks per day) (odds ratio =0.221; 95% CI, 0.063–0.778; $P = 0.019$) (Table V).

DISCUSSION

This study assessed the prevalence of adherence among adolescents with T1DM in Qatar and its relationship

Table III. Effect of demographic and clinical characteristics on glycemic control among adolescents with type 1 diabetes mellitus in Qatar.*

Characteristic	Controlled (HbA_{1c} <7%), No. (%)	Uncontrolled (HbA_{1c} ≥7%), No. (%)	P†,‡	HbA_{1c}, Median (IQR)	P§,‖
Age category, y (n = 192)					
12–15	10 (7.2)	128 (92.8)	>0.99‡	9.3 (2.6)	0.633§
16–18	4 (7.4)	50 (92.6)		9.6 (2.8)	
Sex (n = 192)					
Male	8 (8.7)	84 (91.3)	0.473†	9.5 (2.6)	0.908§
Female	6 (6.0)	94 (94.0)		9.2 (2.9)	
Nationality (n = 192)					
National	5 (4.5)	107 (95.5)	0.075†	9.7 (3.3)	0.001§
Nonnational	9 (11.3)	71 (88.8)		8.9 (2.8)	
Family history of diabetes (n = 192)					
Yes	2 (3.6)	53 (96.4)	0.357‡	9.7 (3.0)	0.238§
No	12 (8.8)	125 (91.2)		9.2 (2.7)	
Insulin delivery method (n = 191)					
Pump	4 (8.5)	43 (91.5)	0.750‡	8.9 (1.8)	0.008§
Injections	10 (6.9)	134 (93.1)		9.6 (3.2)	
Duration of diabetes, y (n = 191)					
1–5	12 (10.8)	99 (89.2)	0.070‡	9.2 (3.1)	0.243‖
6–10	1 (1.6)	61 (98.4)		9.3 (2.1)	
>10	1 (5.6)	17 (94.4)		10.6 (2.5)	
BMI category (n = 191)					
Underweight (<18.5 kg/m^2)	4 (10.8)	33 (89.2)	0.354‡	9.4 (3.1)	0.354‖
Normal weight (18.5–24.9 kg/m^2)	9 (9.1)	90 (90.9)		9.2 (3.0)	
Overweight (25–29.9 kg/m^2)	1 (2.9)	34 (97.1)		9.3 (2.9)	
Obese (≥30 kg/m^2)	0 (0)	20 (100)		9.8 (1.7)	
Adherence (mean BGMF per day) (n = 191)					
Adherent (≥4 checks per day)	10 (12.8)	68 (87.2)	0.016†	9.0 (2.55)	0.002§
Nonadherent (<4 checks per day)	4 (3.5)	109 (96.5)		9.7 (2.95)	

BGMF = blood or interstitial glucose monitoring frequency; BMI = body mass index; HbA_{1c} = glycated hemoglobin; IQR = interquartile range.

* Total samples sizes represent participants for whom we have data on their BGMF.

† Pearson χ^2 test was used to compute the P value.

‡ Fisher exact test was used to compute the P value.

§ Mann-Whitney U test was used to compute the P value.

‖ Kruskal-Wallis test was used to compute the P value.

with glycemic control. To our knowledge, this is the first study in Qatar to assess the level of adherence among adolescents with T1DM. The findings indicate that the rate of adherence among adolescents with T1DM in Qatar, measured through BGMF, was only approximately 40%. This rate of adherence is comparable to a previous study that reported adherence rate to blood glucose monitoring recommendations of 48%.[29] Moreover, a previous study found that the percentage of days that adolescents had a BGMF of ≥4 ranged from 46% to 48%.[11] In contrast, another study had reported a higher level of adherence

Table IV. Univariate binary logistic regression of the determinants of glycemic control among adolescents with type 1 diabetes mellitus in Qatar.*

Variable	B	Exp (B) (95% CI)	*P*†
Adherence (mean BGMF per day) (n = 191)	−1.388	0.250 (0.075–0.827)	0.023‡
Age category (n = 192)	−0.024	0.977 (0.293–3.258)	0.969‡
Sex (n = 192)	0.400	1.492 (0.497–4.476)	0.475‡
Nationality (n = 192)	−0.998	0.369 (0.119–1.145)	0.084‡
Family history of diabetes (n = 192)	0.934	2.544 (0.550–11.761)	0.232‡
Insulin delivery method (n = 191)	0.220	1.247 (0.342–4.177)	0.721‡
Duration of diabetes, y (n = 191)	1.265	3.544 (0.956–13.139)	0.058‡
BMI category (n = 191)	1.742	5.707 (0.728–44.733)	0.097‡

BGMF = blood or interstitial glucose monitoring frequency; BMI = body mass index.
* Total sample sizes represent participants for whom we have data on their glycated hemoglobin.
† Univariate binary logistic regression analysis was used to compute the *P* values.
‡ Significant *P* values that qualify to the multiple regression model ($P < 0.25$).

Table V. Multivariate binary logistic regression of the determinants of glycemic control among adolescents with type 1 diabetes mellitus in Qatar.

Variable	B	Exp (B) (95% CI)	*P**
Adherence (mean BGMF per day) (n = 189†)	−1.509	0.221 (0.063–0.778)	0.019
Nationality	−0.981	0.375 (0.113–1.248)	0.110
Family history of diabetes	−0.766	2.150 (0.439–10.538)	0.345
Duration of diabetes	1.322	3.750 (0.959–14.657)	0.057
BMI category	1.565	4.783 (0.579–39.483)	0.146

BGMF = blood or interstitial glucose monitoring frequency; BMI = body mass index.
* Multivariate binary logistic regression analysis was used to compute the *P* values.
† Total sample size represents participants for whom we have data on all the variables.

to blood glucose monitoring recommendations of 76.5%.[30] However, this study included both children and adolescent, which might have resulted in the higher adherence rate. In addition, the level of adherence obtained in the present study is in concert with a study that reported that the overall adherence for children with chronic illnesses did not exceed 50%, especially with diseases that require more complex behaviors, such as blood or interstitial glucose monitoring.[31] The median mean BGMF was 3 checks per day. This median was significantly higher among younger adolescents (12–15 years of age) compared with older adolescents (16–18 years of age). Previous studies that assessed the mean BGMF of adolescents found comparable means of 2.75 to 3.5 checks per day.[11,27,32] The effect of age on adherence and glycemic control was assessed in many studies, and most studies concluded that younger adolescents had better adherence and lower HbA_{1c} levels compared with older adolescents.[29,33,34] This finding may be attributed to the fact that parents are usually more involved in monitoring and supervision of younger age groups than older adolescents, when parental involvement diminishes.[29]

Moreover, >90% of the adolescents had suboptimal diabetes control with an HbA_{1c} of ≥7%. The median HbA_{1c} among the studied individuals was 9.3%.

Previous studies have found that the mean/median HbA_{1c} levels among adolescent and children ranged from 8% to as high as 11%.[27,29,30,32,35,36] In addition, a previous study conducted in 2018 in Qatar among adolescents and children with T1DM using CSII found a baseline HbA_{1c} of 9.7%, which is comparable to our study findings.[24] Qatari nationals had a higher median HbA_{1c} of 9.7% compared with nonnationals (8.9%), with a difference of approximately 1%. Moreover, adolescents using insulin pump had a significantly lower HbA_{1c} level of 8.9% compared with patients using multiple daily injections (9.6%). This finding is consistent with other studies that confirmed the effectiveness of CSII in reducing HbA_{1c} levels.[24,37] However, only approximately 25% of adolescents in our study used CSII as insulin delivery method, which might explain the high mean HbA_{1c} level.

This study did not find a significant effect of the duration of diabetes on adherence or glycemic control. In contrast, a previous study found that the shorter the duration of diabetes, the better the glycemic control, with a difference of up to 2% in HbA_{1c}.[29] However, the later study compared patients with a duration of diabetes of <1 year to patients with a duration of diabetes of >1 year.

Adherence, which was assessed by a BGMF of ≥4 checks per day, had a significant effect on glycemic control. For instance, adherent adolescents had significantly better diabetes control compared with nonadherent adolescents. This effect was also concluded by a previous study that reported a significantly lower mean HbA_{1c} level among adherent adolescents.[29] In addition, a statistically significant weak negative correlation was found between the mean BGMF per day and HbA_{1c} level. Similarly, evidence from the published literature suggests that there is an association between improved adherence (measured as higher BGMF) and reduced HbA_{1c}.[16–18,27,34,38–40] Moreover, a meta-analysis of 2492 youths with T1DM reported that there was an adherence-glycemic control link, with a mean effect size of –0.28 (95% CI, –0.32 to –0.24) across 21 studies.[15] Consistent with prior findings, adherence to BGMF recommendations significantly predicted glycemic control.[11,29,41–43] However, the combined model was only able to explain 9% of the variance in glycemic control with all other covariates, such as duration of diabetes and BMI, not significantly contributing to the final model. Similarly, previous evidence supported the lack of effect of covariates (age, insulin delivery method, and ethnicity) on HbA_{1c}.[43] In contrast, previous studies revealed that some other covariates, such as age,[27,29,41] diabetes duration,[27,29,41] depressive symptoms,[27] primary caregiver,[29] and daily insulin dose,[41] significantly contributed to the model. Nevertheless, these studies included children in addition to adolescent populations, which might justify the fact that in this study age and duration of diabetes were not significant contributors to glycemic control.

Strengths and Limitations

This study is the first in Qatar to assess adherence among adolescents with T1DM.The study also adds to the existing body of evidence regarding the relationship between adherence and glycemic control by using mainly objective data (meter downloads) to assess adherence instead of merely relying on subjective approaches. This method helped in getting more robust data that represent actual patient behaviors. One of the greatest limitations of this study was that there were no data and analysis about whether the method of blood glucose monitoring affects adherence or diabetes control. Data were collected from patients who used glucometers and those who used FGM; however, no data are available on the number of patients in each group. The method of blood glucose monitoring may affect the frequency and consequently the level of adherence. It may also ultimately affect diabetes control. Therefore, the findings should be interpreted with this limitation in mind. Relying on BGMF as a proxy for adherence is generally a well-established method; nevertheless, it only reflects adherence related to blood glucose monitoring without taking into consideration other essential aspects of diabetes adherence. In addition, relying on meter downloads only makes the data subjected to some technological errors in addition to intentional or unintentional manipulations of meter readings reported earlier.[44] Moreover, because of the retrospective study design used, some data were missing and it was difficult to confirm whether patients used >1 device for glucose monitoring. These limitations resulted in having adherence data for 193 patients, a sample size that was lower than estimated, which may result in insufficient power and increase the chances of type 2 error. Finally, convenient sampling technique was used because of the absence of a sampling frame.

CONCLUSION

This study is the first to explore the rate of adherence among adolescents with T1DM in Qatar, and it found that adolescents with T1DM in Qatar have a poor adherence rate of approximately 40%, with >90% having suboptimal diabetes control. The current findings suggest that adherence was a significant independent predictor of glycemic control; however, it only explained 9% of the variability. This finding warrants further exploration of other possible predictors of suboptimal glycemic control that is highly prevalent among adolescent population in Qatar.

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DECLARATIONS OF INTEREST

The authors have indicated that they have no conflicts of interest regarding the content of this article.

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Address correspondence to: Ahmed Awaisu, PhD, Department of Clinical Pharmacy and Practice, College of Pharmacy, QU Health, Qatar University, PO Box 2713, Doha, Qatar. E-mail: aawaisu@qu.edu.qa.