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ABOUT COVER

Peer Review of *World Journal of Diabetes*, Erkan Gokce, MD, Professor, Department of Radiology, Tokat Gaziosmanpasa University, School of Medicine, Tokat 60100, Türkiye. drerkangokce@gmail.com

AIMS AND SCOPE

The primary aim of *World Journal of Diabetes* (*WJD*, *World J Diabetes*) is to provide scholars and readers from various fields of diabetes with a platform to publish high-quality basic and clinical research articles and communicate their research findings online.

WJD mainly publishes articles reporting research results and findings obtained in the field of diabetes and covering a wide range of topics including risk factors for diabetes, diabetes complications, experimental diabetes mellitus, type 1 diabetes mellitus, type 2 diabetes mellitus, gestational diabetes, diabetic angiopathies, diabetic cardiomyopathies, diabetic coma, diabetic ketoacidosis, diabetic nephropathies, diabetic neuropathies, Donohue syndrome, fetal macrosomia, and prediabetic state.

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ORIGINAL ARTICLE

Retrospective Cohort Study

Association between glucose levels of children with type 1 diabetes and parental economic status in mobile health application

Wen-Hao Zhang, Chao-Fan Wang, Hao Wang, Jie Tang, Hong-Qiang Zhang, Jiang-Yu Zhu, Xue-Ying Zheng, Si-Hui Luo, Yu Ding

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Wen-Hao Zhang, Hong-Qiang Zhang, Xue-Ying Zheng, Si-Hui Luo, Yu Ding, Department of Endocrinology, The First Affiliated Hospital of University of Science and Technology of China, Division of Life Sciences and Medicine, University of Science and Technology of China, Hefei 230001, Anhui Province, China

Chao-Fan Wang, Department of Endocrinology and Metabolism, The Third Affiliated Hospital of Sun Yat-sen University, Guangdong Provincial Key Laboratory of Diabetology, Guangzhou 510000, Guangdong Province, China

Hao Wang, Jie Tang, Jiang-Yu Zhu, Graduate School, Bengbu Medical College, Bengbu 233000, Anhui Province, China

Co-first authors: Wen-Hao Zhang and Chao-Fan Wang.

Co-corresponding authors: Si-Hui Luo and Yu Ding.

Corresponding author: Yu Ding, MD, Doctor, Department of Endocrinology, The First Affiliated Hospital of University of Science and Technology of China, Division of Life Sciences and Medicine, University of Science and Technology of China, No. 96 Jinzhai Road, Hefei 230001, Anhui Province, China. yuding6815@163.com

Abstract

BACKGROUND

The glycemic control of children with type 1 diabetes (T1D) may be influenced by the economic status of their parents.

AIM

To investigate the association between parental economic status and blood glucose levels of children with T1D using a mobile health application.

METHODS

Data from children with T1D in China's largest T1D online community, TangTangQuan®. Blood glucose levels were uploaded every three months and parental economic status was evaluated based on annual household income. Children were divided into three groups: Low-income (< 30000 Yuan), middle-income (30000-100000 Yuan), and high-income (> 100000 yuan) (1 Yuan = 0.145 United States Dollar approximately). Blood glucose levels were compared among the groups

and associations were explored using Spearman's correlation analysis and multivariable logistic regression.

RESULTS

From September 2015 to August 2022, 1406 eligible children with T1D were included (779 female, 55.4%). Median age was 8.1 years (Q1-Q3: 4.6-11.6) and duration of T1D was 0.06 years (0.02-0.44). Participants were divided into three groups: Low-income (n = 320), middle-income (n = 724), and high-income (n = 362). Baseline hemoglobin A1c (HbA1c) levels were comparable among the three groups (P = 0.072). However, at month 36, the low-income group had the highest HbA1c levels (P = 0.036). Within three years after registration, glucose levels increased significantly in the low-income group but not in the middle-income and high-income groups. Parental economic status was negatively correlated with pre-dinner glucose (r = -0.272, P = 0.012). After adjustment for confounders, parental economic status remained a significant factor related to pre-dinner glucose levels (odds ratio = 13.02, 95%CI: 1.99 to 126.05, P = 0.002).

CONCLUSION

The blood glucose levels of children with T1D were negatively associated with parental economic status. It is suggested that parental economic status should be taken into consideration in the management of T1D for children.

Key Words: Type 1 diabetes; Children and adolescents; Glycemic control; Economic status; Mobile health application

Core Tip: The study's strength lies in its ability to capture an extended time frame of self-monitoring blood glucose data, reflecting glycemic control in children and adolescents with type 1 diabetes (T1D) across household income, using the mobile health application. As well as the study scenario was changed from a traditional single-center offline retrospective analysis to the largest T1D online community in China, "TangTangQuan®", to dynamically observe blood glucose changes in children registered for three years and provide experience for online support glucose management.

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INTRODUCTION

Type 1 diabetes (T1D) is an autoimmune disease that attacks pancreatic β-cells, thus leading to lifelong insulin deficiency [1]. In 2021, approximately 8.4 million people worldwide were living with T1D, including an estimated 1.5 million patients under the age of 20 years[2]. Despite remarkable advances in diabetes therapeutics and technologies, the management of T1D in childhood remains exceptionally challenging[3]. According to the International Pediatric Registry (SWEET), the hemoglobin A1c (HbA1c) levels of most children and adolescents with T1D do not meet the International Society for Pediatric and Adolescent Diabetes (ISPAD) current target of less than 7%[4,5].

Children with diabetes require sustained and substantial support from their families to effectively manage their condition over an extended period of time[3]. Studies have shown that increased parental involvement is positively correlated with improved glycemic outcomes[6,7]. Family background factors, such as socioeconomic status, household composition, and ethnicity, have been linked to metabolic control in children with T1D, which is a key determinant of diabetes-related complications[8,9]. In children and adolescents with T1D, there is evidence of a relationship between parental economic status or education and better self-management[10] and health-related quality of life[11]. Notably, children from high-income families tend to have lower HbA1c levels than those from low-income families[10,12-14]. These family factors may influence adherence to recommended self-care practices (either directly or indirectly)[15].

The use of mobile health applications (mHealth Apps) has increased the availability of efficacious behavioral interventions for family diabetes management[16,17]. These applications (Apps) can assess, prompt, and educate individuals with diabetes[18] by offering brief behavioral change strategies in the context of their daily lives without time-intensive attendance at in-person intervention sessions delivered in a healthcare setting[19]. Studies have shown that new technologies such as online support can help patients to easily access their diabetes care team[20], local peer support [21,22], and tailored information about the disease and its management provided by their diabetes team[23]. Although the use of mHealth Apps has been shown to improve health outcomes in adult populations with T1D[22], this has not been demonstrated in children with T1D[24-26]. When considering that parents of children with T1D may be the primary users of mHealth apps, it is essential to assess the relationship between parental economic status and glycemic control in children with T1D. However, there is still a lack of such studies. In addition, previous studies[12-14] on the relationship between family factors and HbA1c in children with T1D did not investigate the relationship between family factors and

self-monitoring blood glucose (SMBG). HbA1c levels are indicative of long-term glycemic control and may not be sensitive to short-term changes. SMBG can compensate for some HbA1c limitations, such as reflecting blood glucose levels at various times of the day[27].

The aim of this study was to investigate the impact of family background on glycemic control in children and adolescents with T1D from families with different income levels. In this study, we compare the glycemic control of HbA1c and SMBG between different household income levels using the mHealth app. The results provide important information on glycemic control in children and adolescents with T1D from families with different income levels.

MATERIALS AND METHODS

Introduction of the mHealth Apps: TangTangQuan®

TangTangQuan® (TTQ) is a Chinese mobile application that provides diabetes self-management education and support for patients with T1D. The app is available for download and free registration from major application markets. TTQ contains four modules: (1) Personal diabetes diaries (including glucose monitoring records); (2) dietary panels; (3) online diabetes education; and (4) peer support communities. The TTQ has the potential to provide guidance and recommendations to individuals diagnosed with T1D regarding glucose monitoring and dietary management. The TTQ system uses a color-based indicator system to alert users of their daily blood glucose. Pink indicates the presence of severe hypoglycemia or hyperglycemia or excessive fluctuations in glucose levels. Orange indicates acceptable fluctuations in glucose levels and the absence of severe hypoglycemia or hyperglycemia. Green indicates stable glucose levels within the ideal range. If an individual's blood glucose levels persistently fall outside of the recommended range, they will receive timely guidance from peer leaders or healthcare professionals. Online diabetes education and consultation services, which can effectively address a significant proportion of users' issues, are available in TTQ. In the case of an emergency, it is highly recommended that individuals seek assistance from the nearest medical facility. Additionally, the TTQ dietary panel offers valuable dietary recommendations to users, including carbohydrate counting, recipe suggestions, and a bolus calculator. The dietary panel enables patients to quantify the total calories and carbohydrates consumed during a meal by selecting food items in grams. The bolus calculator can provide insulin bolus recommendations based on patient-generated data, making it a useful tool for managing diabetes. The guidance for administering a bolus is determined by the amount of dietary intake, which is calculated from the total carbohydrates and insulin-to-carbohydrate ratio. Additionally, the correction dose is calculated from the current blood glucose level, the target blood glucose level, and insulin sensitivity factor while also considering any remaining insulin. This information can be used to provide accurate insulin bolus recommendations to patients.

Study design and participants

This retrospective study aimed to investigate the association between household income and glycemic levels in children and adolescents with T1D. The study population was gathered from the T1D China Study, which is a large-scale population and hospital-based registration study that has enrolled patients with T1D from 105 hospitals across China since 2014 (www.chictr.org.cn, ChiCTR2000034642). The project's primary objective is to establish a longitudinal cohort of T1D patients in China to investigate disease epidemiology and improve T1D management[22,28]. The study participants were introduced to the smartphone-based application TTQ by attending endocrinologists at the participating hospitals in 2015. The registration and use of the TTQ are at the disposal of the participants. Those who agreed to use the TTQ could incorporate electronic medical records into the individual diabetes diary module[22].

Patients who registered with the TTQ from September 2015 to August 2022 were recruited for the study. The day of registration was established as the baseline. The patients underwent a follow-up every three months, during which the arithmetic mean of their blood glucose levels was calculated at 3-month intervals subsequent to their registration. The follow-up period ended 36 months after registration or on November 30, 2022. The inclusion criteria were as follows: (1) Patients who were diagnosed with T1D by an endocrinologist from a secondary hospital or above; (2) children or parents of children aged younger than 18 years at baseline who used the app; (3) individuals who agreed to provide annual household income per capita data and consented to upload blood glucose monitoring data; and (4) individuals who agreed to participate in this study. The exclusion criteria were as follows: (1) Non-T1D, including type 2 diabetes and monogenic diabetes; (2) household income level not available; and (3) blood glucose monitoring data not available.

Data collection

We collected the following data from the TTQ app at baseline: (1) Demographic information (age, sex, parents' educational level, and annual household per capita income); and (2) diabetes-related information [duration of T1D, age at T1D onset, chronic diabetic complications such as diabetic retinopathy, nephropathy, or neuropathy, family history, disease information at onset such as HbA1c, typical symptoms, ketosis, ketoacidosis and insulin treatment, including multiple daily insulin injections (MDIs), continuous subcutaneous insulin infusion (CSII), or other insulin regimens]. Although guidelines recommend MDI or CSII for patients with T1D[29], a previous study[30] suggested that a considerable number of patients in China should be treated with premixed insulin, which we defined as "other insulin regimens". We divided the study population into two groups based on parents' education level: A low-education group (secondary school and below) and a high-education group (college and above). The annual household per capita income is calculated by dividing the total annual income of all household members by the total number of individuals in the household. We further categorized these groups into low-income (< 30000 Yuan), middle-income (30000-100000 Yuan), and high-income (> 100000 Yuan) (1 Yuan ≈ 0.145 United States Dollar) based on annual data from China Statistical

Yearbook-2022[31].

Outcome measurements

During the study period, glucose readings recorded in the TTQ of eligible users were extracted. The SMBG data mainly included seven time periods: Prebreakfast blood glucose (G0h-breakfast), post-breakfast 2 h blood glucose (G2h-breakfast), pre-lunch blood glucose (G0h-lunch), post-lunch 2 h blood glucose (G2h-lunch), predinner blood glucose (G0h-dinner), post-dinner 2 h blood glucose (G2h-dinner), and bedtime blood glucose (G-bedtime). We calculated the arithmetic mean blood glucose level every 3 months after registration. The primary outcome of this study was the difference in HbA1c, mean preprandial blood glucose, mean postprandial blood glucose, and mean bedtime blood glucose.

Statistical analysis

Descriptive summaries of the demographic, lifestyle, and clinical characteristics of the participants are presented as annual household income per capita. Continuous variables are presented as medians with interquartile ranges or means with SDs, as appropriate, whereas categorical variables are summarized using counts and percentages. We performed chi-square tests for categorical variables, ANCOVA for continuous variables with a normal distribution, and Kruskal-Wallis *U* tests for continuous variables with a skewed distribution to compare differences in each baseline characteristic among different household income statuses.

To investigate whether each outcome variable differed among the three household income statuses, we conducted ANCOVA or Kruskal-Wallis *U* tests, as appropriate. We assessed correlations between household income and mean preprandial blood glucose, mean postprandial blood glucose, age, duration of T1D, and parental education using Spearman's rank correlation. The associations between household income and glycemic control were evaluated using logistic regression with adjustments for confounders. We determined whether the child's blood glucose reached the target at each time period according to the ISPAD recommended target values for blood glucose control[5], with the following target values being used: Preprandial blood glucose, 4.0-7.0 mmol/L; postprandial blood glucose, 5.0-10.0 mmol/L; and bedtime blood glucose, 4.4-7.8 mmol/L. We conducted two-sided tests with statistical significance set at $P < 0.05$ using *R* (version 4.1.1) for statistical analyses.

RESULTS

Characteristics of the study participants

A total of 1406 eligible children with T1D were included in the analysis. Table 1 presents the baseline characteristics of the participants. The median age was 8.11 years (Q1-Q3: 4.64-11.61), and 44.59% were male. The median duration of T1D was 0.06 years (0.02-0.44). At baseline, individuals with middle and high incomes were younger, had a shorter duration of diabetes, were more often male, had higher parental education, used more insulin pumps, and had less onset of ketoacidosis than those with low incomes ($P < 0.05$). The baseline HbA1c level was highest in the low-income group (12.8%; Q1-Q3: 10.8%-14.4%), followed by the high-income group (12.3%; Q1-Q3: 11.0%-13.7%) and the middle-income group (12.0%; Q1-Q3: 10.0%-14.0%).

Comparison of blood glucose levels: Low vs middle vs high household income groups

Figure 1A shows that the trajectory of HbA1c levels over time (from 0-36 months) was similar among the three household income groups. There was a substantial decrease in HbA1c levels in all household income groups up to month 3, with modest differences being observed among the three groups in terms of HbA1c [Low *vs* middle *vs* high: 9.20% (8.40%-10.30%) *vs* 9.30% (8.30%-10.80%) *vs* 8.90% (8.20%-10.10%), respectively; $P = 0.008$]. Between month 9 and month 33, there was no significant difference in the HbA1c levels among the three groups. However, at month 36, the high-income group had significantly lower HbA1c levels than the other two groups. The low-income group had the highest HbA1c levels [10.80% (9.15%-11.90%) *vs* 9.50% (8.43%-11.47%) *vs* 8.70% (7.95%-9.95%), respectively; $P = 0.036$].

To explore the short-term glycemic control of different household income levels, we tested the differences in blood glucose levels among different groups of household income over seven time periods (Figure 1B-D and Figure 2). During the first six months after registration, the differences in blood glucose levels among the three groups were mainly observed during breakfast and lunch (G0h/2 h-breakfast and G0h/2 h lunch), as shown in Figure 1B and C, Figure 2A and B. The high-income group had the lowest glucose levels among the three groups ($P < 0.05$). After nine to thirty-six months of registration, differences in blood glucose levels among the three groups were mainly observed at dinner (G0/2 h-dinner), as shown in Figures 1D and 2C. Similarly, the glucose level of the high-income group was significantly lower than that of the other two groups ($P < 0.05$).

Comparison of glycemic changes during the 36 months after registration

Table 2 shows that during the 36th month after registration, G0h/2 h-breakfast, G0h/2 h-lunch, G0h/2 h-dinner, and G-bedtime were greater in the low-income group than in the low-income group at month 3 ($P < 0.05$ except for the G2h-breakfast). In contrast, the changes in blood glucose levels over 36 months differed across seven time periods in the middle- and high-income groups. Specifically, there was an increase in G0h-breakfast, G0h-lunch, G2h-lunch, and G-bedtime, whereas there was a reduction in G2h-breakfast, G0h-dinner, and G2h-dinner. However, these differences were not statistically significant ($P > 0.05$). To further analyze the comparison of glycemic changes at 36 months after

Table 1 Baseline characteristics of participants with type 1 diabetes

Characteristics	All, *n* = 1406	Low-income, *n* = 320	Middle-income, *n* = 724	High-income, *n* = 362	*P* value
Age (yr)	8.11 (4.64, 11.61)	10.06 (5.23, 13.18)	7.84 (4.61, 11.29)	7.15 (3.83, 10.76)	< 0.001
Duration of T1D (yr)	0.06 (0.02, 0.44)	0.12 (0.03, 0.92)	0.06 (0.02, 0.40)	0.04 (0.01, 0.22)	< 0.001
HbA1c at onset (%)	12.10 (10.50, 14.00)	12.80 (10.80, 14.40)	12.00 (10.00, 14.00)	12.30 (11.00, 13.70)	0.072
Sex					0.004
Male	627 (44.59)	123 (38.44)	319 (44.06)	185 (51.10)	
Female	779 (55.41)	197 (61.56)	405 (55.94)	177 (48.90)	
Parents' education level (*n* = 1383)[1]					< 0.001
Low level	493 (35.65)	211 (67.63)	244 (34.32)	38 (10.56)	
High level	890 (64.35)	101 (32.37)	467 (65.68)	322 (89.44)	
Insulin treatment					< 0.001
CSII	631 (44.88)	129 (40.31)	300 (41.44)	202 (55.80)	
MDI	719 (51.14)	180 (56.25)	391 (54.01)	148 (40.88)	
Others	56 (3.98)	11 (3.44)	33 (4.56)	12 (3.31)	
Typical symptoms at onset[2] (*n* = 1292)					0.552
No	69 (5.34)	14 (4.91)	40 (5.98)	15 (4.44)	
Yes	1223 (94.66)	271 (95.09)	629 (94.02)	323 (95.56)	
DKA at onset (*n* = 1288)					0.002
No	373 (28.96)	70 (24.56)	180 (27.15)	123 (36.18)	
Yes	915 (71.04)	215 (75.44)	483 (72.85)	217 (63.82)	
Diabetes family history (*n* = 1366)					0.138
No	1053 (77.09)	240 (76.92)	552 (78.97)	261 (73.52)	
Yes	313 (22.91)	72 (23.08)	147 (21.03)	94 (26.48)	

[1]Based on the education level of the parents, the study population was divided into a low education group (secondary school and below) and a high education group (college and above).

[2]Typical symptoms at onset including, polydipsia, polyphagia, polyuria and weight loss.

Data are presented as median (interquartile range), or number (%). T1D: Type 1 diabetes; HbA1c: Hemoglobin A1c; CSII: Continuous subcutaneous insulin infusion; MDI: Multiple daily insulin injections; DKA: Diabetic ketoacidosis.

registration in each insulin regimen subgroup (Table 3), this study considered that different insulin regimens may have significant effects on children's glycemic control. In the CSII subgroup, there was a significant increase in G0h/2 h-breakfast, G0h/2 h-lunch, G0h/2 h-dinner, and G-bedtime at month 36 compared to month 3 in the low-income group ($P < 0.05$ except for the G2h-breakfast group). However, there was no significant difference in blood glucose at any time point at month 36 between the middle- and high-income groups. In the MDI subgroup, the changes in blood glucose levels at 36 months were similar to those in the CSII subgroup across the three income groups, and the differences were not significant.

The relationship between household income and blood glucose levels

To examine whether household income independently influences blood glucose levels, we first examined the associations between seven time periods of blood glucose levels at the 36th month and household income, along with important clinical covariates at baseline, by using Spearman's rank correlation. The correlation matrix shown in Supplementary Table 1 indicates that household income was weakly and negatively correlated with variation in baseline age and duration (r = -0.14 and r = -0.07, respectively; $P < 0.05$), whereas it was strongly correlated with parents' education level (r = 0.41, $P < 0.001$). Additionally, household income was negatively correlated with HbA1c (r = -0.214, P = 0.023) and G0h-dinner (r = -0.272, P = 0.012), whereas no significant differences were found in other blood glucose levels.

To assess the independent associations of household income with target glycemic control at month 36, we performed logistic regression models adjusted for baseline clinical covariates. The list of potential confounders included age, gender, duration of diabetes, insulin treatment, and parents' education level. The results of univariate and multivariate analyses

Table 2 Comparison of glycemic changes at 36 months after registration

Glucose level at different time periods (mmol/L)	Low-income		*P* value	Middle-income		*P* value	High-income		*P* value
	3th month	36th month		3th month	36th month		3th month	36th month	
Pre-breakfast	6.60 (5.70, 7.90)	7.65 (6.80, 8.72)	0.008	6.30 (5.40, 7.60)	7.15 (6.00, 8.03)	0.023	6.25 (5.50, 7.40)	6.60 (5.83, 7.20)	0.584
Post-breakfast	8.40 (7.10, 9.65)	8.75 (7.40, 9.70)	0.436	8.30 (7.05, 10.10)	7.80 (6.80, 10.00)	0.550	7.90 (7.00, 9.47)	6.90 (6.40, 7.82)	0.058
Pre-lunch	7.10 (6.10, 8.60)	8.85 (6.53, 11.05)	0.013	7.20 (6.07, 8.80)	7.50 (6.00, 10.10)	0.589	7.00 (5.90, 8.40)	7.40 (5.80, 7.80)	0.866
Post-lunch	7.40 (6.50, 8.90)	9.80 (7.75, 11.85)	< 0.001	7.70 (6.70, 9.10)	8.05 (6.98, 10.45)	0.194	7.40 (6.50, 8.40)	7.50 (6.70, 10.60)	0.533
Pre-dinner	8.10 (6.60, 10.20)	9.20 (7.95, 11.75)	0.005	8.15 (6.70, 10.20)	7.80 (6.90, 11.60)	0.882	7.60 (6.30, 9.75)	6.80 (5.60, 8.00)	0.095
Post-dinner	7.60 (6.60, 8.90)	9.40 (7.25, 11.90)	0.002	7.80 (6.60, 9.20)	7.70 (6.28, 10.15)	0.900	7.60 (6.70, 8.70)	7.55 (6.35, 9.40)	0.870
Bedtime	8.20 (7.05, 9.65)	9.60 (8.20, 11.45)	0.018	8.30 (7.10, 9.80)	8.40 (6.80, 9.90)	0.754	7.90 (7.00, 9.60)	8.00 (7.65, 10.50)	0.328

Data are presented as median (interquartile range).

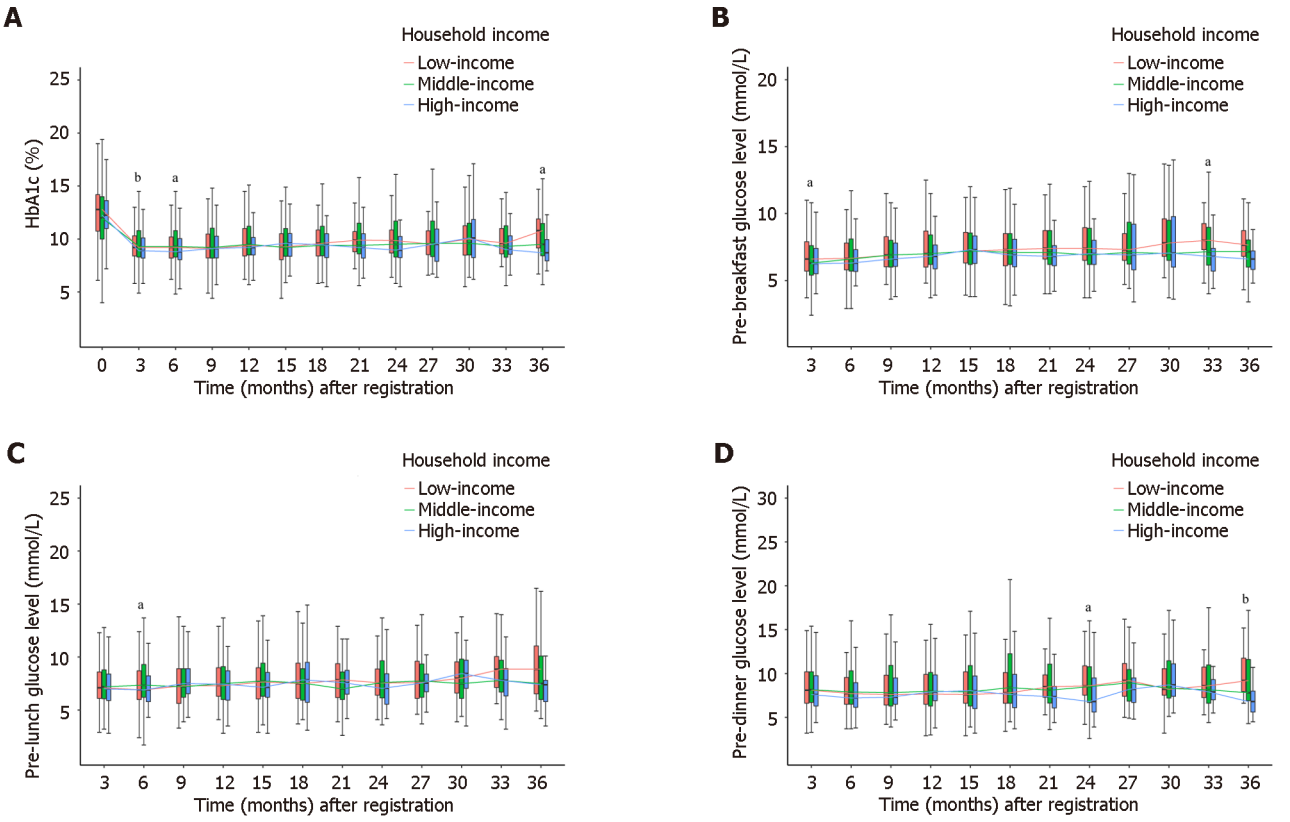

Figure 1 Comparison of hemoglobin A1c and preprandial blood glucose level: Low *vs* middle *vs* high household income groups. A: Comparison of hemoglobin A1c level among three groups; B: Comparison of pre-breakfast blood glucose level among three groups; C: Comparison of pre-lunch blood glucose level among three groups; D: Comparison of pre-dinner blood glucose level among three groups. $^{a}P < 0.05$; $^{b}P < 0.01$. HbA1c: Hemoglobin A1c.

are presented in Table 4. Using low-income as a reference group, we found that participants from high-income had increased odds of achieving G0h-dinner target glycemic control [odds ratio (OR) = 16.92, 95%CI: 3.21 to 135.11, $P = 0.001$] in the unadjusted model (Model 1). Similar outcomes were obtained after adjusting for potential confounders (Model 2). The association between household level and the odds of achieving G0h-dinner target glycemic control remained significant. Specifically, the middle-income group was 9.06 times more likely to have better G0h-dinner glycemic control than the low-income group (OR = 9.06, 95%CI: 1.79 to 73.61, $P = 0.003$), while the high-income group was 13.02 times more likely to have better G0h-dinner glycemic control than the low-income group at month 36 (OR = 13.02, 95%CI: 1.99

Table 3 Glycemic changes in subgroups of different insulin treatment regimens

Glucose level at different time periods (mmol/L)	Low-income		*P* value	Middle-income		*P* value	High-income		*P* value
	3th month	36th month		3th month	36th month		3th month	36th month	
CSII subgroup									
Pre-breakfast	6.30 (5.57, 7.70)	7.81 (1.83)	0.01	6.30 (5.40, 7.32)	7.13 (2.22)	0.289	6.05 (5.50, 7.03)	6.46 (1.58)	0.521
Post-breakfast	8.60 (7.10, 9.85)	8.75 (7.90, 9.70)	0.644	8.80 (7.30, 10.40)	7.70 (7.00, 9.70)	0.347	7.90 (7.00, 9.50)	7.00 (6.55, 7.75)	0.148
Pre-lunch	7.10 (6.10, 8.60)	9.60 (6.30, 11.60)	0.042	7.15 (6.00, 8.40)	6.60 (5.97, 8.18)	0.747	6.80 (5.90, 8.22)	7.50 (5.80, 7.80)	0.892
Post-lunch	7.40 (6.68, 8.90)	10.70 (7.55, 12.50)	0.003	8.00 (6.80, 9.30)	9.20 (7.90, 10.60)	0.097	7.40 (6.55, 8.45)	7.50 (7.20, 10.60)	0.468
Pre-dinner	7.70 (6.50, 9.70)	9.40 (8.60, 11.90)	0.001	7.90 (6.55, 10.00)	7.80 (6.10, 10.90)	0.636	7.20 (6.10, 9.00)	6.10 (5.55, 7.45)	0.263
Post-dinner	7.75 (6.73, 8.90)	10.00 (8.25, 12.35)	0.001	7.80 (6.60, 9.20)	7.70 (6.95, 9.10)	0.785	7.40 (6.60, 8.65)	7.60 (5.25, 10.00)	0.708
Bedtime	8.25 (6.90, 10.15)	10.13 (2.74)	0.027	8.20 (7.20, 9.65)	7.42 (2.24)	0.114	7.80 (7.00, 9.00)	8.21 (2.28)	0.646
MDI subgroup									
Pre-breakfast	6.70 (5.80, 7.97)	7.50 (7.20, 8.40)	0.127	6.30 (5.40, 7.70)	7.15 (6.07, 8.03)	0.057	6.40 (5.60, 7.50)	6.10 (6.00, 7.10)	0.849
Post-breakfast	8.20 (7.15, 9.40)	8.55 (7.32, 9.15)	0.752	8.00 (6.90, 9.65)	8.15 (6.80, 10.00)	0.982	7.90 (6.97, 9.72)	6.60 (6.40, 7.80)	0.258
Pre-lunch	7.15 (6.35, 8.53)	8.40 (7.50, 9.60)	0.112	7.30 (6.20, 9.15)	8.00 (6.00, 10.40)	0.41	7.20 (5.85, 8.60)	7.00 (6.20, 7.90)	0.894
Post-lunch	7.40 (6.40, 8.90)	8.85 (7.83, 10.05)	0.023	7.50 (6.60, 8.90)	7.70 (6.40, 10.00)	0.616	7.40 (6.30, 8.10)	6.95 (6.30, 8.65)	0.921
Pre-dinner	8.35 (6.82, 10.40)	8.60 (7.43, 10.15)	0.459	8.40 (7.10, 10.28)	8.05 (7.18, 11.60)	0.826	8.70 (6.90, 10.70)	7.30 (6.00, 7.85)	0.117
Post-dinner	7.60 (6.40, 9.15)	8.30 (6.83, 10.05)	0.319	7.60 (6.50, 9.17)	7.70 (5.95, 10.60)	0.924	7.70 (6.80, 8.80)	7.50 (7.20, 8.70)	0.873
Bedtime	8.10 (7.20, 9.45)	8.80 (7.70, 10.65)	0.298	8.35 (7.18, 9.80)	8.60 (7.40, 11.00)	0.579	8.45 (6.95, 10.20)	11.00 (7.90, 12.10)	0.176

Data are presented as median (interquartile range) or mean (SD). T1D: Type 1 diabetes; CSII: Continuous subcutaneous insulin infusion; MDI: Multiple daily insulin injections.

to 126.05, $P = 0.002$).

DISCUSSION

In this retrospective study based on a mobile healthcare App, we found that children and adolescents with T1D from low-income families had worse glycemic control than those from middle- and high-income families. We also discovered a negative relationship between blood glucose levels and household income levels, particularly for the G0h-dinner group. Our findings have important clinical implications, thus suggesting that the parental economic status of children with T1D should be fully considered for better glycemic control in diabetes management. The results of our study are similar to those of previous research on HbA1c[12-14], which demonstrates an inverse association between HbA1c and household income. Furthermore, our study based on the mHealth app provided more details on glycemic control, such as SMBGs; these allow children and adolescents with T1D to record preprandial, postprandial, and bedtime blood glucose levels, thus enabling us to monitor the effects of household income on glycemic management and providing experience for online assistance in glucose management for children with T1D.

We observed that children with T1D from middle- and high-income households had younger registration ages, shorter diabetes durations, lower incidences of diabetic ketoacidosis (DKA), and greater parental educational levels than children from low-income families. One possible explanation for these differences is that parents with high-income levels tend to have higher levels of education (89.44% of them have a high education level), which may enable them to recognize T1D

Table 4 The relationship between household income and glycemic control by using binary logistic regression analysis

	Model 1	Model 2
Pre-breakfast		
Low	Ref.	Ref.
Middle	1.25 (0.50 to 3.23)	1.40 (0.49 to 4.16)
High	3.18 (0.94 to 11.67)	2.15 (0.52 to 9.52)
Post-breakfast		
Low	Ref.	Ref.
Middle	1.24 (0.39 to 3.91)	0.84 (0.22 to 3.08)
High	0.58 (0.14 to 2.70)	0.41 (0.07 to 2.37)
Pre-lunch		
Low	Ref.	Ref.
Middle	1.91 (0.74 to 5.12)	2.11 (0.74 to 6.31)
High	1.38 (0.34 to 5.26)	1.42 (0.30 to 6.51)
Post-lunch		
Low	Ref.	Ref.
Middle	2.42 (0.91 to 6.59)	4.17 (1.26 to 15.52)
High	1.20 (0.30 to 5.00)	0.59 (0.11 to 3.28)
Pre-dinner		
Low	Ref.	Ref.
Middle	6.00 (1.47 to 40.79)	9.06 (1.79 to 73.61)
High	16.92 (3.21to 135.11)	13.02 (1.99 to 126.05)
Post-dinner		
Low	Ref.	Ref.
Middle	1.85 (0.72 to 4.87)	1.68 (0.58 to 5.01)
High	0.91 (0.25 to 3.40)	0.79 (0.18 to 3.49)
Bedtime		
Low	Ref.	Ref.
Middle	1.15 (0.26 to 6.01)	1.07 (0.17 to 7.50)
High	1.50 (0.18 to 10.22)	0.36 (0.03 to 3.56)

Model 1: Unadjusted; Model 2: Including, household income, sex, age, duration of type 1 diabetes, insulin treatment, and parents' education level.

symptoms early and seek timely medical treatment[32,33]. Conversely, low levels of education have been linked to low levels of diabetes knowledge among mothers of children with T1D[34], as well as lower body mass index and worse fitness in children[35,36]. Additionally, parents with educational attainment beyond the secondary level or high socioeconomic status have been found to have a protective effect against the onset of DKA[37]. Another explanation for the observed differences in household income and outcomes among children with T1D may be related to their self-care ability. Research suggests that higher socioeconomic status of parents is linked to better executive function and self-control in children[38,39]. The developmental tasks of children and adolescents with T1D require the gradual acquisition of increasing levels of independence in many facets of personal decision-making and general self-care[40]. However, despite the high incidence of DKA at disease onset among children from high-income families, with a proportion of 63.82%, previous studies[37,41] have indicated that parental suspicion of diabetes was associated with milder DKA at hospital admission. Therefore, it is recommended that health education programs for T1D be reinforced to facilitate early recognition of diabetes through typical diabetes symptoms (such as polydipsia, polyphagia, polyuria, and weight loss), thereby enabling prompt diagnosis and treatment of the condition in children.

In this study, the authors found that household income was negatively correlated with HbA1c and the G0-dinner level, as indicated by Spearman's rank correlation. Regression analysis further demonstrated that the associations between household income and G0-dinner glycemic control remained significant even after adjusting for potential covariates such

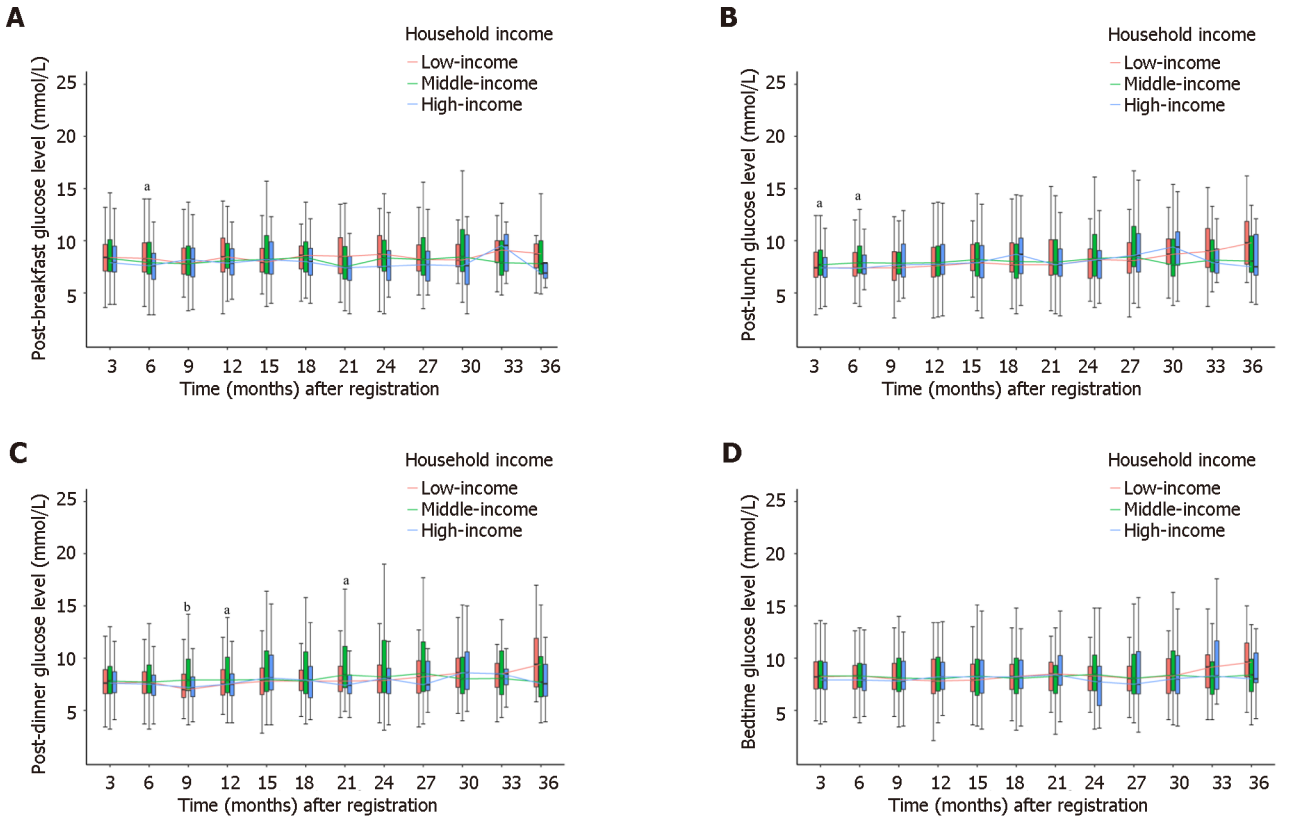

Figure 2 Comparison of postprandial and bedtime blood glucose level: Low *vs* Middle *vs* High household income groups. A: Comparison of post-breakfast 2 h blood glucose level among three groups; B: Comparison of post-lunch 2 h blood glucose level among three groups; C: Comparison of post-dinner 2 h blood glucose level among three groups; D: Comparison of bedtime blood glucose level among three groups. $^{a}P < 0.05$; $^{b}P < 0.01$. HbA1c: Hemoglobin A1c.

as sex, age, duration of T1D, insulin treatment, and parents' education levels. These results are consistent with those of previous studies[12-14]. Additionally, this study showed that children from low-income families had significantly higher blood glucose levels than those from high-income families across all time periods. This suggests that the relationship between household income and glycemic control is complex and may involve factors beyond financial support. The authors suggest that lower household income combined with poor diabetes knowledge may explain this finding. This could indicate that families lack access to the necessary resources or information to participate in effective self-care, such as monitoring blood glucose levels or adjusting carbohydrate intake to appetite across household income levels. Although CSII or MDI is the recommended treatment regimen for T1D according to ADA guidelines[42,43], subgroup analysis indicated that blood glucose levels in children from low-income groups tended to be higher than those at baseline in almost all periods, particularly in the CSII group. Therefore, it is imperative to consider the management of diabetes beyond selecting a suitable course of treatment.

Our research demonstrated that using mHealth Apps to assist parents with diabetes management did not improve glycemic control in children or adolescents with T1D, especially in low-income families where blood glucose levels are often higher than those in the early months after registration. Although several mHealth Apps have been developed for T1D patients of various ages, research examining the efficacy of mHealth Apps for glycemic management in children with T1D is still limited. Both studies[26,44] demonstrated that mHealth Apps could not reduce HbA1c in children with T1D. Despite little research on T1D self-care and outcomes, mHealth Apps can provide significant benefits in terms of social connectedness, quality of life, adjustment, cost, and convenience[45]. A sole focus on health indicators such as adherence and HbA1c diminishes other benefits for specific patients and families[45]. Indeed, different mHealth Apps are relevant based on individual factors such as age, finances, and location. Providers must consider holistic outcomes and promote suitable mHealth Apps when recommending them to individuals and families[45].

The strength of this study lies in the ability to identify an extended time frame of SMBG data (thus reflecting glycemic control in children and adolescents with T1D across household income), using the mHealth app. In addition, the study scenario was changed from a traditional single-center offline retrospective analysis to the largest T1D online community in China ("TTQ") to dynamically observe blood glucose changes in children who were registered for three years and who provided experience for online support glucose management. However, there were several limitations to this study. First, there was a lack of sufficient HbA1c and continuous glucose monitoring data, mainly from user-uploaded blood glucose information. Second, some family background information, such as household composition and number of siblings, was not collected on the questionnaire. Therefore, we could not assess the associations of these items with preprandial glycemic stability in the present study. Finally, as in other observational studies, although we adjusted for several covariates related to glycemic control, residual confounding by unidentified confounders is still possible.

The results of this observational study may provide low-income households with references to support the self-care of diabetic patients, such as training in carbohydrate counting, insulin calculation, and awareness of typical diabetes symptoms. Additionally, the study results suggest leveraging mobile medical Apps to provide social support for managing diabetes in children with T1D. In the future, we intend to conduct multidimensional and multiperspective comprehensive studies, including qualitative, quantitative, and clinical studies, to investigate the role and mechanisms of parental socioeconomic and psychological factors on the blood glucose of children with T1D. These studies can also provide advice for individualized clinical treatment strategies that consider children's parental economic status.

CONCLUSION

Children with T1D from low-income households were found to have poorer glycemic control than those from high- to middle-income families. The blood glucose levels of children with T1D were found to be negatively correlated with parental economic status. Therefore, it is suggested that parental financial status should be considered when managing T1D in children.

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FOOTNOTES

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Country of origin: China

ORCID number: Si-Hui Luo 0000-0001-8503-0310; Yu Ding 0000-0003-1617-2125.

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