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ORIGINAL RESEARCH

Patient-Centered Positive Factors Influencing Glycemic Control in Adolescents with Type 1 Diabetes Mellitus in China: A Cross-Sectional and Longitudinal Study

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Objective: This study aimed to explore the stable longitudinal patient-centered self-protective factors of glycosylated hemoglobin (HbA1c) in adolescents with type 1 diabetes mellitus (T1DM).

Methods: We used both cross-sectional and longitudinal datasets at the Diabetes Education Center and National Endocrine and Metabolism Centre of a university hospital in China from April 2020 to July 2022. Participants were assessed using the Adolescent Diabetic Behavior Rating Scale (DBRS), Diabetes Strengths and Resilience Measure for Adolescents (DSTAR-Teen). HbA1c and other clinical variables were obtained from the medical record at the same time. 266 adolescents (131 male, age 14.1±3.9 years) completed the cross-sectional assessments and 131 (62 male, age 14.6±3.3 years) participated in a follow-up at a 1-year visit interval.

Results: Logistic regression analysis of cross-sectional data of 266 cases showed that there were significant positive effects between pump treatment (β=0.090, OR 2.460, P=0.005), DBRS scores (β=2.593, OR 13.366, P=0.002) and the meeting of standard HbA1c (<7.5%, 58 mmol/mol). Disease duration (β=−0.071, OR 0.932, P=0.033) was negatively correlated with it. The longitudinal multivariate generalized estimation equation model showed that DBRS scores (β=3.165, OR 23.681, P=0.009) and DSTAR-Teen scores (β=0.050, OR 1.051, P=0.012) had a positive influence on the meeting of standard HbA1c over one year time of 131 cases.

Conclusion: Self-care and resilience had higher cross-temporal stability in influencing glycemic control over time. To reach a better glycemic control and improve long-term health outcomes, attention should be paid to the detection and enhancement of these patient-centered promoters.

Keywords: type 1 diabetes mellitus, T1DM, hemoglobin a1c, hba1c, adolescent, self-care, resilience

Introduction

Studies have shown that the incidence of type 1 diabetes mellitus (T1DM) increased during recent decades.[1] T1DM is one of the most common endocrine and metabolic conditions occurring in childhood. There are more than 1.2 million T1DM patients under the age of 20 worldwide, with an increase of about 149,500 each year.[2] Therefore, the potential social and economic burden of T1DM cannot be ignored. Given that diabetes-related complications are mainly caused by hyperglycemia, Glycosylated hemoglobin (HbA1c) is an outstanding marker of long-term glycaemic control and is, therefore, an excellent predictor of complications.[3]

For youth with T1DM, maintaining optimal glycaemic control is not easy. Glycemic control is still very poor particularly in adolescents.[4] The study on blood glucose control and management of T1DM in Beijing (the capital of China) showed that the average HbA1c of patients under 18 years old was 8.5%, and the rate of blood glucose control

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reaching the standard was only 15.0%. There is still a certain gap between the control of HbA1c of children and adolescents in China and in developed countries.[5] In addition, among all Asian countries, China has the highest prevalence of T1DM. Compared with other developing countries in Asia, the blood glucose control of children with T1DM in China is not any better, such as India.[6] Therefore, it is important to identify the relevant factors that affect glycemic control in Chinese adolescents with T1DM.

In practice, nursing for T1DM often focuses on identifying and reducing barriers to improve outcomes rather than measuring and enhancing benefits and facilitators. The barriers discussed include family and social factors from the external environment as well as psychological disadvantages inherent in the adolescents themselves. External obstacles include peer pressure (bullying), social stigma, passive smoking,[7–10] etc. Internal adverse factors mainly include depression and anxiety, diabetes-related stress,[11–16] etc. Besides, some studies have found the importance of positive protective factors in adolescents. Extrinsic factors including family support, parent-child relationship quality, perceived diabetes-specific peer support, and shared decision-making among caregivers and healthcare providers may show benefits in terms of self-care and glycemic control.[17–20] But we have to admit that most of these external factors are relatively difficult for us clinical medical staff to intervene.

When we focus on internal influences, self-care is an essential, well-reported, patient-centered positive factor in maintaining health in people with diabetes.[21] As there are studies showing that self-care improves the quality of life and clinical outcomes of both type 1 and type 2 diabetes patients.[22–24] Diabetes resilience is another important intrinsic protective factor for adolescent diabetes patients that has been paid attention to.[25–28] However, it should be noted that the above studies are cross-sectional and cannot explain causality. Further longitudinal studies are needed to further clarify.

We firmly believe that while other factors play a supporting role, adolescents themselves are key roles in optimizing disease management and glycemic control. Therefore, this study intends to explore the relationship between patient-centered self-protective factors and HbA1c of adolescents with TIDM through a longitudinal study, so as to provide a reliable scientific basis for clinical evaluation and intervention for diabetes educators in China.

Materials and Methods

Settings and Participants

We used both cross-sectional and longitudinal datasets at the Diabetes Education Center and National Endocrine and Metabolism Centre of a university hospital (Class 3) in China from April 2020 to July 2022. All of these patients had spontaneously come to the diabetes clinic for examination, treatment or consultation. Adolescents aged 10–18 years with a diagnosis of T1DM and a course of disease longer than 6 months were enrolled from the center after obtaining written consent from both children and their parents, while those patients with other diseases (including those with severe acute complications, such as acute infection and diabetic ketoacidosis) and language communication disorders were excluded. This study was conducted in accordance with the Declaration of Helsinki. Approval for the study protocol was granted by the research ethics committee of the First Affiliated Hospital of Nanjing Medical University (2019-SR-121).

After completing the baseline visit, all participants were told to return to the clinic 12 months later for a follow-up visit.

Data Collection

Sociodemographic and Clinical Variables

All participants (accompanied by a primary caregiver) completed a sociodemographic questionnaire-based interview with the help of a specifically trained nurse. Clinical variables were obtained by consulting their medical records at each visit. According to American Diabetes Association clinical practice recommendations[29] for children at this age, HbA1c < 7.5% was considered to have optimal glycaemic control. All of the personal information was recorded and kept confidential.

Adolescent Diabetic Behavior Rating Scale (DBRS)

The DBRS scale was originally developed by McNabb et al[30] in 1994. In 2006, Iannotti et al[31] revised the scale, and Cronbach's α of each dimension was 0.84–0.94. The Chinese version of the Scale was adapted from the modified version of Iannotti to assess the self-care behavior of T1DM adolescents.[32] Including two versions of using insulin pen

(36 items in total) and insulin pump (37 items in total), the 4 dimensions of this scale are self-behavior adjustment (8 items), blood glucose monitoring and control (10 items), daily basic management (14 items), and insulin injection management (pen: 4 items, pump: 5 items), scoring using Likert rating method. When the number of options is 5 (score 0–4), divide the score by 4. When there are 6 options (score 0–5), divide the score by 5. Finally, the average score of all items was calculated. The total average score ranged from 0 to 1, the higher the score, the higher the self-care ability. The scale comprehensively covers the main aspects of patients' self-care behaviors, with an overall Cronbach's α of 0.92.[33]

Diabetes Strengths and Resilience Measure for Adolescents (DSTAR-Teen)

This is a self-reported measure of resilience related to T1DM coping, including adaptive attitudes and behaviors. This scale was compiled by Hilliard in 2017 with an overall Cronbach's α of 0.89.[34] Our team translated this scale into Chinese and tested Cronbach's α as 0.90.[35] The Chinese version includes 12 items on the three dimensions of seeking help (4 items), self-care confidence (4 items), and family resources (4 items). Each question has five choices, and is assigned a score of 1–5 from "never" to "almost always". The scores for all the questions were added up. The total score ranged from 12 to 60, with higher scores indicating higher resilience.

Statistical Analysis

Categorical and continuous data were described using descriptive statistics (mean, standard deviation, frequencies, and percentages). For cross-sectional data, univariate analysis were realized by independent sample *t*-test and Chi-square test. Multivariate analysis was performed by binary logistic regression analysis. For longitudinal data, the paired sample *t*-test and Chi-square tests were used to compare the continuous and categorical variables at baseline visit and follow-up, respectively. Multivariable longitudinal binomial regression models were conducted using generalized estimating equation modeling to assess the factors associated with HbA1c over time. Statistical analyses were performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). P values of ≤ 0.05 and 95% confidence intervals were used to report the statistical significance and precision of the results.

Results

Demographics and Clinical Characteristics

280 adolescents were approached for the study. 266 (131 male, age 14.9±3.6 years) of them agreed and completed the cross-sectional assessments. For a number of reasons (mainly the novel coronavirus outbreak), only 131 (62 male, age 14.6±3.3 years) of the 266 adolescents were on time for follow-up approximately 1 year later. Cross-sectional and follow-up response rates were 95% and 49.25%, respectively. In both the cross-sectional and longitudinal data at baseline, about half of the adolescents had achieved optimal glycaemic control, and only 40.5% (53/131) had reached optimal glycaemic control at a follow-up one year later. 11 adolescents changed their insulin infusion mode from insulin pen to insulin pump while 3 adolescents changed from insulin pump to insulin pen at follow-up. Other demographics and clinical characteristics are shown in Table 1.

Factors Influencing Glycemic Control Based on Cross-Sectional Data

In order to analyze the influencing factors of achieving optimal blood glucose control, the variables listed in Table 1 were taken as independent variables, and whether the optimal glycaemic control was achieved was taken as dependent variables. Treatment regimens (F=16.515, P<0.001), family monthly income (F=17.479, P=0.002), disease duration (t=−1.728, P=0.045), DBRS scores (t=4.389, P<0.001), and DSTAR-Teen scores (t=4.526, P<0.001) were significant in univariate analysis. Then the five variables were entered into the binary logistic regression model. Logistic regression analysis of cross-sectional data of 266 cases showed that there was an association between pump treatment (β=0.090, OR 2.460, P=0.005) and DBRS scores (β=2.593, OR 13.366, P=0.002) and the meeting of optimal glycaemic control of the patients. Disease duration (β=−0.071, OR 0.932, P=0.033) was negatively associated with it. (see Table 2).

Table 1 Demographic and Clinical Data of Adolescents with T1DM in Cross-Sectional Study and Longitudinal Cohorts Study

Variables	Cross-Sectional Data (N=266)	Longitudinal Data (N=131)		
		Baseline Visit	Follow-up	*P*
Age(years)	14.9±3.6	14.6±3.3	15.6±3.2	0.011
Duration of diabetes(years)	4.9±3.3	4.2±3.6	5.2±3.6	0.024
BMI (kg/m2)	19.6±3.9	19.7±2.6	20.0±2.6	0.370
Treatment regimens				
Insulin pump	93(35.0%)	50(38.2%)	58(44.3%)	0.315
Multiple daily injections	173(65.0%)	81(61.8%)	73(55.7%)	
Education				
Elementary School	47(17.7%)	19(14.5%)	18(13.7%)	0.947
Junior School	48(18.0%)	27(20.6%)	27(20.6%)	
High School	171(64.3%)	85(64.9%)	86(65.6%)	
Family monthly income(yuan)				
≤10,000	139(52.3%)	77(58.8%)	72(55.0%)	0.533
>10,000	127(47.7%)	54(41.2%)	59(45.0%)	
Monthly diabetes costs(yuan)				
<500	90(33.8%)	33(25.2%)	20(15.3%)	0.101
500–1000	76(28.6%)	44(33.6%)	44(33.6%)	
>1000	100(37.6%)	54(41.2%)	67(51.1%)	
Dwelling state				
Living with families	238(89.5%)	128(97.7%)	121(92.4%)	0.123
Board at school	28(10.5%)	3(2.3%)	10(7.6%)	
DBRS scores	0.59±0.19	0.61±0.16	0.65±0.16	0.029
DSTAR-Teen scores	40.81±10.90	39.31±11.24	41.18±10.30	0.161
HbA1c				
<7.5% (58 mmol/mol)	131(49.2%)	68(51.9%)	53(40.5%)	0.063
≥7.5%(58 mmol/mol)	135(50.8%)	63(48.1%)	78(59.5%)	

Abbreviations: HbA1c, hemoglobin A1c; BMI, Body mass index.

Table 2 Logistic Regression Results of Factors Influencing Glycemic Control (HbA1c < 7.5%) (N=266)

Parameter	*β*	OR	95% CI of OR	*P*
Treatment regimens				
Insulin pen	Ref.			
Insulin pump	0.900	2.460	1.306–4.631	0.005
Disease duration	−0.071	0.932	0.873–0.994	0.033
DSTAR-Teen scores	0.031	1.032	0.998–1.067	0.068
DBRS scores	2.593	13.366	2.621–68.151	0.002

Abbreviations: *β*, coefficient; CI, confidence interval; OR, odds ratio.

Factors Influencing Glycemic Control Over Time Based on Longitudinal Data

In this study, the data collected of the same 131 objects with a one-year interval tended to be correlated, so we used the generalized estimation equation(GEE) to analyze the repeated measurement data of each individual. GEE can solve the

Table 3 Generalized Estimating Equation Results of Factors Influencing Glycemic Control (HbA1c < 7.5%) Over One Year Time (N=131)

Parameter	*β*	OR	95% CI of OR	*P*
Treatment regimens				
Insulin pen	Ref.			
Insulin pump	−0.156	0.856	0.045–1.807	0.683
Disease duration	0.109	1.019	0.922–1.126	0.714
DSTAR-Teen scores	0.050	1.051	1.011–1.093	0.012
DBRS scores	3.165	23.681	2.204–254.391	0.009

Abbreviations: *β*, coefficient; CI, confidence interval; OR, odds ratio.

correlation problem of longitudinal data, and improve the efficiency of data over time. The longitudinal multivariate generalized estimation equation model showed that DBRS scores (β=3.165, OR 23.681, P=0.009) and DSTAR-Teen scores (β=0.050, OR 1.051, P=0.012) had a positive influence on the meeting of optimal glycaemic control over time. The effect of the type of treatment regimens or the duration of the disease on HbA1c was not observed. (see Table 3).

Discussion

McLarty et al[4] compared adolescents with other age groups of type 1 diabetics and found that adolescents were more likely to have poor glycemic control [HbA1c 12.8% (116 mmol/mol)], which was even higher than the overall mean HbA1c. In the cross-sectional study, only about 49.2% (131/266) of patients achieved optimal glycemic control, and at the one-year follow-up, the optimal glycemic control rate even dropped to 40.5% (53/131), which is a grim reality. This may be due to the fact that patients with poor glycemic control tend to visit medical institutions more frequently and seek help. Considering the fact that adolescents with T1DM have elevated glycemic control, we need to learn more about which factors positively influence their glycemic control so that effective interventions can be implemented. In this study, a longitudinal cohort was established based on repeated cross-sectional studies and found that self-care and resilience had higher cross-temporal stability in influencing HbA1c over one year time.

In cross-sectional data, adolescents using the insulin pump regimen had better glycemic control than patients using the multiple injections regimen. However, in the cohort data, there was no statistically significant difference in the effect of different insulin infusion regimens on glycemic control in adolescents. The effectiveness of insulin pump therapy versus multiple daily injections has been debated for many years.[36,37] This may be related to the different designs and settings of the studies. It is accepted that insulin pump therapy improves quality of life in patients with T1DM[38] because it reduces the pain of multiple insulin injections. But the use of insulin pump presents a series of tricks for better daily blood glucose control. A situation in China is that most T1DM patients only use insulin pump as an instrument for insulin infusion. Patients or their parents tend to set insulin doses according to the doctor's orders. In daily life, they seldom adjust the basic and bolus dosage of insulin dynamically according to their meals, snacks, or exercises. Therefore, we need to take this into account when guiding patients in the choice of insulin infusion tools.

In cross-sectional data, patients with a longer course of disease were less likely to meet optimal glycaemic control. One reason for this may be that patients' islet function gradually deteriorates over time,[39] meaning that blood glucose control becomes increasingly difficult. Also, Most participants were still in puberty at their one-year interval, and it is a relatively difficult period for blood glucose control, as adolescents have to face a variety of challenges, including growth and development needs, unstable emotions, peer pressure,[7] etc. In addition, studies have shown that metabolic control worsens during puberty because insulin resistance rises during puberty, but reduces to prepubertal levels at the end of puberty.[10,40,41] And the implication for us is that medical staff cannot take for granted that as the course of the disease progresses, adolescents with T1DM can better control their blood glucose.

2018 ISPAD clinical practice consensus guidelines pointed out that children and adolescents with T1DM need to be provided with psychological care.[42] And the premise of providing effective psychological care is to clarify the

psychological-related factors that can affect blood glucose control. Study shows that children and adolescents with T1DM seem to have more psychological distress like depression and anxiety, emotional instability, need for social acceptance, as well as possible psychopathic traits.[43] Nevertheless, some patients can still achieve optimal outcomes, which is inseparable from their diabetes strengths and resilience.[28] Although our cross-sectional study did not find a direct relationship between resilience and $HbA1_C$, our previous research has found resilience had a direct effect on self-care and an indirect effect on the control of HbA1C.[26] As such, we speculate that glycemic control is mainly affected by self-care in the early stage of the disease, and the protective effect of diabetes strengths and resilience becomes more prominent as the disease progresses over time. Nevertheless, the score of patients in this study is still lower than that of adolescents with T1DM in Turkey (48.18±7.74),[27] indicating that there is still much room for improvement in the resilience of Chinese adolescents.

Self-care for T1DM is undeniably complex and important. Adolescents spend half of their day at school away from their parents. Therefore, they must master enough self-care skills to maintain their blood glucose at a near-normal level.[44] In our study, the effect of DBRS scores on blood glucose was confirmed both in cross-sectional and longitudinal data. With the passage of time, the positive effect of self-care on blood glucose control became increasingly important. Over the past few decades, diabetes self-care education programs have proven to be cost-effective in promoting and facilitating blood glucose control[45] and other indicators.[46] Therefore, for adolescents with T1DM, we believe that self-care is the cornerstone of disease management. We advocate that, like other diabetes-related complications, self-care should also be regularly assessed, and self-care education should be emphasized and strengthened in China to promote blood glucose control and delay the occurrence of complications, as our DRBS score is lower than other reported levels.[33]

Limitations

We have to admit that the follow-up of T1DM in China still faces very serious challenges,[47] especially in the recent years of the novel coronavirus pandemic. So the 1-year follow-up rate of the study was less than 50%, which may lead to potential bias in this study.

Conclusion

This study focused on patient-centered protective factors for Chinese adolescents with T1DM and found that self-care and resilience had higher cross-temporal stability in influencing HbA1c over one year time. In order to achieve better glycemic control and improve long-term health outcomes, more emphasis should be paid to these aspects of assessment and intervention in daily disease management.

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Disclosure

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