Diabetes, Metabolic Syndrome and Obesity

Dovepress
Taylor & Francis Group

Open Access Full Text Article

ORIGINAL RESEARCH

Knowledge, Attitudes, and Practices of Chronic Type 2 Diabetes Patients in China Toward Continuous Glucose Monitoring: An Online Questionnaire Survey

Bingling Liu[1], Xueyi Wu[2], Xiao Zou[1], Fei Sun[1], Jie Yu[1]

[1]Department of Endocrinology, Jiujiang City Key Laboratory of Cell Therapy, Jiujiang, 332000, People's Republic of China; [2]Department of Endocrinology, The Second People's Hospital of Guiyang, Guiyang, 550081, People's Republic of China

Correspondence: Jie Yu, Department of Endocrinology, Jiujiang City Key Laboratory of Cell Therapy, No. 1 People's Hospital, Jiujiang, 332000, People's Republic of China, Tel +86-18370277823, Email 47938498@qq.com

Purpose: Investigate the knowledge, attitude, and practices (KAP) of type 2 diabetes patients regarding continuous glucose monitoring (CGM).

Methods: A cross-sectional study was undertaken at the First People's Hospital of Jiujiang City from Sep 20, 2023, to Dec 10, 2023.

Results: A total of 633 patients with type 2 diabetes mellitus accessed the questionnaire link. Of these, 544 patients completed the questionnaires. After data cleaning, 493 questionnaires were included in the analysis, resulting in a response rate of 86% and an effective rate of 91%. Among the 493 participants, 66.9% were male, and 70.8% reported using continuous glucose monitoring (CGM). Median scores: knowledge 17 (14, 26), attitude 34 (32, 40), and practice 20 (17, 24). Positive correlations existed between knowledge and attitude ($r = 0.562$, $P < 0.001$), knowledge and practice ($r = 0.653$, $P < 0.001$), and attitude and practice ($r = 0.661$, $P < 0.001$). Logistic regression revealed that being male, participating in diabetes education, and possessing higher knowledge and attitude scores were independently associated with positive practices. Structural equation model (SEM) showed knowledge directly influenced attitude ($\beta = 0.538$, $P = 0.010$) and practice ($\beta = 0.433$, $P = 0.010$), while attitude directly influenced practice ($\beta = 0.450$, $P = 0.010$). Knowledge indirectly impacted practice through its influence on attitude ($\beta = 0.242$, $P = 0.010$).

Conclusion: Type 2 diabetes patients exhibited insufficient knowledge but positive attitudes and practices toward CGM. Recommends educational interventions to enhance knowledge, potentially improving CGM utilization and outcomes in this population. Regular and comprehensive diabetes education should be integrated into routine clinical practice to optimize self-management and overall patient outcomes.

Keywords: type 2 diabetes, continuous glucose monitoring, knowledge, attitude, practice

Introduction

Type 2 diabetes, a chronic metabolic disorder characterized by high blood sugar levels due to insulin resistance or deficiency, presents a significant public health challenge globally.[1–3] Its symptoms range from increased thirst and hunger to blurred vision and slow healing of wounds.[4] The epidemiology of type 2 diabetes underscores its growing burden, with millions affected worldwide, necessitating the importance of diligent blood glucose monitoring for effective management.[5] Studies consistently show that well-structured diabetes education programs can significantly enhance self-management skills, leading to better glycemic control, reduced hospitalizations, and improved adherence to treatment regimens.[6,7] In addition, continuous Glucose Monitoring (CGM) emerges as a pivotal tool, offering real-time insights into glucose levels, thereby aiding in better glycemic control and reducing the risk of diabetes-related complications.[8,9]

CGM technology represents a significant advancement in diabetes management. Unlike traditional blood glucose meters, CGM systems continuously track glucose levels through a sensor inserted under the skin, providing data on glucose trends and

Received: 17 July 2024
Accepted: 21 December 2024
Published: 6 January 2025

patterns.[10,11] This continuous monitoring facilitates more nuanced decision-making in diabetes care, enabling adjustments in diet, exercise, and medication to maintain optimal glucose levels.[12] Patients view continuous glucose monitoring (CGM) as a valuable tool that enhances their understanding of blood glucose patterns and empowers better diabetes management. Real-time data and trend insights enable informed decisions on insulin, diet, and activity, fostering positive behavior changes. While CGM improves self-efficacy, many patients rely on healthcare professionals to interpret historical data for long-term treatment adjustments, and some express mixed feelings about alarm notifications.[13,14]

The theoretical framework of Knowledge, Attitudes, and Practices (KAP) provides a lens to assess and understand health behaviors.[15,16] KAP studies in the context of diabetes and CGM have been instrumental in identifying how patients' knowledge and attitudes towards CGM influence their practical engagement with the technology. However, there exists a knowledge gap in comprehensive KAP research specifically oriented towards CGM in type 2 diabetes. This gap highlights the need for focused research to gain in-depth insights into the knowledge levels, attitudes, and practices of patients with type 2 diabetes regarding CGM. Such research is crucial for identifying barriers to effective CGM use, designing targeted educational interventions, and ultimately enhancing the quality of diabetes care. The significance of this study, therefore, lies in its potential to contribute valuable information to the field, aiding in the optimization of CGM use and improving health outcomes for individuals with type 2 diabetes.

Material and Methods

Study Design and Participants

This cross-sectional study was conducted at the First People's Hospital of Jiujiang City, spanning from September 20 to December 10, 2023. It targeted individuals diagnosed with type 2 diabetes. To ensure ethical compliance, the study received approval from the Medical Ethics Committee of the First People's Hospital of Jiujiang City, documented under Approval No: JJSDYRMYY-YXLL-2023-193.Prior to participation, informed consent was obtained from all study subjects, affirming their voluntary involvement and understanding of the study's purpose and procedures.

Eligibility for the study was determined based on specific inclusion and exclusion criteria. Inclusion criteria were: a confirmed diagnosis of type 2 diabetes, the ability to communicate effectively in the local language with adequate reading and writing skills, and a willingness to participate, evidenced by the provision of informed consent. Exclusion criteria encompassed: the presence of cognitive impairments, severe organic diseases or complications, concurrent malignancies, and acute diabetic emergencies such as ketoacidosis or hyperosmolar coma. The survey was administered through the Questionnaire Star platform, utilizing WeChat, WeChat groups, and Moments for dissemination. Despite the target demographic being individuals with type 2 diabetes, the survey inadvertently attracted responses from non-diabetic individuals. These responses were identified and excluded from the analysis based on the respondents' self-reported diabetes status within the survey.

Questionnaire Introduction

The questionnaire's development was guided by pertinent guidelines and existing literature in the field. Initially crafted, it underwent a thorough review by an endocrinology expert to ensure its relevance and accuracy. Subsequently, a pilot test was conducted with a sample of 40 participants to assess the tool's effectiveness. This pre-testing phase resulted in a high Cronbach's α coefficient of 0.977 for the overall scale, indicating excellent internal consistency. The individual dimensions of the questionnaire also demonstrated strong reliability, with Cronbach's α values of 0.979 for knowledge, 0.982 for attitude, and 0.965 for practice dimensions. The finalized questionnaire is structured into four distinct sections: basic information, knowledge, attitude, and practice.

In the knowledge section, respondents are presented with 14 items and asked to rate their level of understanding on a scale of "a. Very knowledgeable (2 points)", "b. Heard of it (1 point)", or "c. Not clear (0 points)". This section has a total possible score range from 0 to 28 points. The attitude section comprises nine items (A1-A8), employing a five-point Likert scale that spans from "5. Strongly agree" to "1. Strongly disagree", allowing for a scoring range of 8 to 40 points. Notably, item A9 in this section is an open-ended question. Finally, the practice dimension includes five items, also using a five-point Likert scale from "5. Always" to "1. Never", with a total scoring range of 5 to 25 points.

Statistical Analysis

Descriptive statistics were utilized to summarize the scores across each dimension of the study. The distribution of the data was represented using either means and standard deviations or medians, 25th percentiles, and 75th percentiles, based on the outcomes of normality tests. For demographic characteristics and response patterns, count data were expressed as N (%). Score differences among participants with varying demographic profiles were analyzed using either *t*-tests or Wilcoxon-Mann–Whitney tests for two-group comparisons. In contrast, ANOVA or Kruskal–Wallis tests were applied for multiple-group comparisons, contingent on the normality of data distribution. Correlation analyses were conducted using either Pearson or Spearman correlation coefficients, as appropriate. To identify factors influencing practices, both univariate and multivariate analyses were conducted, using medians as cutoffs for each dimension. Variables were selected for multivariate regression based on a significance threshold of $P < 0.1$ in the univariate analysis. P-values were reported to three decimal places, and a P-value of less than 0.05 was deemed to indicate statistical significance. In the assessment of interrelationships among the questionnaire dimensions, structural equation modeling (SEM) was used, with particular attention to exploring the mediating role of attitudes between knowledge and practice.

Results

A total of 633 patients with type 2 diabetes mellitus accessed the questionnaire link. Among them, 89 patients declined to provide online informed consent and withdrew from the survey. After excluding responses with logic errors or indications of inattentiveness based on completion time, 544 complete questionnaires were collected. Of these, 493 were deemed valid and included in the final analysis, resulting in a response rate of 86% and an effective rate of 91%. The reliability of the questionnaire was confirmed, with an overall Cronbach's α of 0.954 for the formal distribution. The Cronbach's α values for the individual dimensions of knowledge, attitude, and practice were 0.953, 0.913, and 0.896, respectively. The Kaiser-Meyer-Olkin (KMO) value was 0.959.

Of the patients with type 2 diabetes who participated in this study, 330 (66.9%) were male, 158 (32%) were aged over 50, and 224 (45.4%) had completed college or obtained a bachelor's degree or higher. Additionally, 185 (37.5%) had been living with diabetes for 1–3 years, and 309 (62.7%) reported a mild severity of their T2DM. Furthermore, 386 (78.3%) had received diabetes knowledge education, 343 (69.6%) had learned about continuous glucose monitoring (CGM) operation and knowledge, and 349 (70.8%) had used CGM. These individuals were more likely to have higher knowledge, attitude, and practice scores (all with P-values < 0.001). Patients of different ages and diabetes durations were more likely to have varying knowledge scores ($P < 0.001$ and $P = 0.002$, respectively). Patients with different levels of type 2 diabetes severity were more likely to exhibit different attitude scores ($P = 0.036$), and patients of different ages were more likely to demonstrate different practice scores ($P = 0.002$). The median (25th percentile, 75th percentile) scores for knowledge, attitude, and practice were 17 (14, 26), 34 (32, 40), and 20 (17, 24), respectively (as displayed in Table 1).

The distribution of knowledge dimensions shown that the two questions with the highest proportion choosing the "very knowledgeable" option were "For most type 2 diabetes patients, the ideal fasting blood glucose control range is 4.4–7.0 mmol/L". (K3) with 54.4% and "Fasting blood glucose, random blood glucose, or a 2-hour blood glucose test after oral glucose intake are the main diagnostic criteria for diabetes". (K2) with 51.1%. On the other hand, the two questions with the highest proportion choosing the "heard of it" option were Flash Glucose Monitoring (FGM) is a type of on-demand CGM, where the wearer actively scans the sensor to obtain current glucose data. It does not require fingerstick calibration, eliminating the pain of frequent blood sampling (K9) with 46.9% and Real-time CGM provides immediate blood glucose information, high or low blood glucose alerts, and displays glucose trend changes, thus serving as an early warning system. Real-time CGM is particularly suitable for patients with significant blood glucose fluctuations and a high risk of hypoglycemia, especially those with repeated nocturnal hypoglycemia or asymptomatic hypoglycemia (K8) with 46.5% (as shown in Table S1).

Patients' attitudes toward continuous glucose monitoring (CGM) were notably positive, with over 85% of participants either strongly agreeing or agreeing with all items. Specifically, 48.9% strongly concurred that monitoring blood glucose at home is an integral aspect of patients' self-management (A1), 47.9% strongly concurred that CGM can aid doctors in

Table 1 Basic Information of Participants and KAP Score

Variables	N (%)	Knowledge score		Attitude score		Practice score	
		Median (25th percentile, 75th percentile)	P	Median (25th percentile, 75th percentile)	P	Median (25th percentile, 75th percentile)	P
Total	493	17(14,26)		34(32,40)		20(17,24)	
Gender			0.736		0.380		0.254
Male	330(66.9)	17(14,26)		34(32,40)		20(17,24)	
Female	163(33.1)	17(14,26)		36(32,40)		20(16,25)	
Age (years)	44(32,55)	/	/	/	/	/	/
Age group (years)			**<0.001**		0.337		**0.002**
≤30	110(22.3)	21(15,28)		35(31,40)		20(18,25)	
31–40	113(22.9)	17(14,27)		35(32,40)		20(17,25)	
41–50	112(22.7)	15.5(13,21)		33(31.5,39.5)		18.5(15,21.5)	
>50	158(32)	16.5(12,23)		34(32,40)		20(17,23)	
Residence			0.098		0.388		0.163
Urban	371(75.3)	17(14,27)		34(32,40)		20(17,25)	
Non-urban	122(24.7)	16(12,22)		34(32,40)		20(16,23)	
Education			0.403		0.168		0.139
Junior high and below	109(22.1)	16(12,24)		34(32,40)		20(16,23)	
High school/ technical school	160(32.5)	18(14,27)		33(32,40)		20(17,24.5)	
College/ bachelor's	212(43)	17(14,26)		35(32,40)		20(17,25)	
Master's and above	12(2.4)	15(14,18.5)		32(28,37)		18(15,19.5)	
Education [Adjusted]			0.310		0.570		0.278
Junior high and below	109(22.1)	16(12,24)		34(32,40)		20(16,23)	
High school/ technical school	160(32.5)	18(14,27)		33(32,40)		20(17,24.5)	
College/ bachelor's and above	224(45.4)	17(14,26)		35(32,40)		20(17,25)	
Occupation			0.052		0.256		0.052
Student	27(5.5)	21(15,28)		32(30,40)		21(18,25)	
Office staff/ leader	103(20.9)	17(14,26)		34(32,40)		20(17,23)	
Farmer	60(12.2)	14(9.5,22.5)		33(30.5,40)		17.5(15,23)	
Freelancer	171(34.7)	17(14,28)		36(32,40)		20(17,25)	
Outdoor laborer	13(2.6)	14(9,22)		32(30,36)		18(15,20)	
Entrepreneur/ businessperson	60(12.2)	17(13.5,23)		33(32,39.5)		20(16.5,22.5)	
Resigned/ retired	49(9.9)	18(14,25)		36(32,40)		20(19,25)	
Other	10(2)	14.5(9,26)		32(32,37)		18.5(15,20)	
Occupation [Adjusted]			0.106		0.439		0.176
Office staff/ leader	103(20.9)	17(14,26)		34(32,40)		20(17,23)	
Farmer	60(12.2)	14(9.5,22.5)		33(30.5,40)		17.5(15,23)	
Freelancer	171(34.7)	17(14,28)		36(32,40)		20(17,25)	
Entrepreneur/ businessperson	60(12.2)	17(13.5,23)		33(32,39.5)		20(16.5,22.5)	
Other	99(20.1)	17(14,26)		34(32,40)		20(18,25)	
Monthly family income (CNY)			0.056		0.905		0.928
≤2000	70(14.2)	19.5(14,28)		35.5(32,40)		20(17,25)	
2000–5000	167(33.9)	18(13,26)		34(32,40)		20(16,25)	
5000–8000	156(31.6)	17(14,28)		34(32,40)		20(17,25)	
>8000	100(20.3)	16(13,21.5)		34(32,39.5)		20(17,22)	
Monthly family income [Adjusted] (CNY)			0.053		0.755		0.833
≤5000	237(48.1)	18(14,26)		34(32,40)		20(17,25)	
5000–8000	156(31.6)	17(14,28)		34(32,40)		20(17,25)	
>8000	100(20.3)	16(13,21.5)		34(32,39.5)		20(17,22)	

(*Continued*)

Table 1 (Continued).

Variables	N (%)	Knowledge score		Attitude score		Practice score	
		Median (25th percentile, 75th percentile)	P	Median (25th percentile, 75th percentile)	P	Median (25th percentile, 75th percentile)	P
Diabetes duration			**0.002**		0.233		0.284
≤1 year	165(33.5)	21(14,28)		36(32,40)		20(17,25)	
1–3 years	185(37.5)	16(12,23)		34(32,40)		20(17,23)	
3–5 years	83(16.8)	17(14,24)		34(32,39)		20(16,23)	
>5 years	60(12.2)	15(13,20.5)		32(32,40)		20(17,22)	
Diabetes duration [Adjusted]			**0.001**		0.118		0.153
≤1 year	165(33.5)	21(14,28)		36(32,40)		20(17,25)	
1–3 years	185(37.5)	16(12,23)		34(32,40)		20(17,23)	
>3 years	143(29)	17(14,23)		33(32,40)		20(17,22)	
Severity of type 2 diabetes			0.159		**0.036**		0.151
Mild	309(62.7)	17(14,28)		34(32,40)		20(17,25)	
Moderate	161(32.7)	17(14,23)		35(32,40)		20(16,22)	
Severe	23(4.7)	15(12,19)		32(28,34)		20(15,22)	
Severity of type 2 diabetes [Adjusted]			0.095		0.250		0.061
Mild	309(62.7)	17(14,28)		34(32,40)		20(17,25)	
Moderate to severe	184(37.3)	17(13.5,23)		34(32,40)		20(16,22)	
Participated in diabetes knowledge education			**<0.001**		**<0.001**		**<0.001**
Yes	386(78.3)	18(14,28)		36(32,40)		20(17,25)	
No	107(21.7)	14(8,20)		32(29,35)		17(15,20)	
Learned CGM operation and knowledge			**<0.001**		**<0.001**		**<0.001**
Yes	343(69.6)	20(14,28)		36(32,40)		20(18,25)	
No	150(30.4)	14(8,17)		32(31,36)		18(15,20)	
Used CGM			**<0.001**		**<0.001**		**<0.001**
Yes	349(70.8)	20(14,28)		36(32,40)		20(18,25)	
No	144(29.2)	14(8,16)		32(30,35)		18(15,20)	

Note: Bold: Indicates values where P < 0.05.

gaining an accurate understanding of the patient's condition (A4), and 43.6% expressed a strong willingness to use CGM (as depicted in Table S2).

Regarding related practices, 39.1% consistently monitored CGM as frequently as prescribed by their doctors (P1). Furthermore, based on the CGM results, 34.7% and 38.9%, respectively, consistently investigated the causes of blood glucose fluctuations (P3) and assisted their doctors in adjusting their glucose-lowering treatments (P5). Additionally, 35.9% and 36.1%, respectively, often maintained detailed records of dietary, exercise, and treatment events (P2) and made adjustments to their diet or exercise routines (P4) (as illustrated in Table S3).

Correlation analyses revealed a significant positive correlation between knowledge and attitude ($r = 0.562$, $P < 0.001$) as well as between knowledge and practice ($r = 0.653$, $P < 0.001$). Furthermore, a positive correlation was observed between attitude and practice ($r = 0.661$, $P < 0.001$) (as presented in Table 2).

Multivariate logistic regression analyses demonstrated that being male (for females: OR = 0.614, 95% CI: [0.392, 0.962], P = 0.033), participating in diabetes knowledge education (OR = 1.798, 95% CI: [1.077, 3.001], P = 0.025), having a knowledge score of greater than or equal to 17 (OR = 4.493, 95% CI: [2.905, 6.948], P < 0.001), and an attitude score of greater than or equal to 34 (OR = 3.313, 95% CI: [2.123, 5.169], P < 0.001) were independently associated with positive practice (as outlined in Table 3).

Figure 1 presents the structural equation model (SEM) before adjustment (Figure 1A) and after adjustment (Figure 1B). Figure 1 shows that the factor loadings of the measurement model in the structural equation are all greater

Table 2 Correlation Analysis of KAP Scores

	Knowledge	Attitude	Practice
Knowledge	1.000	0.562(P<0.001)	0.653(P<0.001)
Attitude	0.562(P<0.001)	1.000	0.661(P<0.001)
Practice	0.653(P<0.001)	0.661(P<0.001)	1.000

than 0.6, further confirming the construct validity of the questionnaire. SEM demonstrated excellent model fit indices, indicating a strong fit to the data (as displayed in Table S4). The results of Bootstrap analysis revealed that knowledge directly influences attitude (β = 0.538, P = 0.010) and practice (β = 0.433, P = 0.010). Attitude also exerts a direct influence on practice (β = 0.450, P = 0.010). Simultaneously, knowledge indirectly impacts practice through its influence on attitude (β = 0.242, P = 0.010) (as outlined in Table 4).

Table 3 Exploring Practice Through Univariate and Multivariate Logistic Regression

Cutoff:≥20/<20	No.	Univariate		Multivariate (forward, P<0.1)		Multivariate (forward, P<0.25)	
		OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P
Gender							
Male	201/330	ref.		ref.		ref.	
Female	86/163	0.717(0.491,1.047)	0.085	0.614(0.392,0.962)	**0.033**	0.614(0.392,0.962)	**0.033**
Age group (years)							
≤30	71/110	ref.					
31–40	68/113	0.830(0.482,1.428)	0.501				
41–50	50/112	0.443(0.258,0.760)	**0.003**				
>50	98/158	0.897(0.541,1.488)	0.674				
Residence							
Urban	220/371	ref.					
Non-urban	67/122	0.836(0.554,1.263)	0.395				
Education [Adjusted]							
Junior high and below	55/109	ref.					
High school/ technical school	97/160	1.512(0.925,2.471)	0.099				
College/ bachelor's and above	135/224	1.489(0.939,2.362)	0.090				
Occupation [Adjusted]							
Office staff/ leader	62/103	ref.					
Farmer	27/60	0.541(0.284,1.030)	0.061				
Freelancer	102/171	0.978(0.594,1.610)	0.929				
Entrepreneur/ businessperson	33/60	0.808(0.425,1.538)	0.517				
Other	63/99	1.157(0.655,2.044)	0.615				
Monthly family income [Adjusted] (CNY)							
≤5000	136/237	ref.					
5000–8000	93/156	1.096(0.727,1.653)	0.661				
>8000	58/100	1.026(0.639,1.646)	0.917				
Diabetes duration [Adjusted]							
≤1 year	102/165	ref.					
1–3 years	102/185	0.759(0.495,1.164)	0.206				
>3 years	83/143	0.854(0.541,1.350)	0.500				

(*Continued*)

Table 3 (Continued).

Cutoff:≥20/<20	No.	Univariate		Multivariate (forward, P<0.1)		Multivariate (forward, P<0.25)	
		OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P
Severity of type 2 diabetes [Adjusted]							
Mild	188/309	ref.					
Moderate to severe	99/184	0.750(0.518,1.084)	0.126				
Participated in diabetes knowledge education							
Yes	247/386	2.976(1.911,4.637)	**<0.001**	1.798(1.077,3.001)	**0.025**	1.798(1.077,3.001)	**0.025**
No	40/107	ref.		ref.		ref.	
Learned CGM operation and knowledge							
Yes	221/343	2.306(1.560,3.408)	**<0.001**				
No	66/150	ref.					
Used CGM							
Yes	228/349	2.715(1.822,4.044)	**<0.001**				
No	59/144	ref.					
Knowledge score							
<17	78/227	ref.		ref.		ref.	
≥17	209/266	7.004(4.690,10.460)	**<0.001**	4.493(2.905,6.948)	**<0.001**	4.493(2.905,6.948)	**<0.001**
Attitude score							
<34	88/236	ref.		ref.		ref.	
≥34	199/257	5.770(3.892,8.556)	**<0.001**	3.313(2.123,5.169)	**<0.001**	3.313(2.123,5.169)	**<0.001**

Note: Bold: Indicates values where P < 0.05.

Discussion

This study reveals that while type 2 diabetes patients generally have positive attitudes and practices towards CGM, there is a notable deficiency in their knowledge about this technology. It is crucial to enhance educational interventions targeting diabetes knowledge, particularly among female patients, to improve the overall effectiveness of CGM practices and outcomes in type 2 diabetes management.

The study's primary finding that patients with type 2 diabetes generally display insufficient knowledge but positive attitudes and practices towards CGM is a pivotal observation. This knowledge gap is not conducive to maintaining positive practices. As Garcia-Perez et al[17] found, diabetic patients often have positive attitudes but relatively poor nutrition knowledge and practices. This disparity suggests that while patients are open to and actively engaging with CGM, their understanding of its full potential and operational intricacies might be limited. This gap in knowledge, despite favorable attitudes, is not uncommon in chronic disease management, as highlighted by previous studies, which emphasize the need for comprehensive patient education.[18–20] The positive practice observed might be attributed to the ease of use and perceived benefits of CGM. However, the lack of knowledge can be a barrier to optimal utilization.

In the inter-group comparisons, the influence of age and diabetes duration on KAP scores is particularly noteworthy. Younger patients and those with a shorter duration of diabetes demonstrated higher knowledge and practice scores. This could reflect the tech-savviness of younger individuals and the heightened attentiveness often seen immediately after a diabetes diagnosis.[21–23] Older patients and those with longer disease duration may experience a decline in engagement or face challenges in adapting to technological advancements. It's critical to involve tailoring educational content to suit different age groups and disease durations. For instance, incorporating technology-based learning for younger patients and providing more hands-on, supportive education for older patients or those with long-standing diabetes could be effective strategies.

 https://doi.org/10.2147/DMSO.S487493

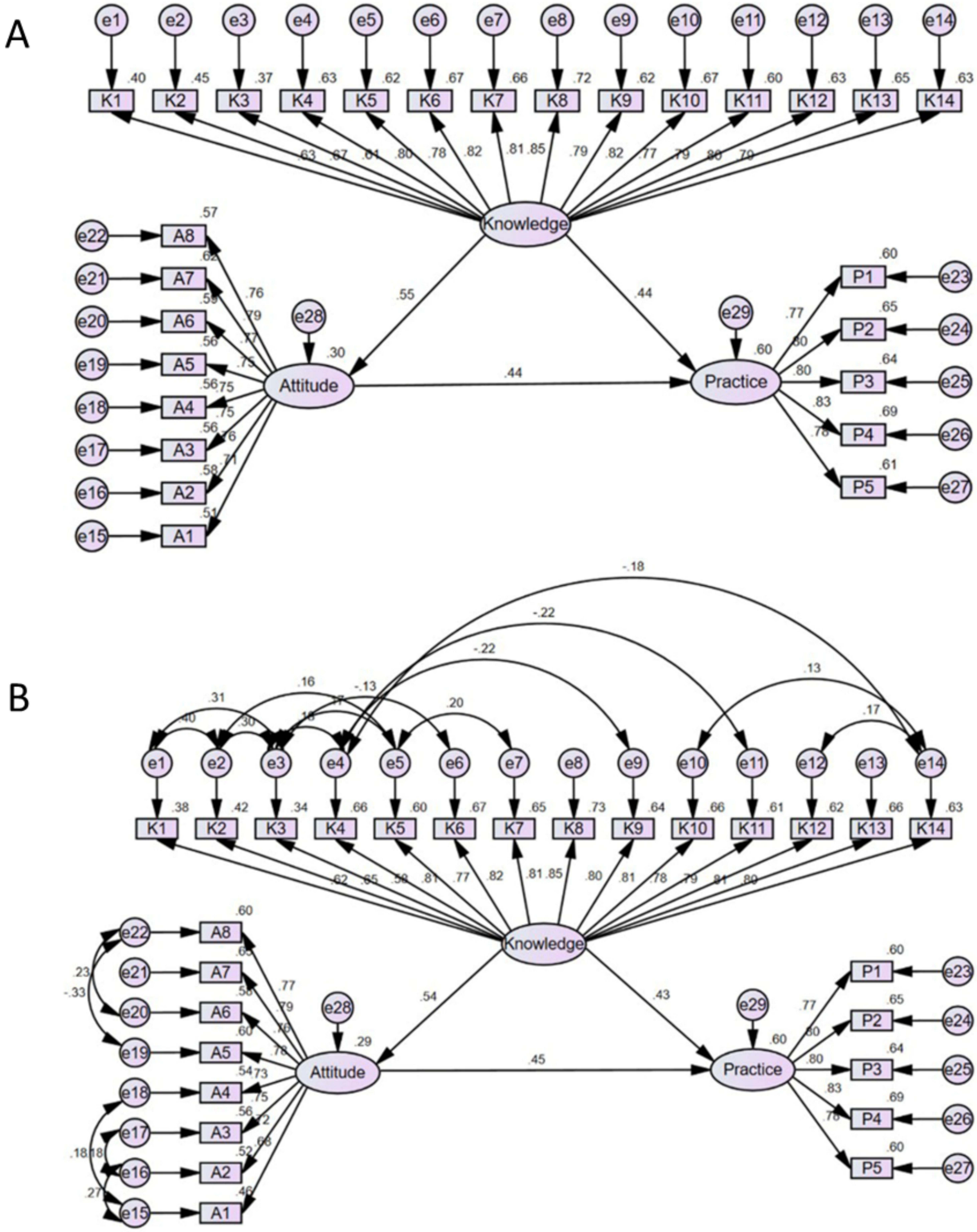

Figure 1 The Structural Equation Model (SEM) Before and After Model Adjustment. The figure presents the structural equation model (SEM) before adjustment (**A**) and after adjustment (**B**). Both models illustrate the relationships among knowledge, attitude, and practice dimensions, along with their respective observed variables (K1-K14, A1-A8, P1-P5). Adjustments in (**B**) include added covariances between error terms and refinements in factor loadings to improve model fit. Rectangles represent observed variables, ellipses denote latent variables, and circles indicate error terms, with standardized regression coefficients shown along the pathways.

Table 4 Bootstrap Analysis of Mediating Effect Significance Test for the Final Mode

Models	Standardized direct effects	P	95% CI		Standardized indirect effects	P	95% CI	
			LLCI	ULCI			LLCI	ULCI
K-A	0.538	0.010	0.470	0.610	-	-	-	-
K-P	0.433	0.010	0.350	0.523	-	-	-	-
A-P	0.450	0.010	0.340	0.533	-	-	-	-
K-P	-	-	-	-	0.242	0.010	0.175	0.304

The multivariate logistic regression analysis highlights several key predictors of positive practice, including gender, participation in diabetes knowledge education, and attainment of certain knowledge and attitude scores. The gender difference in practice, with males more likely to engage in positive practices, suggesting that gender-specific factors can influence health behavior in diabetes.[24,25] The strong influence of diabetes education on practice reiterates the critical role of knowledge in empowering patients. Clinically, this underscores the need for gender-sensitive educational interventions and the importance of setting tangible knowledge and attitude benchmarks as part of diabetes care programs.

Correlation analyses and SEM results further solidify the interconnectedness of knowledge, attitude, and practice. The positive correlations and direct influence of knowledge on attitude and practice, and the indirect effect of knowledge on practice through attitude, align with the theory of planned behavior, which posits that knowledge shapes attitudes, subsequently influencing behavior.[26–28] These findings suggest that improving knowledge can have a cascading effect on attitude and practice. The study by Hawthorne et al[29] demonstrated that patients with greater diabetes knowledge exhibited better glycemic control. This further underscores the importance of enhancing patients' knowledge levels. Clinically, this could translate into developing multidimensional education programs that not only disseminate information but also focus on shaping positive attitudes towards self-management practices. Interventions might include motivational interviewing and goal-setting strategies, which have been shown to positively influence attitudes and behaviors in chronic disease management.[30]

In the knowledge dimension, the highest scoring item was K3, indicating most participants understood the ideal fasting blood glucose control range for type 2 diabetes. This awareness is crucial for effective diabetes management and mirrors findings from studies, which emphasized the importance of glycemic control knowledge in diabetes care.[31] In contrast, the lowest scoring item, K14, related to the understanding of standardized CGM reports, suggests a significant knowledge gap. This gap is concerning as detailed knowledge of CGM reports is essential for effective diabetes management. To address this, diabetes education programs should place greater emphasis on interpreting CGM data. Tailored educational initiatives, possibly incorporating interactive digital tools, could enhance patient understanding of CGM reports, thereby enabling them to make informed decisions about their health.

In attitudes, the highest level of agreement was seen in A2, where participants recognized that effective blood glucose monitoring could reduce the risk of complications. This aligns with previous study, which highlighted patient awareness of the long-term benefits of diligent glucose monitoring.[32] However, the lowest scores were seen in A8, reflecting uncertainty about the comparative effectiveness of CGM over traditional methods. This hesitancy might stem from a lack of comprehensive understanding of CGM's benefits.[33,34] Healthcare providers should focus on clearly communicating the advantages of CGM, using evidence-based data to reinforce its superiority over traditional monitoring methods in certain clinical scenarios. Additionally, sharing patient success stories could also help in reinforcing positive attitudes toward CGM.

Regarding practice, P1 scored the highest, indicating that most patients are adhering to the recommended frequency of blood glucose monitoring. This adherence is a positive indicator of patient engagement and responsibility in managing their diabetes, a correlation also noted in other research.[35] Conversely, P3, which relates to analyzing blood glucose results to identify causes of fluctuations, scored the lowest. This finding suggests a need for improved patient education in interpreting blood glucose data, as understanding fluctuations is critical for proactive diabetes management. Clinicians could address this by providing training sessions on data interpretation, potentially supplemented by decision-support tools that help patients understand and act on their blood glucose readings more effectively. The observed positive correlations between knowledge, attitudes, and practices, as shown in the SEM analysis, highlight the central role of knowledge in shaping attitudes and behaviors. Younger patients and those with shorter diabetes durations tended to score higher in knowledge and practices, suggesting that recent diagnoses and familiarity with technology may enhance patient engagement. On the other hand, older patients and those with longer disease durations may benefit from more tailored educational support to overcome potential barriers. The significant association between participation in diabetes education and higher KAP scores further emphasizes the value of structured education programs. Addressing knowledge gaps through targeted interventions could not only improve CGM utilization but also empower patients to make more informed decisions about their care, ultimately enhancing diabetes management outcomes.

The study has notable limitations, including its single-center design at the First People's Hospital of Jiujiang City, which may limit the generalizability of the findings to a broader population due to unique local demographic and socio-economic factors. In addition to collecting data from the hospital, we distributed our questionnaire through online channels to include patients who did not visit the hospital for follow-up care or those from rural or community healthcare settings. However, we acknowledge that this approach does not completely eliminate selection bias, as 75% of the participants were from urban areas, as indicated in the results. Additionally, its cross-sectional nature restricts the ability to infer causality between the knowledge, attitudes, and practices of patients regarding CGM and long-term health outcomes. Reliance on self-reported data also introduces the possibility of response bias, as patients' perceptions and reporting accuracy might affect the validity of the results. Furthermore, potential interviewer-related bias cannot be entirely excluded. Despite these limitations, the study's strengths lie in its substantial sample size, robust statistical analysis including multivariate logistic regression and Structural Equation Modeling, and its significant contributions to understanding the current state of knowledge and attitudes towards CGM among type 2 diabetes patients, providing valuable insights for healthcare policy and education strategies.

Conclusion

In conclusion, the study highlights that while patients with type 2 diabetes generally exhibit positive attitudes and practices towards CGM, there remains a notable deficiency in their knowledge about this technology. Given the significant positive correlations between knowledge, attitudes, and practices, it is essential to enhance educational interventions for type 2 diabetes patients, focusing on improving their understanding of CGM to optimize their usage and benefits from this technology. Moreover, the need for diabetes education extends beyond just CGM. Regular and comprehensive diabetes education should be integrated into routine clinical practice to ensure that patients are well-informed and empowered to manage their condition effectively.

Data Sharing Statement

All data generated or analysed during this study are included in this published article and its Supplementary Information file.

Ethics Approval and Consent to Participate

To ensure ethical compliance, the study received approval from the Medical Ethics Committee of the First People's Hospital of Jiujiang City, documented under Approval [No: JJSDYRMYY-YXLL-2023-193]. Obtained written informed consent from all subjects prior to participation, affirming[1] their voluntary involvement and understanding of the study's purpose and procedures. All methods were performed in accordance with the relevant guidelines. All procedures were performed in accordance with the Declaration of Helsinki.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Funding

The study was supported by Jiujiang City Double Hundred and Double Thousand Talent Project. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Disclosure

The authors report no conflicts of interest in this work.

References

1. Ashley K, Smith K, Brunsgaard LH, Stevenson E, West D, Avery L. Identifying Behavioural Determinants to Uptake and Adherence to a Whey Protein Supplement for the Management of Type 2 Diabetes: a Qualitative Interview Study. *Nutrients*. 2022;14(3). doi:10.3390/nu14030565
2. Huang KH, Guan SS, Lin WH, et al. Role of Calbindin-D28k in Diabetes-Associated Advanced Glycation End-Products-Induced Renal Proximal Tubule Cell Injury. *Cells*. 2019;8(7). doi:10.3390/cells8070660
3. Ren L, Cheng Y, Qin F. Herbal Formula Gegen-Qinlian Decoction for Type 2 Diabetes Mellitus: a Meta-Analysis of Randomized Controlled Trials. *Evid Based Compl Alternat Med*. 2020;2020:3907920. doi:10.1155/2020/3907920
4. Koomen JV, Stevens J, Monster-Simons MH, Heerspink HJL, Mol PGM. A Review of the Dose Justification of Phase 3 Trials to Regulatory Authorities for Drugs Intended for the Treatment of Type 2 Diabetes in Europe. *Front Pharmacol*. 2021;12:626766. doi:10.3389/fphar.2021.626766
5. Zafar H, Channa A, Jeoti V, Stojanović GM. Comprehensive Review on Wearable Sweat-Glucose Sensors for Continuous Glucose Monitoring. *Sensors*. 2022;22(2). doi:10.3390/s22020638
6. Funnell MM, Brown TL, Childs BP, et al. National Standards for Diabetes Self-Management Education. *Diabetes Care*. 2010;33(Supplement_1): S89–S96. doi:10.2337/dc10-S089
7. Siminerio LM, Piatt G, Zgibor JC. Implementing the chronic care model for improvements in diabetes care and education in a rural primary care practice. *The Diabetes educator*. 2005;31(2):225–234. doi:10.1177/0145721705275325
8. Grabia M, Socha K, Soroczyńska J, Bossowski A, Markiewicz-żukowska R. Determinants Related to Oxidative Stress Parameters in Pediatric Patients with Type 1 Diabetes Mellitus. *Nutrients*. 2023;15(9). doi:10.3390/nu15092084
9. Zhou L, Deng M, Zhai X, et al. The Effects of Dietary Nutrition Intake on Glycemic Variability in Type 1 Diabetes Mellitus Adults. *Diab Therap*. 2021;12(4):1055–1071. doi:10.1007/s13300-021-01028-8
10. Bruttomesso D, Boscari F, Lepore G, et al. A “Slide Rule” to Adjust Insulin Dose Using Trend Arrows in Adults with Type 1 Diabetes: test in Silico and in Real Life. *Diabetes Ther*. 2021;12(5):1313–1324. doi:10.1007/s13300-021-01020-2
11. Costa D, Lourenço J, Monteiro AM, et al. Clinical Performance of Flash Glucose Monitoring System in Patients with Liver Cirrhosis and Diabetes Mellitus. *Sci Rep*. 2020;10(1):7460. doi:10.1038/s41598-020-64141-x
12. Malandrucco I, Russo B, Picconi F, Menduni M, Frontoni S. Glycemic Status Assessment by the Latest Glucose Monitoring Technologies. *Int J Mol Sci*. 2020;21(21). doi:10.3390/ijms21218243
13. Clark TL, Polonsky WH, Soriano EC. The Potential Impact of Continuous Glucose Monitoring Use on Diabetes-Related Attitudes and Behaviors in Adults with Type 2 Diabetes: a Qualitative Investigation of the Patient Experience. *Diabs Technol Ther*. 2024.
14. Lawton J, Blackburn M, Allen J, et al. Patients’ and caregivers’ experiences of using continuous glucose monitoring to support diabetes self-management: qualitative study. *BMC Endocr Disord*. 2018;18:1–10.
15. Khalid A, Haque S, Alvi S, et al. Promoting Health Literacy About Cancer Screening Among Muslim Immigrants in Canada: perspectives of Imams on the Role They Can Play in Community. *J Prim Care Community Health*. 2022;13:21501319211063051. doi:10.1177/21501319211063051
16. Mumena WA. Maternal Knowledge, Attitude and Practices toward Free Sugar and the Associations with Free Sugar Intake in Children. *Nutrients*. 2021;13(12). doi:10.3390/nu13124403
17. Wang H, Song Z, Ba Y, Zhu L, Wen Y. Nutritional and eating education improves knowledge and practice of patients with type 2 diabetes concerning dietary intake and blood glucose control in an outlying city of China. *Public Health Nutrition*. 2014;17(10):2351–2358. doi:10.1017/s1368980013002735
18. Coppola A, Sasso L, Bagnasco A, Giustina A, Gazzaruso C. The role of patient education in the prevention and management of type 2 diabetes: an overview. *Endocrine*. 2016;53(1):18–27. doi:10.1007/s12020-015-0775-7
19. Duke SA, Colagiuri S, Colagiuri R. Individual patient education for people with type 2 diabetes mellitus. *Cochrane Database Syst Rev*. 2009;2009(1):Cd005268. doi:10.1002/14651858.CD005268.pub2
20. Hildebrand JA, Billimek J, Lee JA, et al. Effect of diabetes self-management education on glycemic control in Latino adults with type 2 diabetes: a systematic review and meta-analysis. *Patient Educ Couns*. 2020;103(2):266–275. doi:10.1016/j.pec.2019.09.009
21. Alduraibi RK, Almigbal TH, Alrasheed AA, Batais MA. Knowledge, attitudes, and practices of primary health care physicians regarding the pre-travel counselling of patients with type 2 diabetes in Riyadh, Saudi Arabia. *BMC Fam Pract*. 2020;21(1):200. doi:10.1186/s12875-020-01273-z
22. Gopalan A, Blatchins MA, Altschuler A, Mishra P, Fakhouri I, Grant RW. Disclosure of New Type 2 Diabetes Diagnoses to Younger Adults: a Qualitative Study. *J Gen Intern Med*. 2021;36(6):1622–1628. doi:10.1007/s11606-020-06481-y
23. Sulaiman S, Leelavathi M, Norasyikin AW. Risk perception and knowledge regarding diabetes among offspring of type 2 diabetics at a tertiary institution. *Med J Malaysia*. 2020;75(6):655–659.
24. Tseng HK, Nkimbeng M, Han HR. Gender differences in psychosocial characteristics and diabetes self-management among inner-city African Americans. *Nurs Open*. 2022;9(5):2425–2433. doi:10.1002/nop2.1259
25. Vázquez-Moreno M, Locia-Morales D, Valladares-Salgado A, et al. Sex/Gender Modifies the Association Between the MC4R p.Ile269Asn Mutation and Type 2 Diabetes in the Mexican Population. *J Clin Endocrinol Metab*. 2021;106(1):e112–e117. doi:10.1210/clinem/dgaa726
26. Adam L, O’Connor C, Garcia AC. Evaluating the Impact of Diabetes Self-Management Education Methods on Knowledge, Attitudes and Behaviours of Adult Patients With Type 2 Diabetes Mellitus. *Can J Diabetes*. 2018;42(5):470–477.e2. doi:10.1016/j.jcjd.2017.11.003

27. Ruszkiewicz K, Jagielski P, Traczyk I. Glycemic control and awareness among diabetic patients of nutrition recommendations in diabetes. *Rocz Panstw Zakl Hig*. 2020;71(2):191–196. doi:10.32394/rpzh.2020.0116
28. Xie Z, Liu K, Or C, Chen J, Yan M, Wang H. An examination of the socio-demographic correlates of patient adherence to self-management behaviors and the mediating roles of health attitudes and self-efficacy among patients with coexisting type 2 diabetes and hypertension. *BMC Public Health*. 2020;20(1):1227. doi:10.1186/s12889-020-09274-4
29. McPherson ML, Smith SW, Powers A, Zuckerman IH. Association between diabetes patients' knowledge about medications and their blood glucose control. *Rese Soci Admini Pharm*. 2008;4(1):37–45. doi:10.1016/j.sapharm.2007.01.002
30. Sato M, Tamura Y, Someya Y, et al. Characteristics associated with elevated 1-h plasma glucose levels during a 75-g oral glucose tolerance test in non-obese Japanese men. *J Diabetes Investig*. 2020;11(6):1520–1523. doi:10.1111/jdi.13245
31. Habibi N, Mousa A, Tay CT, et al. Maternal metabolic factors and the association with gestational diabetes: a systematic review and meta-analysis. *Diabetes Metab Res Rev*. 2022;38(5):e3532. doi:10.1002/dmrr.3532
32. Shimoda H, Takahashi T. Perioperative management in a patient with type 1 diabetes mellitus who presented severe hypoglycemia during dental implant surgery: a case report. *BMC Oral Health*. 2018;18(1):204. doi:10.1186/s12903-018-0679-z
33. Cappon G, Vettoretti M, Sparacino G, Facchinetti A. Continuous Glucose Monitoring Sensors for Diabetes Management: a Review of Technologies and Applications. *Diabetes Metab J*. 2019;43(4):383–397. doi:10.4093/dmj.2019.0121
34. Yapanis M, James S, Craig ME, O'Neal D, Ekinci EI. Complications of Diabetes and Metrics of Glycemic Management Derived From Continuous Glucose Monitoring. *J Clin Endocrinol Metab*. 2022;107(6):e2221–e2236. doi:10.1210/clinem/dgac034
35. Trout KK, McCool WF, Homko CJ. Person-Centered Primary Care and Type 2 Diabetes: beyond Blood Glucose Control. *J Midwifery Womens Health*. 2019;64(3):312–323. doi:10.1111/jmwh.12973