Xu *et al. BMC Health Services Research* (2025) 25:618
https://doi.org/10.1186/s12913-025-12788-5

BMC Health Services Research

RESEARCH

Impact of digital integrated health platforms on diabetes management: evidence from Tianjin, China

Zhaoqi Xu[1], Xiaoyu Xi[1*] and Ennan Wang[2*]

Abstract

Objective Evaluate the impact of digital integrated health platforms on diabetes patients' health in Tianjin.

Method Analyzed data from 2,883 patients under Tianjin's digital integrated health platform using descriptive statistics and Probit regression.

Results Chronic disease management significantly reduced fasting glucose by 1.68%, postprandial glucose by 3.4%, and HbA1c by 0.45%. High-compliance patients experienced greater reductions, including a 5.55% decrease in fasting glucose.

Conclusion Digital health platforms effectively improve glycemic control, especially with high patient compliance, supporting their broader implementation in chronic disease management.

Keywords Digital health platform, Chronic disease management, Diabetes patients

Introduction

In the context of deepening the reform of the medical and health system, China places significant emphasis on developing medical alliances and actively explores diverse operational models for medical alliances nationwide. In 2021, China introduced a new policy focused on prioritizing public health. This initiative goes beyond traditional medical "treatment" services and extends to providing comprehensive health management services. In this context, the concept of "integrated health" emerged. "Integrated health", as an innovative form of medical consortium, aims to provide comprehensive health services for residents through collaborative cooperation among medical institutions. It includes family doctors, pharmaceutical services, specialized disease management and referral services. This effectively promotes the hierarchical diagnosis and treatment system and meets the growing public health demands.

Since the onset of the COVID-19 in 2020, people's daily lives have been significantly impacted. To mitigate the transmission of the virus, individuals have had to impose travel restrictions and minimize their outings. During this period, digital integrated health founded on health principles harnessed the benefits of internet platforms to efficiently facilitate epidemic prevention and control efforts. Residents can conduct self-assessment, health training, information sharing, contact tracing, and decision support at home, thereby enabling a swift and effective response to the COVID-19 pandemic. Numerous successful global instances

*Correspondence:
Xiaoyu Xi
cpuxixiaoyu@163.com
Ennan Wang
wen@njmu.edu.cn
[1]School of International Pharmaceutical Business, China Pharmaceutical University, 639 Longmian Avenue, Nanjing, Jiangsu, China
[2]School of Health Policy & Management, Nanjing Medical University, 101 Longmian Avenue, Nanjing, Jiangsu, China

substantiate the efficacy of digital health communities, such as the "Maladie Coronavirus" platform in France, which provides symptom checking and self-management services; and the "safe in COVID-19" digital platform in Greece that records healthcare data and facilitates doctor-patient communication [1]. These examples demonstrate the successful implementation of digital integrated health on a global scale.

The Chinese government has also acknowledged the significance of digital integrated healthcare platforms and has implemented multiple policies to fully utilize the medical service management function of internet medical platforms during the epidemic. For instance, the Tianjin government has enhanced the development of integrated health through digital management and has promoted digitalization of primary healthcare facilities. By integrating chronic disease management, pharmacy management, and tiered medical services through digital platforms, Tianjin government aims to optimize medical resource allocation and establish an efficient health maintenance system centered on people's health gradually. In this context, Sanming City in Fujian Province, China, has pioneered the establishment of a citywide hospital internet digital service platform and a remote medical service network with the technical support of WeDoctor company. This innovation promoted the coverage of high-quality medical resources to primary medical institutions effectively. Furthermore, Shanghai, Zhenjiang, and Wuhan, among other cities have implemented payment reform centered on medical alliances, which not only improved the efficiency of medical insurance funds but also guided residents to make rational healthcare choices.

In recent years, the increasing prevalence of chronic diseases has presented significant challenges to China's healthcare service system, particularly regarding the capacity of primary healthcare institutions to manage these conditions [2, 3]. In the process of establishing a digital integrated health community in Tianjin, the city has proactively implemented a health responsibility framework for chronic disease management based on a 'Pay-For-Performance' model within medical insurance, thereby providing comprehensive health management services for patients with diabetes and other chronic illnesses. While there have been studies examining the health impacts of community-based health management on diabetes patients, empirical verification remains limited, and few investigations have integrated internet technologies into diabetes management strategies. Along with the increasing global prevalence of chronic conditions such as diabetes and hypertension, and digital health platforms are evolving to provide more personalized, continuous care [4, 5]. The integration of advanced technologies like telemedicine, AI-powered health analytics, and real-time remote monitoring, which will transform chronic disease management in the future [6]. Considering that, it is essential to carry out the study on the effectiveness of digital health platform for chronic disease management. This paper aims to assess whether the digital integrated health community can effectively enhance residents' health outcomes and identify its influencing factors. Specifically, our key contributions are threefold compared with previous studies: First of all, this research has substantial first-hand data through in-depth analysis of the empirical data on the construction of digital integrated health in Tianjin. Unlike studies based on literature reviews or qualitative analysis, this research examined the effectiveness of digital integrated health models, especially for improving the health of diabetes patients, using quantitative indicators. The use of real-world data demonstrates the efficacy of digital integrated health and addresses a gap in current research regarding the empirical assessment of internet integration in chronic disease management within China. Secondly, this study emphasized the impact of patient compliance on management outcomes, showing significant effects on blood glucose control and hemoglobin A1c improvement in highly adherent patients. This provides critical insights for the advancement of strategies aimed at managing chronic diseases in future contexts. Furthermore, this paper also highlights China's leading experience in digital healthcare management, which provides a reference for global digital healthcare transformation. Finally, this paper combines empirical data and qualitative observations to provide a comprehensive analytical perspective, enhancing the practical application value of the study, especially in the areas of precision intervention in chronic disease management and optimizing medical resources allocation. To address these questions preliminarily, this study evaluates both the establishment and developmental effects of the digital health community model in Tianjin.

The rest of the paper proceeds as follows. "Literature review and hypothesis formulation" section presents the theoretical framework for the impact of social medical insurance on health shock and consumption downgrading. "Data and methodology" section describes the data and empirical strategy for identifying the impact of social medical insurance. "Results" section contains my main estimates results, robustness test and interaction effect and heterogeneity analysis results. In "Discussion" section, we conclude with a discussion of policy implications.

Literature review and hypothesis formulation

Based on digital platforms, the digital integrated health mainly provides home healthcare services and chronic disease management services currently. Of these, chronic disease management services are mainly targeted at diabetes, hypertension, coronary heart disease, and cerebral infarction patients, with a focus on building chronic disease management centers. Based on the family doctor responsibility system, the digital integrated health aims to promote the health of residents by providing standardized "prevention, diagnosis, treatment, management, and health maintenance" services for patients with chronic diseases. For example, the chronic disease management center provides health management services for diabetes patients, including establishing personal electronic health records, pre-consultation guidance, complication prevention and education on blood sugar control, consultation services, prescription of healthy lifestyle, screening for complications, and guidance on diet, exercise, and lifestyle management, as well as providing online management services at home.

Since the inception of the Digital Health Community, Tianjin has formalized agreements with 267 primary healthcare facilities across 16 districts, progressively establishing chronic disease management centers and enrolling patients with chronic conditions. In recent years, the integrated health model has been widely regarded as a revolutionary approach to medical services, which emphasizes coordination among different medical institutions. Many studies have used research methods such as literature reviews and Delphi method to conduct in-depth analyses of integrated health [7, 8]. For example, a qualitative study has been conducted to explore stakeholders' perspectives on integrated care models, disclosing potential facilitators of healthcare integration and potential impediments to its development [7]. There has also been quantitative study that utilized meta-analysis to evaluate the efficacy of healthcare integration in improving healthcare quality, accessibility, and patient satisfaction [9]. Ding Liang et al. carried out a qualitative research study utilizing semi-structured interviews, revealing that integrated health can enhance both the quality and efficiency of healthcare services [10]. Rocks et al. concluded through a meta-analysis that the establishment of integrated healthcare can significantly reduce costs and enhance patient outcomes in studies conducted over a duration exceeding 12 months [11]. This conclusion aligns with findings from prior research focused on the management of individual chronic diseases [12–14]. Moreover, a substantial body of research suggests that the interdisciplinary collaboration and technology integration have emerged as pivotal determinants for the successful integrated health program [15–18].

In the process of health management for diabetes, the integrated healthcare emphasizes forming a comprehensive system that integrates primary, hospital, and community healthcare services to ensure the availability of optimal healthcare options for patients [19]. This model underscores the importance of among healthcare professionals, including doctors, nurses, nutritionists, social workers, and pharmacists, thus forming a coherent and complete medical service [20]. The key components include personalized care plans, proactive monitoring, and patient education. Meanwhile, using digital health technologies such as electronic health records and remote healthcare services plays a crucial role in promoting communication and ensuring continuity of health care [21–23]. This comprehensive approach not only improved blood sugar control and reduced complications, but also increased patients' satisfaction with diabetes management, enhanced self-efficacy, and showed the potential of integrated healthcare in advancing the standard of care for chronic diseases.

Based on the results of earlier research, the hypothesis is formulated:

H1: Participation in digital integrated health platforms significantly reduces blood glucose and HbA1c levels in diabetes patients.

Data and methodology

Data sources

The data for this study were collected from diabetes patients who participated in the chronic disease management program under Tianjin's digital integrated health platform. The sample includes 2,883 patients who had continuous blood glucose records available from March to November 2021.

The data were obtained from primary healthcare institutions participating in the digital health platform, specifically from home doctor visits and management prescriptions. These records include variables such as fasting blood glucose (Glu_fbg), postprandial blood glucose (Glu_pbg), glycosylated hemoglobin (HbA1c), body mass index (BMI), patient compliance (cpl), high blood pressure (hbp), in management (mng), and other demographic details.

Missing values were identified and removed. Any patient records with incomplete or inconsistent data, such as missing glucose or HbA1c measurements, were excluded from the analysis. Data consistency checks were performed to ensure that the blood glucose levels fell within reasonable ranges (e.g., fasting blood glucose values above 18.0 mmol/L were flagged and reviewed). We also ensured that all variables, including patient compliance and health management status, were coded consistently. The criteria for high compliance were as follows: (1) The patient received out-of-hospital management from a healthcare practitioner; (2) Blood glucose can be tested at least once a month. Table 1 shows the descriptive statistics of the main variables.

Here is the explanation of some variables. First, the glucose variable includes data from other time periods, where other time periods refer to blood sugar levels measured at night, before bedtime, before lunch, before

Table 1 Descriptive statistics of main variables

Variable name	Variable meaning and classification		Average	Variance	Min	Max
age	age		65.10	8.90	24	92
Glu	Blood glucose (unit: mmol/L)	fbg	7.09	1.27	3.8	18.32
		pbg	9.95	2.92	4.3	25
		Other time	8.99	3.89	4	24
HbA1c	HbA1c (unit: %)		7.09	1.20	4.7	12.8
BMI	BMI = Weight/height^2		25.57	2.91	15.2	35
gender	Gender: 1=male; 0=female		N (male) =1419; N (female) =1464			
hbp	Hypertension: 1=yes, 0=no		N (yes) =1857; N (no) =1026			
mng	In management center: 1=yes, 0=no		N (yes) =1670; N (no) =1213			
cpl	High compliance: 1=yes, 0=no		N (yes) =411; N (no) =2472			

dinner, and at random times. They can basically represent the daily blood sugar levels of the patient. Second, although all diabetes patients who visited the primary medical institutions providing chronic disease management services were included in the study, the study was conducted on a voluntary basis, and not all patients signed up for chronic disease management. Therefore, the sample includes non-management people, and the ratio of the number of management people is basically 1.38:1. It is expected that two groups can be compared and analyzed to explore the effect of diabetes management under digital integrated healthcare. Third, even if the chronic diabetes management service is included, if the patient's compliance is poor, the management effect may be limited. As a result, this study establishes compliance metrics tailored to the project's specific circumstances. If the patient follows the health manager's out-of-hospital management and cooperates with at least one blood glucose monitoring per month, they are considered to be compliant, otherwise they are considered poorly compliant. There are 24.61% people with high compliance among the managed population.

According to the descriptive results shown in Table 1, the diabetes patients included in the sub-level digital integrated healthcare in Tianjin are mostly elderly people, with a balanced gender ratio. In terms of blood pressure indicators, the ratio of hypertensive patients to non-hypertensive patients was found to be 1.81:1. In terms of blood sugar levels, as all the samples were from diabetes patients, the average blood sugar levels were higher than the upper limit of the normal range for both fasting and post-meal periods (fasting: 6.1 mmol/L; one hour after meal: 9.4 mmol/L). Based on the data of glycated hemoglobin, the reasonable control target for diabetes patients is HbA1c < 7.0%, while the average value of the sample indicators in this study is 7.09%, and HbA1c is also higher than the standard value. According to the BMI index, the sample diabetes patients have a higher BMI and are overweight.

Measurement model

In order to further accurately analyze the impact of chronic disease management on patients' health levels, this study selects the control of blood sugar for diabetes patients as the dependent variable, and measures the improvement of patients' health status. All analyses were conducted using Stata/MP 17.0.

Given that blood glucose levels vary among patients at different times, including fasting, post-meal, and other times, and measurement standards differ, this study classifies patients into the following three categories based on the Digital Integrated Health clinical management standards (blood glucose measurement results at different times: First, red-flag patients, i.e. those with more severe diabetes, with fasting blood glucose of ≥10mmol/L or postprandial blood glucose of > 13.9mmol/L after a meal; second, green-flag patients, i.e. those with mild diabetes indicators, when the patient is under 65 years old, with random blood glucose < 7.0mmol/L or postprandial blood glucose < 10.0mmol/L, and when the patient is equal to or above 65 years old, with fasting or pre-meal blood glucose < 8.3mmol/L; the third situation is yellow flag, i.e. patients with medium diabetes indicators between red flag and green flag patients. After dividing the patients into three categories according to the above criteria, we established a variable $indicator_i$ to measure the improvement in the health status of diabetes patients. If the severity of the patient's diabetes improves, changing from red to yellow, or yellow to green, or red to green, then $indicator_i$=1, indicating a downgrade, otherwise $indicator_i$=0. For the study, we choose the Probit model for econometric analysis. The Probit model was selected because the dependent variable, representing improvement in diabetes management (e.g., reduction in blood glucose or HbA1c levels), is binary (indicating whether a patient has shown improvement or not). The Probit model is well-suited for binary outcomes as it models the probability of a discrete outcome based on explanatory variables, allowing us to estimate the likelihood of health improvements as a function of patient characteristics and management participation. Though Probit models can require more computational resources, especially with large datasets and many variables, this is generally manageable.

The Probit model is shown in Eq. (1).

$$indicator_i = \beta_0 + \beta_1 mng_i + \beta_2 X_i + u_i \quad (1)$$

In this model, mng_i is the core explanatory variable, representing whether the patient participates in diabetes chronic disease management. X_i represents control variables, including the patient's age, gender, BMI index, and whether they have hypertension, and *ui* is the disturbance term.

Compared to the immediate blood glucose concentration, glycated hemoglobin can reflect the degree of blood glucose control in patients over a period of 8–12 weeks, so in the robustness test of this article, although the same classification method was used to divide patients into three categories, the glycated hemoglobin concentration was used to measure the degree of control: patients with glycated hemoglobin concentration of 9% or above are red flag patients; patients under the age of 65 with glycated hemoglobin of less than 7% or patients aged 65 or above with glycated hemoglobin of less than 8.0% are green flag patients; those between the two are yellow flag patients.

Furtherly, the average marginal effect (AME) is calculated to quantify the actual impact of management involvement on the probability of downgrade. The AME is calculated as shown in Eq. (2).

$$AME = \frac{1}{N}\sum_{i=1}^{N}\beta_1 \cdot (\beta_0 + \beta_1 mng_i + \beta_2 X_i + \mu_i) \quad (2)$$

This method accounts for the distribution of covariates across all observations.

In addition, studies on patient compliance were included. The judgment criteria of compliance are: High compliance was defined as patients receiving both in-hospital and out-of-hospital management by health care professionals and being able to perform blood glucose testing at least once a month (cpl = 1). Otherwise, it is low (cpl = 0). Similar to the aforementioned measurement model, Probit model is chosen for measurement analysis, as shown in Eq. (3).

$$indicator_i = \beta_0 + \beta_1 cpl_i + \beta_2 X_i + u_i \quad (3)$$

In this model, cpl_i is the core explanatory variable, representing the patient's level of adherence, X_i represents control variables, including the patient's age, gender, BMI index, whether they have hypertension, and u_i is the disturbance term.

Results

Descriptive results

This study focuses on the establishment of digital integrated health, particularly whether a chronic disease management project can improve residents' health levels. First, we observed the changes in blood sugar levels of the enrolled patients before and after receiving chronic disease management, as shown in the first four rows of Table 2. The data shows that chronic disease management led to a reduction in both blood glucose and HbA1c levels across the study population. Specifically, fasting blood glucose (Glu_fbg) decreased by 1.68%, postprandial glucose (Glu_pbg) decreased by 3.40%, and HbA1c levels decreased by 0.45%. Patients with higher compliance experienced even greater reductions, such as a 5.55% reduction in fasting blood glucose and a 5.20% reduction in postprandial glucose. In addition to the blood glucose value, the concentration of glycated glucose protein in patients after management was also lower than that before management, indicating that chronic disease management has a better control effect on blood glucose in patients. Furthermore, this study categorizes the population based on compliance levels. It examines the differences in blood glucose and glycosylated

Table 2 Changes in blood sugar of different compliance groups in the management population

Sample population	Variable	Number of populations	Beginning (at enrollment)	Results (after management)	Change (%)
People in management	Glu_ fbg	1261	7.311	7.188	-1.68
	Glu_pbg	606	10.09	9.747	-3.40
	Glu_othertime	82	8.549	8.398	-1.77
	HbA1c	538	7.136	7.104	-0.45
High compliance	Glu_fbg	359	7.437	7.024	-5.55
	Glu_pbg	236	10.11	9.584	-5.20
	Glu_othertime	38	8.747	8.366	-4.36
	HbA1c	184	7.174	7.136	-0.53
Low compliance	Glu_fbg	902	7.261	7.253	-0.11
	Glu_pbg	370	10.09	9.850	-2.38
	Glu_othertime	44	8.377	8.425	0.57
	HbA1c	354	7.116	7.087	-0.41

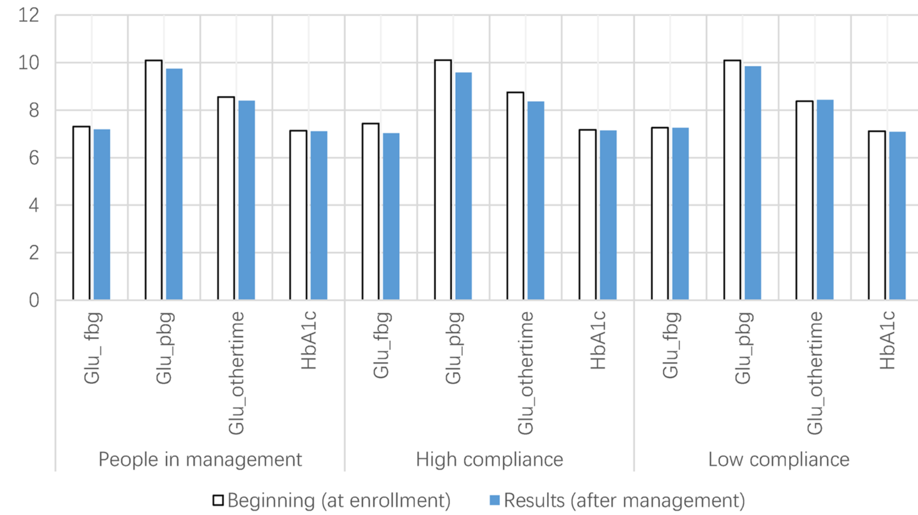

Fig. 1 Changes in blood glucose values in different managed populations

Table 3 Effects of management of chronic diseases on diabetic patients

	Benchmark regression (Probit)		Robust test (Probit)	
	indicator	*indicator*	*indicator*	*indicator*
mng	0.152**	0.140**	0.282*	0.296*
	(0.068)	(0.071)	(0.163)	(0.173)
age		0.025		-0.114**
		(0.031)		(0.051)
age2		-0.000		0.001*
		(0.000)		(0.000)
gender		-0.098		-0.140
		(0.067)		(0.163)
bmi		0.011		-0.024
		(0.012)		(0.027)
hbp		-0.110		-0.004
		(0.071)		(0.168)
_cons	-1.603***	-2.221**	-2.349***	2.510
	(0.116)	(1.013)	(0.277)	(1.657)
N	2883	2883	1054	1054

Standard deviations are in parentheses. *, **, *** indicate statistical significance at the 10%, 5%, and 1% confidence levels, respectively. Age2: Squared term of age to test non-linear age effects

hemoglobin concentrations between patients exhibiting high compliance and those demonstrating low compliance, as illustrated in the final eight rows of Table 2. The findings indicate that patients exhibiting high compliance experienced a more significant reduction in blood glucose levels and HbA1c concentrations compared to both the overall cohort of patients undergoing chronic disease management and the subgroup of patients with low compliance.

Figure 1 provides a more vivid and intuitive description of the changes in blood glucose and glycated hemoglobin concentration before and after enrollment in the population management program. Consistent with the conclusions drawn from Table 2, both suggest that the blood glucose levels of diabetic patients participating in the chronic disease management program were effectively controlled, with particularly significant improvements in the health status of those with high compliance. By emphasizing the practical significance of the results, we highlight how even modest statistical improvements in glycemic control can lead to meaningful health outcomes for diabetes patients.

Baseline regression results

The first two of Table 3 are the results of whether to participate in chronic disease management on the blood glucose concentration of diabetic patients. The first column included results without controlling variables, and the second column included results with controlling variables such as age, sex, and the patient's physical and

Table 4 Patient compliance's impact on diabetes patients' health in chronic disease specialized management

	Probit	
	indicator	*indicator*
cpl	0.296***	0.298***
	(0.092)	(0.092)
age		0.018
		(0.045)
age2		-0.000
		(0.000)
gender		-0.111
		(0.084)
bmi		0.012
		(0.015)
hbp		-0.091
		(0.094)
_cons	-1.679***	-2.225
	(0.128)	(1.436)
N	1670	1670

***Indicates statistical significance at the 1% confidence level

related disease characteristics. According to the results, participation in chronic disease management has a significant positive impact on diabetic patients reaching the standard, and effectively reduces the blood glucose concentration of diabetic patients. According to the marginal effect calculated from the results in the second column, it can be seen that the probability of achieving blood glucose reduction for participants in chronic disease management increases by 2.2%, and this result is significant at the 5% confidence level.

In order to further verify the robustness of the above results, we classify then according to HbA1c levels, and obtained the results shown in the last two columns of Table 3 after regression. Similarly, the first and second columns are the results of whether or not other control variables are added. According to the results, the inclusion of chronic disease management still has a significant positive impact on the standard reduction of patients, indicating that the inclusion of chronic disease management program can significantly improve the disease severity of diabetes patients. According to the marginal effect calculated by the measurement results after adding control variables, patients who participated in chronic disease management had a 1.8% increased probability of improving their HbA1c levels compared with patients who did not participate in chronic disease management, which is significant at a 10% confidence level. The result is consistent with the baseline regression result, which indicates that the basic conclusion of this paper has a certain robustness.

Analysis of influence factors

The analysis presented above indicates that involvement in chronic disease management programs can significantly enhance blood sugar control among individuals with diabetes. However, according to the clinical practice of doctors, although patients choose to participate in chronic disease management, their compliance varies. To further investigate the influence of patients' clinical compliance on outcomes, this article undertakes a more comprehensive analysis of the sample of patients engaged in chronic disease management. With compliance as the core explanatory variable, this study explores the impact of patient adherence on their blood glucose control.

The results are shown in Table 4. According to the results, patient compliance also has a significant positive impact on the descending index. Even if the patients also participate in chronic disease management, patients with strong compliance have a higher probability of reduction. According to the marginal effects calculated from the second column, the probability of downgrading is increased by 5.1% for patients with high compliance compared to those with low compliance, and this result is statistically significant at a confidence level of 1%.

Discussion

This study analyzed the health management data of diabetic patients in the grassroots digital integrated health empirically to explore the impact of the chronic disease management project on their health status and the role of patient compliance in health management. The findings of the study suggest that the management of chronic diseases within digital integrated health significantly enhances patients' blood glucose control, particularly among those exhibiting high levels of compliance.

The findings indicate that engagement in chronic disease management programs can substantially reduce blood glucose levels among diabetic patients, highlighting the beneficial impact of digital integrated health on health management. Both descriptive statistical analysis and Probit regression modeling reveal that participation in chronic disease management significantly reduces patients' fasting, postprandial, and other time-point blood glucose levels, as well as their hemoglobin A1c concentrations. The benchmark regression results indicate that chronic disease management can significantly increase the probability of achieving target values for patients, approximately 2.2%, which is statistically significant at a 5% confidence level.

These results reflect the effectiveness of systemized management services provided by primary healthcare institutions in digital integrated health in improving the health outcomes of diabetes patients. This aligns with the findings of prior research, which have demonstrated that community-based chronic disease management programs can significantly reduce blood glucose levels, blood pressure, cholesterol levels, and weight while enhancing patients' overall quality of life [24–26]. The core of chronic disease management is long-term, continuous health monitoring and intervention, and digital integrated health can provide integrated management models, enabling patients to benefit from more continuous and comprehensive health management services.

In addition, in order to verify the robustness of the study results, the index of glycosylated hemoglobin (HbA1c) was used as a surrogate variable for further analysis. Robustness tests indicate that even when using glycated hemoglobin concentration as a standard, participation in chronic disease management still has a significant positive impact on patients' health improvement. The regression results show that participating in chronic disease management can increase the probability of achieving the target by 1.8%, which is statistically significant at a 10% confidence level and consistent with the benchmark regression results.

The results of robustness test further support the conclusion of this paper on the effectiveness of chronic disease management in improving the long-term health status of patients. Since HbA1c can reflect a patient's average blood sugar level over the past 2–3 months, it is a key indicator of long-term blood sugar control and more representative of the lasting effects of chronic disease management. Therefore, the significance of the robustness analysis results reaffirms the potential role of digital health in long-term health management.

Further analysis in this study revealed the critical role of patient compliance in chronic disease management. The results showed that even if the patients participated in chronic disease management program, the level of their compliance greatly affected the health management effect. As shown in Table 2; Fig. 1, fasting, postprandial and other periods of blood glucose reduction and the improvement of HbA1c concentration in patients with high compliance were significantly higher than those in patients with low compliance. This was further validated by Probit model analysis, with the results in Table 4 showing a 5.1% increase in the probability of downscaling in patients with high adherence compared to those with low adherence, which was significant at the 1% confidence level.

These results indicate that improving patient compliance is a key factor in ensuring the effectiveness of chronic disease management programs. Highly compliant patients are more likely to actively cooperate in the management program, follow medical advice for regular monitoring and treatment, and achieve better glycemic control outcomes. This finding is consistent with previous research, which indicates that patient compliance is one of the key factors affecting the effectiveness of chronic disease management [23, 27]. Patients with low compliance may not be able to receive health management according to the plan, leading to poor management outcomes. Therefore, the role of compliance in chronic disease management cannot be ignored.

In the regression model, this study introduced several control variables (such as age, gender, BMI, hypertension, etc.) to control for other factors that may affect the effectiveness of health management. Although these variables did not have a decisive impact on the main conclusions, their role is still worth paying attention to. The study found that the effect of age on the outcome was complex, which may reflect the fact that as patients age, their metabolic levels, physical function, and response to health management may change. In addition, the regression coefficients of BMI and hypertension variables were not statistically significant, but in the context of chronic disease management, these factors' potential impact on individual health status still has reference value.

The findings of this study provide empirical support for the application of digital integrated health in chronic disease management. The study shows that through systematic management at the primary healthcare level, patients can effectively control their blood sugar levels and improve their overall health status. Firstly, they enable real-time, continuous monitoring, allowing healthcare providers to track patient progress and intervene promptly. Secondly, the platforms offer personalized care, providing tailored advice on diet, exercise, and medication, which is difficult to achieve in traditional settings. Lastly, digital platforms enhance patient engagement through tools that boost compliance, which is critical for improving health outcomes. Regarding the differences in outcomes between patients enrolled in management and those not enrolled, our study found that patient compliance plays a significant role. Patients with higher compliance showed significantly better blood glucose control and HbA1c improvement. Overall, the research findings emphasize the positive role of the comprehensive management model of digital integrated health in chronic disease management, and also provide strong evidence for further improving chronic disease management efficiency and achieving optimal allocation of medical resources.

Strength and limitations

The strength of this study lies in using real health data, especially glucose monitoring data of diabetes patients, which makes the results more credible and has realistic reference value. The study delves into the impact of patient adherence on the effectiveness of chronic disease management and reveals the significant effects of high adherence patients in controlling blood sugar and improving HbA1c. This provides specific guidance for optimizing future chronic disease management. Additionally, the study analyzes the actual operational effects of digital medical platforms in the context of Chinese policy, which has both academic and practical reference value. Finally, the flexibility and adaptability of the digital integrated health during the pandemic ensured the continuity of basic medical services and demonstrated its important role in public health crises.

However, although this study demonstrates many advantages of the digital integrated health in chronic disease management, there are still some limitations. First of all, the improvement of low-adherence patients in the management program was small, indicating that how to motivate and support low-adherence patients during the promotion of the digital integrated health is a key issue to be addressed in the future. Possible measures include enhancing patients' health awareness, improving the level of personalized services, and providing more health incentives to promote their active participation in health management. Secondly, this study is based on data from Tianjin, a city with relatively advanced healthcare infrastructure and digital health adoption. However, this setting may not fully represent regions with different levels of economic development, healthcare accessibility, or digital integration. For example, rural areas or economically disadvantaged regions may face barriers such as lower internet penetration, limited digital literacy, and insufficient healthcare staffing, which could impact the effectiveness of digital health interventions. Future research should validate our findings in regions with varying healthcare capacities, such as smaller cities, rural areas, or provinces with different health policies, to examine whether similar health improvements can be achieved. In addition, future research can further explore the long-term health effects of the digital integrated health and its impact on the cost-effectiveness of the medical system through more rigorous research designs such as randomized controlled trials. In addition, the study design was an observational study, and the interference of confounding factors cannot be completely excluded. Future studies can consider using randomized controlled trials to further verify the findings of this study.

Conclusion

In conclusion, this study illustrates the efficacy of digital integrated health in managing chronic diabetes, particularly in enhancing patients' glycemic control and optimizing healthcare services. Patients with high compliance derive greater benefits from these digital platforms, underscoring that active engagement and adherence are critical factors for the successful implementation of chronic disease management.

To improve patient compliance and optimize digital health management, we propose enhancing patient education through digital platforms for personalized health information, reminders, and public awareness campaigns to emphasize the importance of disease management. Expanding access to digital health services by improving internet and mobile connectivity, especially in underserved areas, will ensure equitable access. Finally, strengthening primary care integration by equipping healthcare providers with digital tools and training will improve coordination and continuity of care, leading to better health outcomes.

Acknowledgements
Not applicable.

Authors' contributions
Zhaoqi Xu: Conceptualization, Methodology, Investigation, Writing manuscript text. Xiaoyu Xi: Supervision. Ennan Wang: Investigation, Validation, Writing—Review and editing. All authors approved the final version of the manuscript.

Funding
This study was supported by National Science Foundation of China (Grant Number: 72404141), the Ministry of education of Humanities and Social Science Project (Grant Number: 23YJCZH204) and the Philosophy and Social Science Project for the University by Jiangsu Education Department (Grant Number: 2023SJYB0297).

Data availability
The data and materials used in this research will be made available upon reasonable request to the corresponding author. The data will be provided in a de-identified format to protect the privacy of the participants.

Declarations

Ethics approval and consent to participate
The research design was reviewed and approved by the Ethics Committee of Nanjing Medical University, Nanjing city, Jiangsu Province, China. Project Number: NMU(2024)12. All methods were carried out in accordance with the Declaration of Helsinki and relevant national and institutional guidelines. In strict adherence to the principle of informed consent, all data were collected anonymously after obtaining the permission and informed consent signed by respondents.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Received: 18 December 2024 / Accepted: 22 April 2025
Published online: 29 April 2025

References

1. Kouroubali A, Kondylakis H, Katehakis DG. Integrated care in the era of COVID-19: turning vision into reality with digital health. Front Digit Health. 2021;3:647938.
2. Ke XT, Wang CL, Salmon JW, Tang WX. Unmet needs as indicator of improving chronic care delivery system in China. Chronic Dis Transl Med. 2021;7(1):1–13.
3. Zhao S, Du R, He Y, He X, Jiang Y, Zhang X. Elements of chronic disease management service system: an empirical study from large hospitals in China. Sci Rep. 2022;12(1):5693.
4. Cancela J, Charlafti I, Colloud S, Wu C. In: Syed-Abdul S, Zhu X, Fernandez-Luque L, editors. Chapter 2 - Digital health in the era of personalized healthcare: opportunities and challenges for bringing research and patient care to a new level. Digital Health: Elsevier; 2021. pp. 7–31.
5. Ong KL, Stafford LK, McLaughlin SA, Boyko EJ, Vollset SE, Smith AE, et al. Global, regional, and National burden of diabetes from 1990 to 2021, with projections of prevalence to 2050: a systematic analysis for the global burden of disease study 2021. Lancet. 2023;402(10397):203–34.

6. Chatterjee JM, Sujatha R. Transforming healthcare: the synergy of telemedicine, telehealth, and artificial intelligence. In: Chatterjee JM, Sujatha R, Saxena SK, editors. Role of artificial intelligence, telehealth, and telemedicine in medical virology. Singapore: Springer Nature Singapore; 2024. pp. 1–29.
7. Zonneveld N, Driessen N, Stüssgen RAJ, Minkman MMN. Values of integrated care: A systematic review. Int J Integr Care. 2018;18(4):9.
8. Barraclough F, Smith-Merry J, Stein V, Pit S. An international competency framework for High-Quality workforce development in integrated care (IC): A modified Delphi study among global participants. Int J Integr Care. 2024;24(2):11.
9. Baxter S, Johnson M, Chambers D, Sutton A, Goyder E, Booth A. The effects of integrated care: a systematic review of UK and international evidence. BMC Health Serv Res. 2018;18(1):350.
10. Liang D, Mei L, Chen Y, Zhou P, Yang X, Huang J. Building a People-Centred integrated care model in urban China: A qualitative study of the health reform in Luohu. Int J Integr Care. 2020;20(1):9.
11. Rocks S, Berntson D, Gil-Salmerón A, Kadu M, Ehrenberg N, Stein V, et al. Cost and effects of integrated care: a systematic literature review and meta-analysis. Eur J Health Econ. 2020;21(8):1211–21.
12. Neumeyer-Gromen A, Lampert T, Stark K, Kallischnigg G. Disease management programs for depression: a systematic review and meta-analysis of randomized controlled trials. Med Care. 2004;42(12):1211–21.
13. Krause DS. Economic effectiveness of disease management programs: a meta-analysis. Dis Manag. 2005;8(2):114–34.
14. Boland MR, Tsiachristas A, Kruis AL, Chavannes NH, Rutten-van Mölken MP. The health economic impact of disease management programs for COPD: a systematic literature review and meta-analysis. BMC Pulm Med. 2013;13:40.
15. Steele Gray C, Zonneveld N, Breton M, Wankah P, Shaw J, Anderson GM, et al. Comparing international models of integrated care: how can we learn across borders?? Int J Integr Care. 2020;20(1):14.
16. Looman W, Struckmann V, Köppen J, Baltaxe E, Czypionka T, Huic M, et al. Drivers of successful implementation of integrated care for multi-morbidity: mechanisms identified in 17 case studies from 8 European countries. Soc Sci Med. 2021;277:113728.
17. Lennox-Chhugani N. Inter-Disciplinary work in the context of integrated Care - a theoretical and methodological framework. Int J Integr Care. 2023;23(2):29.
18. Dobbins MI, Thomas SA, Melton SL, Lee S. Integrated care and the evolution of the multidisciplinary team. Prim Care. 2016;43(2):177–90.
19. Tan GD, Kozlowska O, Rea RD. Integrated care and diabetes: challenges, principles and opportunities. Clin Integr Care. 2021;4:100037.
20. Tan HQM, Chin YH, Ng CH, Liow Y, Devi MK, Khoo CM, et al. Multidisciplinary team approach to diabetes. An outlook on providers' and patients' perspectives. Prim Care Diabetes. 2020;14(5):545–51.
21. Robson N, Hosseinzadeh H. Impact of telehealth care among adults living with type 2 diabetes in primary care: a systematic review and Meta-Analysis of randomised controlled trials. Int J Environ Res Public Health. 2021;18(22):12171.
22. Patel V, Reed ME, Grant RW. Electronic health records and the evolution of diabetes care: a narrative review. J Diabetes Sci Technol. 2015;9(3):676–80.
23. Blonde L. Current challenges in diabetes management. Clin Cornerstone. 2005;7(Suppl 3):S6–17.
24. Zarora R, Immanuel J, Chivese T, MacMillan F, Simmons D. Effectiveness of integrated diabetes care interventions involving diabetes specialists working in primary and community care settings: A systematic review and Meta-Analysis. Int J Integr Care. 2022;22(2):11.
25. Levengood TW, Peng Y, Xiong KZ, Song Z, Elder R, Ali MK, et al. Team-Based care to improve diabetes management: A community guide Meta-analysis. Am J Prev Med. 2019;57(1):e17–26.
26. Jia W. Diabetes care in China: innovations and implications. J Diabetes Investig. 2022;13(11):1795–7.
27. Zhang W, Yang P, Wang H, Pan X, Wang Y. The effectiveness of a mHealth-based integrated hospital-community-home program for people with type 2 diabetes in transitional care: a protocol for a multicenter pragmatic randomized controlled trial. BMC Prim Care. 2022;23(1):196.

Publisher's Note