

Giving Voice to Low-Income Older Adults with T2DM: Design and Evaluation of the JTG Dietary Management System in a Carbohydrate-Centric Culture

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Abstract

Background: Dietary management is central to T2DM care, yet low-income older adults in northern China face cultural, economic, and literacy barriers. Digital tools rarely reflect carbohydrate-centric eating patterns or the usability needs of this population.

Objective: To design and evaluate Jintang Weishi (JTG), a culturally tailored dietary management system for low-income older adults with T2DM in Shanxi.

Methods: We conducted a 90-day randomized controlled trial (N=40; age ?55 years) in Shanxi, China, enrolling participants from low-income households, defined as monthly household income <¥3,000 for urban residents and <¥1,750 for rural residents. Participants were randomized to receive JTG plus standard care or standard care alone. Primary outcomes were diabetes knowledge (DKT), daily carbohydrate intake, and HbA1c, assessed at baseline, intervention completion, and follow-up. Usability was evaluated through a 10-item user survey. Randomization balanced baseline knowledge.

Results: The intervention group showed large gains in DKT (mean ?T2-T0=+9.3 vs +0.1 in controls; P<.001), substantial reductions in daily carbohydrate intake (–414.1 Kcal vs –13.2 Kcal; between-group difference –400.9 Kcal, 95% CI –506.4 to –295.4; t??=–7.45; P<.001), and a greater HbA1c decline (–1.18 percentage points from 8.02% to 6.84% vs –0.01 in controls; P<.001). Usability ratings indicated high acceptability among older users

Conclusions: In a setting where staple diets are carbohydrate-heavy and digital literacy varies, a culturally adapted, patient-centered system improved knowledge, diet, and short-term glycemic control. Future work should evaluate durability and mechanisms of change over longer follow-up and examine implementation pathways that integrate multidisciplinary support and community-based services to sustain engagement and scale impact

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Trial Registration: Not Applicable

Keywords: Type 2 diabetes mellitus; dietary management; carbohydrate intake; low-income older adults; digital health; cultural adaptation

1 Introduction

1.1 T2DM Risks and Care Barriers Among Shanxi's Elderly

Type 2 diabetes mellitus (T2DM) is a chronic metabolic disorder associated with insulin resistance and β -cell dysfunction, leading to sustained elevated blood glucose levels and potentially severe complications such as cardiovascular disease, kidney failure, and blindness [1,2,3]. In Shanxi Province, a 2013 cross-sectional study found that individuals adhering to a carbohydrate-rich diet, typical of the region's traditional eating habits, were significantly more likely to develop type 2 diabetes mellitus [4].

As a historical center of a northern wheat-based dietary pattern, Shanxi's elderly population tends to consume large amounts of carbohydrate-rich foods, primarily derived from wheat and other refined grains. This dietary habit has been associated with increased risk for metabolic disorders in northern Chinese populations [5], contributing to an increased risk of T2DM onset and progression. This dietary pattern is further compounded by limited health literacy and low awareness of diabetes and its early warning signs. As a result, delayed care-seeking is common in rural China. Over 60 percent of individuals living with diabetes report postponing diagnosis and treatment, often waiting until complications emerge before seeking medical attention [7-9]. Even after entering the healthcare system, older adults may encounter persistent barriers to effective disease management, including ineffective communication with healthcare providers, difficulty understanding clinical recommendations, and a lack of structured support for sustained self-management at home [10]. Together, excessive carbohydrate intake, low health literacy, and gaps in ongoing care create a critical management challenge for older adults with T2DM in Shanxi.

1.2 Culturally Tailored Digital Solutions for T2DM Care

Conventional methods of care often fall short of meeting the long-term needs of individuals with chronic conditions such as T2DM, particularly in rural regions where healthcare access is uneven and follow-up resources are limited [11,12].

Although consistent monitoring and adherence to diet and medication are essential for diabetes control [15], these goals are frequently undermined by sparse clinical follow-up, poor patient understanding, and deeply embedded cultural eating habits. As a result, adherence tends to be low, and glycemic control remains suboptimal.

National data indicate that only 47.7% of people who are diagnosed with T2DM in China achieve HbA1c levels below 7% [13], lagging those reported in high-income countries, such as Switzerland (68.6% with HbA1c <7%) [14].

In recent years, digital health technologies have presented new opportunities to support the long-term management of T2DM, particularly outside traditional clinic settings [16,17]. Mobile apps and wearable devices enable continuous blood glucose monitoring, provide personalized tips on diet and exercise, and send reminders for medication administration. These functions can help patients manage their condition in daily life, improve treatment consistency, and reduce glycemic variability [18,19]. However, most existing digital interventions for T2DM and other chronic diseases are developed based on Western populations and do not

adequately reflect the cultural, dietary, and healthcare contexts of users in China. Most existing digital interventions for T2DM and other chronic diseases are developed based on the clinical features, dietary patterns, and healthcare systems of Western populations. The recommended nutritional plans, typically low-fat and high fiber, often rely on Western food ingredients that do not align with the daily meals of Chinese patients [20]. Additionally, these tools often overlook traditional Chinese health beliefs, which are prevalent among older individuals. As a result, the adoption and long-term adherence remain low in regions such as Shanxi.

1.3 User-Centered Design of a Digital T2DM Intervention

To enhance diabetes self-management in this population, we conducted qualitative interviews with older adults diagnosed with T2DM in Shanxi, along with their family caregivers. The study aimed to address three research questions: (1) What do older adults understand about T2DM and the health risks associated with high carbohydrate diets? What beliefs or misconceptions shape their perceptions? (2) Among those who are aware of these risks and have attempted behavior change, what behavioral changes, particularly in dietary practices, have been attempted, and what barriers have they encountered? (3) Among those who have not made changes, what factors (e.g., cultural norms, daily constraints, financial limitations, or low motivation) influence their dietary behavior?

To address the challenges revealed in the study, we designed JTG, a digital health system for T2DM management that reflects the cultural and dietary practices of older adults in Shanxi. The system addresses the unique challenges faced by this population and integrates three core components to deliver structured, locally relevant support for long-term T2DM management: **(1) Health Education:** While many existing digital interventions overlook the unique needs of older adults [21,22], JTG provides accessible and relevant educational content to improve health literacy among older adults with T2DM in Shanxi. The app communicates the long-term health risks of excessive carbohydrate consumption, such as poor glycemic control and associated complications through easily understandable and culturally appropriate formats. By enhancing users' understanding of the link between diet and disease, JTG encourages proactive behavior change and supports more effective self-management. **(2) Culturally Tailored Management:** To support sustainable dietary changes, JTG goes beyond general education by aligning nutritional guidance with local eating practices. Prior research underscores the importance of culturally tailored interventions in improving diabetes outcomes across diverse populations [23]. In response, JTG provides localized modifications of traditional Shanxi cuisine, such as low-sugar, high-fiber adaptations of signature dishes like knife-cut noodles use affordable, widely available ingredients and align. The intervention promotes cultural relevance and clinical appropriateness, supporting sustainable behavior change. **(3) Support Through Conversational AI:** JTG features a conversational interface to enable real-time interaction with an AI-based health assistant. It offers personalized guidance on symptoms, diet, and medication using plain language and intuitive navigation suited for older adults with varying health literacy. This

function improves access to health information in underserved areas and supports more equitable, confident self-management of T2DM.

2 User Research

2.1 Objectives

This study aimed to identify key pain points related to disease awareness, self-management practices, and the acceptance of digital interventions among older adults in Shanxi, a demographic known for persistent dietary habits of carbohydrate-rich diet. The insights gained were used to inform the functional design and interaction optimization of the *Jintang Weishi* (JTG) application, ensuring that the intervention addresses the specific needs of this population and supports a human-centered approach to digital diabetes management.

2.2 Methods

2.2.1 Participant Recruitment Participants were enrolled through outreach on

Chinese social media platforms, including Xiaohongshu, WeChat, Bilibili, and Baidu Tieba. Eligibility screening required that participants be at least 55 years old, reside in Shanxi Province, have a diagnosis of T2DM or be at risk for developing diabetes, and report regular consumption of carbohydrate-dense foods. A total of 53

participants were included. Of these, 43 were confirmed T2DM cases based on ADA criteria (fasting plasma glucose ≥ 7.0 mmol/L or HbA1c $\geq 6.5\%$) [24], while 10 met prediabetic risk criteria with comparable dietary behaviors.

The sample included 30 men and 23 women, aged 59 to 78 years (mean 68.35 years, SD 7.24). Among them, 24 participants resided in urban communities and 29 in rural areas. Regarding education level, 1 participant had college-level education or higher, 1 had completed high school or technical secondary school, 22 had junior high school education, 19 had completed primary school, and 10 were illiterate. The duration of T2DM ranged from 2 to 34 years, with a mean duration of 8.1 years.

These characteristics contributed to a broadly representative sample.

Interview Protocol Semi-structured interviews were conducted by a multidisciplinary research team with background in medicine, anthropology, sociology, and design to obtain a comprehensive understanding of diabetes management among older adults in Shanxi Province. To ensure cultural relevance and participant comfort, interviews were conducted in each participant's native language (Mandarin or Jin Chinese) and lasted approximately 45 to 60 minutes. At the beginning of each interview, participants were asked whether they understood the importance of dietary control in the prognosis and recovery of T2DM.

Interviewers then explored participants' awareness of the concept of carbohydrate - rich diets, whether they had long-standing habits of excessive carbohydrate consumption, whether they had attempted to adjust their diet in response to their T2DM diagnosis, and what specific challenges they encountered in managing a healthier diet.

2.3 Findings

2.31 Health Literacy Gaps Related to T2DM The interviews revealed significant deficiencies in health literacy among older adults in Shanxi with T2DM or prediabetic tendencies, particularly regarding the risks associated with high carbohydrate diet which reflect the region's traditional diet. For example, 29 participants (54.71%) had a vague understanding of the disease's underlying mechanisms, and 33 (62.26%) lacked basic awareness of the implications of a high - carbohydrate diet. Only 3 participants could accurately mention core pathophysiological factors such as insulin resistance or β -cell dysfunction. More than half attributed T2DM merely to "high blood sugar" or excessive intake of overtly sweet foods such as milk tea, soda, and fruit. In contrast, 45 participants expressed little to no concern about the impact of traditional Shanxi staples such as hand pulled noodles, dalu noodles, and dandan noodles (刀削面, 刀切面, 刀拉面) on blood glucose levels, despite their role as dietary staples and their high carbohydrate content with sustained glycemic effects. This lack of awareness was particularly significant in rural participants. Among the 29 rural residents interviewed, only 7 could correctly identify the underlying causes of T2DM or recognize the importance of dietary management. Moreover, 17 rural participants reported relying on local folk remedies, such as physically striking the body to combat dizziness to cope with T2DM symptoms. This finding further underscoring the need for targeted health education in underserved communities.

2.32 Self-Management Challenges Among the 53 interviewees, 24 (45.3%) expressed a clear personal intention to reduce their intake of high-carbohydrate foods, while the remaining participants primarily followed externally guided dietary plans. For those attempting self-regulated carbohydrate reduction, six key challenges were identified (Table 1).

The most reported challenge was a limited understanding of high-carbohydrate foods, cited by 22 participants (41.5%). Many equated "carbohydrates" solely with sugar, assuming that using sugar substitutes or avoiding desserts was sufficient (e.g., participants 2, 3, 4, 7, 21). Awareness of hidden sugars—such as fructose syrup in baked goods or added sugars in sauces—was notably low (e.g., participants 2, 4, 7, 11, 13), often resulting in misinformed food choices.

The second most frequent issue was the influence of traditional dietary habits of, reported by 19 participants (35.8%). In Shanxi Province, longstanding cultural norms strongly favor the consumption of carbohydrate-rich foods. 16 participants expressed psychological dependence on noodle-based meals and reluctant to reduce their intake. As one interviewee stated, "I've enjoyed eating noodles all my life. If I can't eat them anymore, what's the point of living?" shows the emotional and cultural depth of this dietary attachment.

Financial constraints further hindered dietary self-management. Fourteen participants (26.4%) stated that economic limitations made it difficult to afford healthier options such as meat, dairy, and fruit. In contrast, high-carbohydrate foods such as noodles, being low-cost and energy-dense, remained a default dietary staple for many. 10 participants explicitly noted they could not afford enough protein-rich or fresh foods.

Less commonly reported but still relevant were situational and physiological factors. Some work-related and social environments that increased exposure to high-carbohydrate foods. For example, participant 17, a baker, regularly consumed cakes and sweet soups during work. One participant (1.9%) engaged in heavy physical labor noted that reducing carbohydrate intake during physically demanding shifts caused fatigue and dizziness.

In addition to dietary barriers, cultural and familial dynamics often complicate efforts to adopt healthier eating behaviors. A total of 35 participants (66.0%) reported that family members—particularly spouses and children—frequently interfered with dietary plans. This included the preparation of sugary “health supplements” or discouragement of exercise due to overprotection.

Finally, although most participants expressed openness toward using digital health tools, significant usability barriers were reported among older adults. Among participants aged 60 years and above, 48 individuals (90.3%) indicated difficulty navigating complex mobile applications. Most could only manage basic functions such as viewing medication reminders, and fewer than 7% reported using advanced features like online consultations or community forums. Infrastructure gaps further compounded access issues: only 15 rural participants (51.7%) owned smartphones capable of running health-related applications.

Table 1. Reported challenges in managing high-carbohydrate diets among older adults with type 2 diabetes mellitus (T2DM) in Shanxi Province (N=53)

No.	Challenges	n (%)
1	Limited understanding of high-carbohydrate foods	22 (41.5)
2	Influence of traditional dietary habits (e.g., noodle-based staples)	19 (35.8)
3	Financial barriers to access suitable foods	14 (26.4)
4	Difficulty resisting food cravings	5 (9.4)
5	Unintentional eating in social or work contexts	2 (3.8)
6	Elevated caloric needs from physically demanding work	1 (1.9)

3 System Design

3.1 Objective

The Jintang Weishi (JTG) system is aimed at providing a culturally sensitive, personalized, and user-friendly digital platform that supports dietary management for older adults with T2DM by promoting health literacy, raising awareness of the risks associated with excessive carbohydrate intake, and guiding users toward healthier eating habits to improve long-term health outcomes for elderly users in Shanxi Province.

3.2 Design Principle

Drawing from prior research, we identified three design principles to guide the development of JTG: health knowledge empowerment, personalization with cultural and economic sensitivity, and simplicity for individuals with low digital literacy.

Health Knowledge Empowerment Given the widespread lack of awareness regarding the link between high-carbohydrate diets and T2DM, the system prioritizes accessible, layered education. JTG communicates the long-term health risks of excessive carbohydrate consumption through multimodal storytelling and easy-to-consume visualizations to increase users' motivation for dietary change.

Personalization with Cultural and Economic Sensitivity To ensure long-term adherence and reduce behavioral resistance, JTG supports personalized recommendations at three levels: (1) **Individual Preferences:** The system collects user data on dietary habits (e.g., preference for noodle-based meals and Shanxi cuisine), exercise routines (e.g., morning walks, plaza dancing), and lifestyle context to construct high-resolution user profiles. These profiles enable tailored dietary guidance down to meal-level carbohydrate planning and food substitutions. (2)

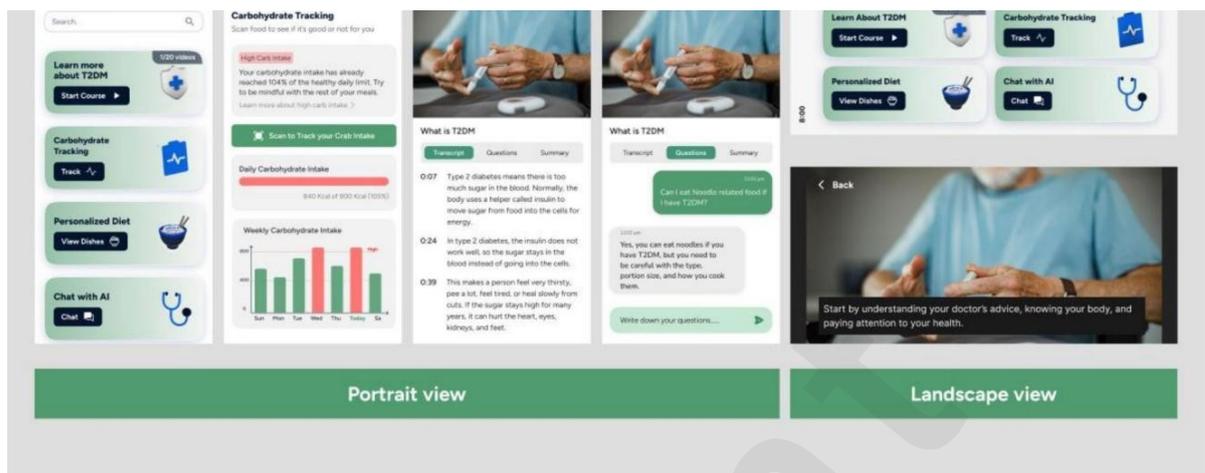
Cultural Relevance: Rather than enforcing strict dietary restrictions, the JTG system adopts a gradual reduction strategy to help users ease their dependence on high-carbohydrate staples such as noodles. This culturally sensitive approach is intended to reduce psychological resistance and promote user acceptance and long-term adherence to dietary changes. (3) **Economic Feasibility:** Recognizing the lower-income context of many Shanxi households, JTG recommends cost-conscious dietary alternatives that reduce carbohydrate load without increasing food expenditures, based on real-time market data and local ingredient availability.

Simplicity for Low Digital Literacy Given that the target users include older individuals with limited digital skills, and some with low or no literacy, the JTG system is developed with a strong emphasis on accessibility and cognitive simplicity. The design prioritizes low-friction interactions. Key interface features include visually driven navigation, voice-assisted prompts, and single-tap access to core functionalities. These design decisions aim to reduce cognitive load, minimize operational complexity, and ensure that users can confidently engage with the system regardless of prior technological experience. This approach reflects inclusive design principles tailored to the needs of digitally marginalized populations.

3.3 Functional Module Overview

The system integrates three core functional components: (1) a health education module tailored to users' cultural and literacy levels; (2) a personalized dietary recommendation engine that considers individual preferences and economic constraints; and (3) a daily carbohydrate tracking tool enhanced with real-time feedback and AI-powered explanations.

Figure 1. Screenshots of JTG Application



3.31 Health education module The health education module adopts a three-tier pyramid structure: (1) the base layer provides foundational knowledge on T2DM etiology and health risks; (2) the intermediate layer focuses on core blood glucose management principles, particularly dietary strategies, and (3) the top layer offers tailored guidelines for preventing and managing complications. Educational content is delivered through multimodal formats to enhance accessibility and comprehension among older adults, as evidence shows that visual-based interventions—particularly video—are more effective than traditional or text-only methods in improving health literacy and understanding of health-related concepts [26]. Formats include 2–3-minute animated videos illustrating the vascular damage caused by glycemic fluctuations, illustrated infographics explaining how high-carbohydrate foods elevate blood glucose, and image–text guides cataloging common high-carbohydrate foods. To address cultural adaptability, Shanxi-specific elements are incorporated—for example, citing The Yellow Emperor’s Inner Canon (“Five grains for nourishment, five fruits for assistance”) to emphasize dietary control. The module supports multiple query modalities, including dialect voice input, text entry, and image-based queries, to accommodate diverse user communication preferences.

3.32 Personalized Dietary Recommendations This module generates individualized meal plans through user profile which includes anthropometric data (height, weight, age), glycemic measures, T2DM history, dietary and physical activity preferences, comorbidities, and socioeconomic context. Recommendations specify ingredient quantities to the gram and visualize carbohydrate content using intuitive icons (e.g., measuring spoons) for ease of interpretation. Local dietary culture is incorporated—such as low-glycemic adaptations of Shanxi noodle dishes (*Youmian Yuyu*, *Sorghum Wotou*)—balancing taste preferences with glycemic control. Economic considerations are addressed by prioritizing cost-effective, locally available foods (e.g., cabbage, carrots, apples), thereby enhancing feasibility and long-term adherence.

3.33 Carbohydrate Intake Tracking The tracking module allows users to keep track of daily carbohydrate consumption by noting the weight and type of foods consumed. The system computes and displays total carbohydrate energy consumption relative to a customized target range calculated according to individual profiles. As intake nears the upper limit, the display color transitions to deep red as a visual warning. An AI health assistant embedded in the dashboard allows users to long-press visualizations for real-time, voice-activated explanations of abnormal values, their potential causes, and clinical implications. Weekly health reports integrate radar charts to depict multidimensional progress and line graphs to monitor long-term trends, offering a comprehensive overview of metabolic control.

3.4 System Architecture

The system consists of a client-side iOS application and a server-side infrastructure. The client side is developed using SwiftUI and the Combine framework, enabling real-time data streams to drive user interface updates. Even for complex chart rendering, the application maintains a stable 60 frames per second. The server side is built on a high-availability Python Django API service capable of processing over one million daily requests. MySQL stores structured user and health data, MongoDB handles unstructured time-series data from monitoring devices, and Redis caches frequently accessed metrics—such as blood glucose and heart rate values—to maintain an average page load latency of less than 300 milliseconds.

Three specialized modules extend the system's capabilities. The image recognition module, built on a customized PyTorch Mobile framework, identifies ingredients from patient-uploaded food photos within 2 seconds and automatically calculates nutritional intake. The natural language processing engine, powered by Hugging Face Transformer models optimized for Chinese medical language and the Jin dialect, interprets colloquial health queries (e.g., "What should I do if my blood sugar is high?") and generates structured responses within seconds. The data analytics engine leverages Python Pandas and NumPy for large-scale data cleaning and uses TensorFlow to build a blood glucose risk prediction model, providing a data-driven basis for personalized intervention strategies.

4 Evaluation

The evaluation aimed to assess three primary outcomes: (1) improvement in participants' knowledge of T2DM and high-carbohydrate foods through the Jintang Weishi (JTG) system; (2) changes in dietary behaviors; and (3) changes in blood glucose outcomes.

4.1 Study Design

4.1.1 Participants We conducted a 90-day experimental study with 40 participants recruited via online social media platforms (WeChat, Xiaohongshu, and Bilibili).

Inclusion criteria were: diagnosis of T2DM, age ≥ 55 years, long-term residency in Shanxi Province, and low-income status, defined as monthly household income $< ¥3000$ for urban residents and $< ¥1750$ for rural residents according to the official criteria from the National Bureau of Statistics of China [27]. Exclusion criteria were advanced-stage T2DM or other severe illnesses.

The final sample included 40 participants, comprising 23 men and 17 women between the ages of 57 and 71 years (mean 63.2, SD 5.44). Of these, 13 participants were from urban areas and 27 were from rural regions. Educational attainment was generally low; only 7 individuals (17.5%) had completed a bachelor's degree or higher.

4.1.2 Procedure The 90-day study was structured into three phases: 1) T0 (Baseline, Days 0–7): Participants underwent initial clinical and behavioral assessments.

Glycated hemoglobin (HbA1c) levels were measured, and baseline lifestyle data were collected, including a 7-day dietary diary used to estimate average daily carbohydrate intake. All participants completed the Diabetes Knowledge Test (DKT), an adapted version of the University of Michigan instrument (28,29). The test was translated into Chinese and revised to remove items not applicable to the Shanxi T2DM population. The DKT includes 20 items covering T2DM etiology, dietary practices, and physical activity management, with scores ranging from 0 to 20. Based on DKT scores, participants were randomized into an intervention group (n=20) or control group (n=20), ensuring comparable baseline knowledge levels across groups. 2) T1 (Intervention Phase, Days 8–30): Participants in the intervention group received training on the use of the Jintang Weishi (JTG) system and began daily use of the platform for self-management support. The control group did not receive any intervention during this period. In the final week of T1, all participants recorded a second 7-day dietary diary and underwent repeat HbA1c testing and DKT assessment. 3) T2 (Follow-Up, Days 31–90): No additional training or intervention was administered in this phase. In the final week, both groups completed a third round of HbA1c testing, dietary diary collection, and DKT completion.

4.1.3 Data Analysis We used the Diabetes Knowledge Test (DKT) to evaluate participants' understanding of T2DM. Dietary behavior was assessed through baseline lifestyle data, which included 7-day dietary diaries and calculation of the mean daily carbohydrate intake. Glycated hemoglobin (HbA1c) was measured as an indicator of average blood glucose levels over the past 2–3 months.

4.14 Ethics Approval and Informed Consent This study received joint approval from the Ethics Committee of the University of Shanghai for Science and Technology and was conducted in accordance with the principles of the Declaration of Helsinki.

Before enrollment, all participants were informed in plain language about the study purpose, procedures, potential benefits, and risks, and written informed consent was obtained. Data collection was fully anonymized, with unique identifiers replacing personal information. The data were used solely for statistical analysis in this study and were permanently deleted upon study completion. To safeguard privacy, the JTG application applied end-to-end encryption for all health data transmissions, prohibited third-party data sharing, and was subject to regular security audits by the research team.

4.2 Result

4.21 Diabetes Knowledge Test (DKT) Outcomes As shown in Table 2, at baseline (T0), mean DKT scores did not differ between the control group (mean 7.3, SD 2.3) and the intervention group (mean 7.3, SD 2.6). At T1, the intervention group demonstrated a significant increase (mean 12.5, SD 2.9), while the control group showed only little change (mean 7.6, SD 2.2). At T2, the intervention group reached a mean of 16.6 (SD 1.6) compared with 7.4 (SD 1.8) in the control group. The mean improvement from baseline (T2-T0) was 9.3 points in the intervention group versus 0.1 points in the control group, a between-group difference of 9.2 points ($P < .001$).

Table 2. DKT scores (mean, SD) between intervention and control groups across three timepoints.

Timepoint	Control, mean (SD)	Intervention, mean (SD)	P value
T0 (Baseline)	7.3 (2.3)	7.3 (2.6)	.99
T1	7.6 (2.2)	12.5 (2.9)	<.001
T2	7.4 (1.8)	16.6 (1.6)	<.001
Δ (T2-T0)	0.1 (2.2)	9.3 (2.2)	<.001

4.22 Carbohydrate Intake Outcomes As shown in Table 3, at baseline (T0), mean daily carbohydrate intake was comparable between the control group (1241.6 kcal, SD 192.4) and the intervention group (1243.9 kcal, SD 223.5; $P=.97$). Over time, the control group showed no significant change in carbohydrate intake from T0 to T2 (mean difference -13.2 kcal, 95% CI -82.6 to 56.2; $P=.71$). In contrast, the intervention group demonstrated a marked reduction in carbohydrate intake, decreasing from 1243.9 kcal (SD 223.5) at T0 to 829.8 kcal (SD 142.3) at T2 (mean difference -414.1 kcal, 95% CI -513.9 to -314.4; $P<.001$). Between-group analysis confirmed a significant effect of the Jintang Weishi (JTG) intervention, with the reduction in carbohydrate intake being substantially greater in the intervention group compared with the control group at both T1 and T2 ($P<.001$).

Table 3. Carbohydrate Intake (mean, SD) between intervention and control groups across three timepoints.

Timepoint	Control, mean (SD), kcal	Intervention, mean (SD), kcal	P value
T0	1241.6 (204.9)	1243.9 (290.0)	0.98
T1	1229.7 (212.2)	1019.1 (190.4)	0.002
T2	1228.3 (193.9)	829.8 (110.5)	<0.001
Δ (T2-T0)	-13.3	-414.1	<0.001

4.23 HbA1c Levels Outcomes As detailed in Table 4, mean baseline HbA1c levels were similar across groups (control: 8.09%, SD 0.71; intervention: 8.02%, SD 0.63; $P = .69$). By T1, HbA1c in the intervention group had decreased to 7.32% (SD 0.64), while the control group remained stable (8.10%, SD 0.72; $P < .001$). At T2, the intervention group achieved a further reduction to 6.84% (SD 0.57), whereas the control group showed no meaningful change (8.08%, SD 0.70; $P < .001$). Overall, the intervention group achieved a 1.18 percentage point reduction from baseline to T2, in contrast to -0.01 in the control group, resulting in a significant between-group difference ($P < .001$).

Table 4. Comparison of HbA1c (%) between intervention and control groups across three timepoints.

Time point	Control, mean (SD)	Intervention, mean (SD)	Mean difference (Exp - Ctrl)	P value
T0	8.09 (0.71)	8.02 (0.63)	-0.07	.69
T1	8.10 (0.72)	7.32 (0.64)	-0.78	<.001
T2	8.08 (0.70)	6.84 (0.57)	-1.24	<.001
Δ (T2-T0)	-0.01 (0.05)	-1.18 (0.21)	-1.17	<.001

4.24 System Usability Evaluation As Shown in Table 4, participants reported high usability and acceptability of the JTG system across all assessed domains.

Willingness to use the system regularly and perceived ease of use both received strong endorsement (Items 1 and 3, mean = 4.7), while confidence in using the system to manage blood glucose was similarly high (Item 9, mean = 4.8). Users also rated the integration of key features positively (Item 5, mean = 4.6), and most believed older adults could learn to use the system with ease (Item 7, mean = 4.9). Negative usability perceptions were minimal. Participants largely disagreed that the system was overly complex (Item 2, mean = 1.2), inconsistent in design (Item 6, mean = 1.3), or burdensome to operate (Items 4, 8, and 10, all means ≤ 1.1). These findings suggest that the JTG system offers an intuitive, low-barrier interface well-suited to older adults managing T2DM.

Table 4. Participants' evaluation of Jintang Weishi (JTG) system usability (N = 20).

No.	Item Statement	Mean Score
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1	I would be willing to use JTG system regularly to manage my diet and blood glucose.	4.7
2	I found the functions of JTG system overly complex. (reverse scored)	1.2
3	I think JTG system is simple and easy to use.	4.7
4	I need technical assistance to use JTG system. (reverse scored)	1.1
5	The features of JTG system (e.g., dietary logging, health alerts) are well-integrated.	4.6
6	I found inconsistencies in the system's design (e.g., illogical interface). (reverse scored)	1.3
7	I believe most older adults could quickly learn how to use JTG system.	4.9
8	I think using JTG system is a hassle. (reverse scored)	1.1
9	I feel confident managing my blood glucose using JTG system.	4.8
10	I need to learn a lot of operational steps before using JTG system (reverse scored)	1.1

Discussion

This study evaluated the effectiveness of the Jintang Weishi (JTG) system among low-income older adults with type 2 diabetes, focusing on knowledge improvement, dietary behavior change, and glycemic outcomes. The findings highlight both the promise and limitations of digital health education interventions in this vulnerable population.

5.1 Improvement in Diabetes Knowledge

Participants in the intervention group demonstrated a substantial increase in diabetes knowledge, while the control group remained largely unchanged. This finding is consistent with prior studies indicating that structured digital education can enhance knowledge and self-care among older adults [30,31]. Traditional health education often relies on text-based materials and clinical consultations, which are less accessible for individuals with limited literacy or financial resources [32]. In contrast, the JTG system delivered simplified and culturally adapted content through short, bite-sized video segments, making information more consumable and engaging [33]. This is particularly relevant in today's digital environment, where older adults are increasingly familiar with short-video platforms and respond positively to concise, visually driven learning formats [34]. By presenting essential concepts such as blood glucose regulation and dietary risk factors in this manner, the JTG system improved comprehension where text-heavy approaches typically fall short. Tailoring delivery to the cognitive, cultural, and literacy needs of vulnerable populations can therefore help reduce disparities in access to health knowledge and empower older adults to engage more effectively in chronic disease management.

5.2 Overcoming Barriers Through Digital Health

Low-income elders with diabetes often encounter structural barriers such as limited access to outpatient education and restricted mobility [35-37]. Care-seeking is frequently delayed, influenced by mistrust of the health system or cultural norms that value endurance and normalize symptoms of aging. As a result, many seek medical help only after complications arise, leading to delayed detection and poorer outcomes [39,40].

Mobile health (mHealth) interventions have been shown to mitigate these challenges by lowering costs, reducing dependence on in-person visits, and embedding education into daily routines [38]. The Jintang Weishi (JTG) system illustrates this approach by providing structured and culturally adapted diabetes education directly at home. This accessible, continuous guidance can increase participants' health literacy so that they can recognize early warning signs and adopt proactive behaviors in diet, monitoring, and care-seeking.

By addressing both structural and behavioral barriers, digital tools like JTG extend beyond information delivery. They support sustained self-management, promote earlier engagement with care, and hold promise for narrowing equity gaps while reducing the long-term burden of diabetes on patients and health systems.

5.3 Overcoming Barriers Through Digital Health

This study showed that the JTG intervention led to a clear improvement in diabetes - related knowledge and promoted healthier dietary choices, particularly by reducing carbohydrate intake within the first three months. In the intervention group, HbA1c fell by 1.18 percentage points (from 8.02% to 6.84%; $P < .001$), while no meaningful change was observed in the control group. These findings indicate that the program provided early metabolic benefits. Nevertheless, earlier studies have reported that the metabolic effects of education-based interventions often diminish within one to three months after the program ends, reflecting a gradual decline in patient adherence [41].

A systematic review emphasizes that interventions lasting over 12 months, especially those backed by multidisciplinary teams and integrated educational formats, yield more enduring and stable metabolic results [42].

This reduction of both carbohydrate intake and HbA1c can be interpreted through the Information-Motivation-Behavioral Skills (IMB) model [43,44]. Patients acquire knowledge, but sustained self-management requires adequate motivation (eg, valuing health, family support) and behavioral skills (eg, dietary regulation, self-monitoring). The systematic design and cultural adaptation of JTG may have collaboratively strengthened these elements, resulting in immediate behavioral and physiological enhancements.

Given that each 1% reduction in HbA1c is associated with a substantial decrease in diabetes complications and an estimated annual cost saving of approximately US \$736 [45,46], the initial impact of JTG demonstrates clear clinical and public health relevance.

5.4 Cultural Adaptation in Dietary Management

In northern China, where rice, noodles, and steamed buns dominate the diet, abstract instructions such as “reduce carbohydrates” can feel impractical. JTG addressed this gap by grounding guidance in familiar staples and portion cues (eg, one bun, half a bowl of rice). The system further employed culturally resonant metaphors, such as describing blood glucose regulation as “balancing energy flows” or dietary balance as “yin–yang coordination.” These explanations were not medical claims but communication strategies that situated biomedical concepts within participants’ existing cognitive and cultural frames. Combined with practical substitutions, such as replacing refined staples with whole grains or increasing fiber-rich vegetables, this approach lowered both cognitive and financial barriers, improved comprehension, and strengthened participants’ self-efficacy. Quantitatively, the intervention was associated with a reduction of more than 400 kcal in daily carbohydrate intake and a mean HbA1c decrease of 1.18% within three months. These outcomes illustrate how cultural adaptation can function as a core mechanism that enables participants to translate clinical recommendations into sustainable routines. Rather than an ancillary feature, cultural tailoring appeared integral to intervention efficacy, consistent with prior evidence demonstrating that culturally adapted interventions can improve engagement, adherence, and long-term self-management [47].

5.5 Limitations and Future Work

This study has several limitations. First, The small sample size (N=40) limits statistical power and generalizability. Second, the three-month follow-up was long enough to capture early improvements but not to determine whether changes in HbA1c or behavior can be sustained. Previous evidence suggests that the metabolic effects of education-based interventions often diminish within one to three months after the program ends [41]. Third, the evaluation relied largely on laboratory outcomes. Key behavioral and psychosocial mediators such as exercise adherence, daily glucose monitoring, dietary quality, and emotional well-being were not considered in the study, leaving gaps in understanding how education translates into clinical outcomes. In addition, the intervention was delivered in a uniform format to all participants. Evidence suggests that a more personalized education plan tailored to individual needs can yield greater improvements in engagement, health literacy, and overall outcomes [42].

In the Future, we plan to evaluate these findings in larger and more diverse cohorts with longer follow-up. Collecting richer behavioral and psychosocial would help clarify mechanisms of change, while strengthened designs that include tailored content, multidisciplinary involvement, and hybrid delivery may improve sustainability. Interventions should also be more patient centered, addressing individual priorities, emotional needs, expectations, and the level of lifestyle changes. At the policy level, combining digital platforms with community-based initiatives such as village-level free clinics could provide a sustainable way to reinforce engagement and extend both clinical and public health impact.

Conclusions

This study underscores the potential of Jintang Weishi (JTG), a culturally tailored dietary management system for low-income elders with T2DM in Shanxi, China. By aligning with carbohydrate-centric dietary practices and incorporating patient perspectives, JTG improved dietary compliance, health literacy, and self-management engagement. Nevertheless, the brief follow-up period and modest sample size highlight the need for longer-term evaluation and larger-scale validation. Future research should investigate behavioral and psychosocial mediators of change and assess the feasibility of integrating JTG into community health services or multidisciplinary care models. Such efforts will help clarify how culturally adapted, patient-centered digital tools can advance diabetes management in resource-constrained settings and inform broader public health strategies.

Abbreviations

T2DM: Journal of Medical Internet Research
JTG: Type 2 Diabetes Mellitus
IMB: Information-Motivation-Behavioral Skills (IMB) model
HbA1c: Glycated hemoglobin
DKT: Diabetes Knowledge Test

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