BMC Geriatrics

RESEARCH

Open Access

Investigating the needs of older adults with type 2 diabetes and conceptualizing a healthy diet management application: a conceptual design

Jinglong Li[1], Rosalam Che Me[1,5*], Nik Nur Izzati Nik Mohd Fakhruddin[2], Faisul Arif Ahmad[3] and Qisen Zhu[4]

Abstract

Background The growing prevalence of diabetes among the older adults has made effective dietary management essential for controlling blood glucose levels and reducing complications. In the age of the Internet of Things (IoT), smart applications and product designs are increasingly recognized as valuable tools for supporting personalized health management and enhancing quality of life. However, most existing mobile health solutions fail to accommodate the specific cognitive and physical needs of older adults with type 2 diabetes. This study aims to explore these unique needs to inform the development of a healthy diet compliance solution tailored to this population.

Methods A qualitative interview approach was employed to investigate the dietary management needs, behaviors, and technological preferences of older adults users. Twelve older adults with type 2 diabetes, aged 60 to 74 years (average age 66.7), participated in interviews conducted at a government hospital. Data were analyzed using ATLAS.ti software to identify key themes, which informed the conceptual design of a targeted healthy diet management application.

Results The findings highlight five critical areas for diabetes care in older adults: diabetes knowledge, glucose monitoring, diet planning, physical activity. Based on these insights, a conceptual app prototype was developed, featuring educational content, simplified glucose tracking tools, personalised meal planning, and integration with activity monitoring. The app design prioritises accessibility, incorporating elderly-friendly elements such as large text, camera picture assistance, and intuitive navigation.

Conclusions This study highlights the potential of tailored mobile applications to support older adults with type 2 diabetes in managing their health more effectively. The proposed application design responds directly to the specific usability needs of this demographic. Future work should include iterative prototyping and user testing to enhance usability and assess real-world impact.

Keywords Older adults with type 2 diabetes, Healthy diet, App design, Design needs, Conceptual design

*Correspondence:
Rosalam Che Me
rosalam@upm.edu.my; c.m.rosalam87@gmail.com

Full list of author information is available at the end of the article

Introduction

As the global population continues to age, the challenges associated with ageing have become increasingly pressing. According to the World Health Organization (WHO), the number of people aged 65 and older is projected to reach 1.5 billion by 2050, representing a significant demographic shift [27]. With ageing comes a heightened risk of chronic diseases, among which diabetes is one of the most prevalent and life-threatening conditions affecting the older adults group [41]. The WHO reports that over 422 million people worldwide have diabetes, with a substantial proportion being older adults. The complications associated with diabetes, such as cardiovascular diseases, kidney failure, vision impairment, and neuropathy, pose severe threats to their health and quality of life [9]. Managing dietary intake is crucial in controlling blood glucose levels and preventing further complications, yet many older adults with type 2 diabetes face difficulties in adhering to an appropriate diet due to various physiological, cognitive, and social challenges [1].

The growing prevalence of diabetes among the older adults presents an urgent need for effective interventions. Many older adults struggle with managing their condition due to a lack of diabetes-related knowledge, limited access to healthcare resources, and difficulties in monitoring blood glucose levels [12]. In addition, cognitive decline, reduced mobility, and sensory impairments further hinder their ability to maintain a healthy diet and lifestyle [25]. Social factors, such as living alone or lacking family support, exacerbate the problem, making it difficult for older adults to prepare balanced meals and monitor their dietary intake. Given these challenges, there is an immediate need to develop effective solutions that facilitate diabetes management among the older adults population and improve their adherence to a healthy diet [19].

In recent years, smart products and digital health technologies have shown great potential in addressing healthcare challenges among the older adults. Wearable devices, mobile health applications, and IoT-based solutions have been widely applied in healthcare management, offering real-time monitoring, personalized recommendations, and data-driven insights [38]. In the context of diabetes management, smart products such as continuous glucose monitors (CGMs), diet-tracking applications, and AI-driven virtual assistants have made significant advancements. These technologies provide older adults users with convenient ways to track their glucose levels, receive dietary recommendations, and maintain a structured health plan [28]. The integration of artificial intelligence, cloud computing, and telemedicine further enhances the effectiveness of these tools, offering older adults with type 2 diabetes patients better support and self-management capabilities [5].

Despite increasing interest in digital health solutions for ageing populations, existing literature and product development often overlook the nuanced needs of older adults—particularly those with chronic conditions such as Type 2 diabetes [26]. Most mobile health applications emphasize general usability without addressing older adults specific interface challenges or the psychological and physiological complexities faced by diabetic seniors [29]. Furthermore, there is a noticeable lack of empirical studies that explore how mobile technologies can be purposefully designed to support daily dietary management while overcoming barriers related to technology acceptance among older adults with type 2 diabetes.

Therefore, this study seeks to fill this critical gap by investigating the lived experiences, daily struggles, and behavioural patterns of older adults with type 2 diabetes as they manage their diets and interact with digital health tools. Unlike prior work, which often treats the older adults as a homogenous group, this research specifically targets Type 2 diabetic older adults, integrating their unique requirements into a user-centered smart product design framework. By conducting in-depth interviews and analyzing their interactions with technology, this study will propose conceptual designs for diet management devices that prioritize usability features such as intuitive navigation, large-font text, voice-assisted input, and simplified interfaces. In addition, this research extends beyond interface usability to emphasize the integration of comprehensive diabetes self-management support, including educational resources, glucose monitoring, meal planning, and physical activity tracking. Through this multifaceted approach, the study introduces a novel framework for designing ageing-oriented smart products that not only improve dietary compliance but also foster higher technological acceptance. Ultimately, this work aims to contribute to the advancement of inclusive, evidence-based product design strategies that promote health autonomy and quality of life among older adults managing diabetes.

Literature review

Prevalence and challenges of type 2 diabetes among the older adults

Diabetes among the older adults is a significant global health concern, particularly in China, where an ageing population exacerbates its prevalence. According to the United Nations'definition, individuals over 60 with diabetes are classified as older adults with type 2 diabetes [33]. Type 2 diabetes (T2DM) is the most common form, affecting nearly 33% of individuals aged 60 and older adults [44]. The primary contributors to senile diabetes include genetic predisposition, environmental

factors, and age-related physiological changes, leading to impaired insulin production and glucose metabolism [18]. The complications of T2DM in older adults patients are severe, including hyperglycemia, vision impairment, kidney failure, cardiovascular diseases, and an increased risk of dementia [17]. According to the American Diabetes Association (ADA), diagnosis criteria include fasting plasma glucose levels of 7.0 mmol/L or higher, postprandial glucose levels of 11.1 mmol/L, or HbA1C levels of 6.5% or higher [20]. The Chinese Diabetes Society defines diabetes as a chronic illness necessitating continuous medical care and multifactorial risk reduction beyond glucose control [23].

The prevalence of T2DM in China has surged since the 1970 s, with significant variations among demographic groups [43]. China currently has over 92.4 million diabetes cases, making it the country with the highest prevalence globally [35]. As China's population continues to age, projections suggest that by 2050, one in four individuals will be over 65, further increasing the diabetic population [36]. Despite advancements in diabetes management, issues such as poor glycemic control, treatment adherence, and psychological distress remain prevalent [30, 34]. Research also highlights that frailty, comorbidities, and polypharmacy complicate diabetes management in older adults [7]. From an economic perspective, diabetes imposes a substantial financial burden on China. Direct treatment costs and opportunity losses account for over half of patients'disposable income [40]. The annual increase in diabetes-related economic burden surpasses the growth rate of GDP and national health expenditures [13]. The financial strain underscores the urgent need for innovative and cost-effective diabetes management solutions.

Role of diet in diabetes management

A healthy diet plays a crucial role in the management of diabetes among older adults [15]. Proper dietary habits help regulate blood sugar levels, reduce the risk of diabetes-related complications, and promote overall well-being [14]. However, many older adults with type 2 diabetes struggle with maintaining a balanced diet due to factors such as cognitive decline, lack of nutritional knowledge, and difficulty in meal preparation [3]. Smart products designed for older adults can provide tailored dietary recommendations, real-time nutritional guidance, and interactive meal planning features. These functionalities empower older adults to make informed food choices, ensuring that their dietary intake aligns with their specific health needs [22]. By incorporating smart technology into dietary management, older adults with type 2 diabetes can experience greater independence and improved adherence to recommended dietary guidelines [4].

Integration of smart products in diabetes management

The integration of smart products in managing the health and well-being of older adults with type 2 diabetes has gained significant attention in recent years. Diabetes, a chronic condition that requires continuous monitoring and management, poses various challenges for older adults [8]. These challenges include difficulties in maintaining a healthy diet, tracking glucose levels, and adhering to prescribed medication regimens [2]. Smart products, such as wearable glucose monitors, AI-powered (Artificial Intelligence powered) diet planners, and mobile health applications, have emerged as potential solutions to bridge these gaps. By leveraging technology, smart products can enhance the self-management capabilities of older adults with type 2 diabetes, thus improving their overall health outcomes and quality of life. Smart products have emerged as a potential aid in diabetes management [37]. A key enabler of smart health applications is ML Kit, Google's mobile machine learning platform that allows developers to embed on-device AI features into Android and iOS apps. ML Kit supports tools like text recognition, barcode scanning, and image labelling, which are particularly useful in diabetic care. For instance, image recognition can help older adults identify food items for automated logging, while text recognition aids in reading nutrition labels or medication instructions. Its offline capabilities and real-time processing make ML Kit well-suited for older adults who need simple, responsive, and privacy-conscious tools [32]. By integrating ML Kit into smart products, developers can improve usability, automate routine health tasks, and personalize support—making it a valuable asset in designing effective, accessible health solutions for the older adults with type 2 diabetes.

Challenges and opportunities in smart product development

Recent advancements in smart product development have increasingly focused on addressing the unique needs of older adults, particularly those with chronic conditions like diabetes. Smart health devices, including wearable glucose monitors, AI-powered meal planners, and voice-assisted applications, aim to enhance self-management and improve adherence to healthy dietary practices [31]. Research highlights that these products must prioritize ease of use, accessibility, and personalization to ensure adoption among older adults. Simplicity in interface design, larger text, and voice-guided assistance have been identified as crucial features for overcoming usability barriers. Additionally, the integration of real-time monitoring and data-driven insights helps older adults with type 2 diabetes track their dietary habits and receive timely recommendations, improving their overall health outcomes [11].

Despite the progress in smart product development, challenges persist in ensuring the widespread acceptance of ageing-oriented smart products designed to support older adults with type 2 diabetes in maintaining a healthy diet [10]. Research indicates that technological acceptance is shaped by factors such as digital literacy, trust in technology, and perceived usefulness. Many older adults with type 2 diabetes face difficulties in adapting to digital interfaces, highlighting the need for intuitive and accessible design. Additionally, concerns regarding data privacy and the lack of reliable, user-friendly support systems further hinder adoption [6]. To enhance acceptance and effectiveness, researchers emphasize the importance of human-centered design, comprehensive user training, and seamless integration with healthcare services, ensuring that these smart products can genuinely support older adults with type 2 diabetes in adhering to healthy dietary practices.

Key needs for older adults with type 2 diabetes in managing a healthy diet

Therefore, review identified five key needs for older adults with type 2 diabetes in managing a healthy diet as Fig. 1 presented: diet knowledge, diet suggestions, activities, glucose monitoring, and usability. First, awareness of glycemic control, food choices, and education is crucial for building diet knowledge. Personalized nutrition plans and mobile apps support healthy diet suggestions. Physical activities play a role in encouraging dietary compliance. Effective glucose monitoring tools must be easy to use and provide timely feedback. Lastly, usability is essential—interfaces must be simple, accessible, and senior-friendly to ensure engagement. These findings guide the design of smart products that meet the real needs of older adults with type 2 diabetes.

In conclusion, the literature review underscores the importance of a healthy diet in managing diabetes among the older audlts and the potential of smart products to support this management. However, it also highlights the challenges in ensuring widespread acceptance and effective use of these products among older adults. The findings from this review will inform the development of a conceptual framework that addresses these challenges and supports the design of smart products tailored to the needs of older adults with type 2 diabetes.

Materials and methods

This study involved in-depth interviews with 12 type 2 diabetic older adults participants recruited from a local hospital between June and August 2024. Participants were selected using purposive sampling to ensure they represented the target user group— older adults with type 2 diabetes who could provide meaningful insights into their daily routines, health needs, and technology use behaviours. A structured interview guide (see supporting documents 3) was used to explore their characteristics, needs, and attitudes toward smart products for healthy diet management.

Interviews were conducted until data saturation was reached—defined as the point at which no new themes or significant insights emerged from additional interviews. Saturation was monitored continuously by reviewing transcripts during the data collection phase [4]. All interviews were audio-recorded, transcribed verbatim, and analysed using ATLAS.ti software. A coding framework was developed based on both the interview guide and

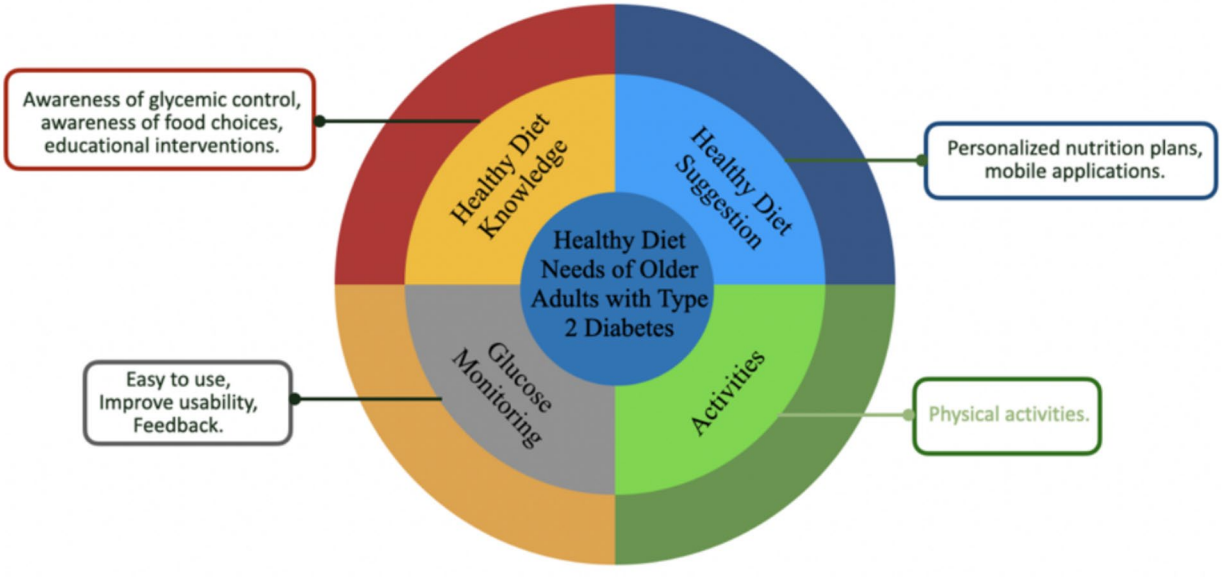


Fig. 1 Key findings on healthy diet needs of older adults with type 2 diabetes. (Source: Author's own drawing)

emergent themes. To ensure consistency, two researchers independently coded a subset of transcripts and then discussed and refined the coding scheme through iterative comparison and consensus. Discrepancies were resolved through discussion, and inter-coder reliability was established to enhance rigor (see supporting documents 7, 10). Themes were validated using triangulation and member checking. Emerging themes were compared across participants to confirm consistency, and illustrative quotes were selected to represent each theme (see supporting documents 8). In addition, key findings were shared with a subset of participants for feedback to ensure that the interpretations accurately reflected their views [24].

The study received approval from the Ethics Committee for Research Involving Human Subjects at Universiti Putra Malaysia (JKEUPM) under reference number JKEUPM-2023–1320 (see supporting documents 1). All procedures were conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants, ensuring confidentiality and voluntary participation.

Table 1 Interview questionnaires

Research Questions	Research Objectives	Interview Questions (Section B, C)
What are the characteristics and need of older adults with type 2 diabetes?	To investigate the characteristics and need of older adults with type 2 diabetes	Q1: How would you describe your current dietary habits?
		Q2: How would you rate your overall satisfaction with your current diet?
		Q3: How receptive are you to receiving guidance or assistance in improving your daily diet?
		Q4: What challenging barriers do you face in maintaining a healthy diet? If you have any specific dietary goals or concerns, please provide details:
What are the preference and attitude of older adults with type 2 diabetes towards using smart products?	To identify the preference and attitude of older adults with type 2 diabetes towards using smart products	Q5: What are the main advantages or concerns you're interested in when it comes to using smart products for maintaining a healthy diet?
		Q6: What features or functionalities would you prefer to have in smart products designed specifically for supporting healthy diets?
		Q7: What kind of support or guidance would you find most valuable from smart products to help with your healthy diet?

(Source: Author's own drawings)

Participants

To ensure data quality and relevance, participants were selected based on specific criteria. They included both experienced and inexperienced smart product users to capture diverse perspectives. All had normal cognitive function, stable health, and basic digital literacy to participate effectively. Demographic details are summarized in Supporting document [5]. Twelve older adults with type 2 diabetes (7 males, 5 females), aged 60 to 76 (M = 66.7), participated in this study. They were selected based on specific criteria: basic digital literacy, normal cognitive function, and stable health. The sample included both experienced and inexperienced smart product users to capture diverse perspectives. Most participants (7) were aged 60–65, with the remainder spanning older age brackets. Interviews were conducted face-to-face at a local hospital with administrative approval and informed consent (referring to supporting document [4]). The sample size was consistent with qualitative research practices, where 10 to 15 participants are generally considered sufficient to achieve data saturation—meaning that no new insights are likely to emerge from additional interviews [4]. In terms of diabetes history, half of the participants (6) had been living with diabetes for more than three years, while the others had a shorter duration of the condition. Regarding education level, most had completed only primary education or less, with 2 having no schooling and 4 being primary school graduates. In terms of living status, participants varied: 5 lived with a spouse, 4 lived with children, and 3 lived alone. Income levels were predominantly below 5000 RMB, with only one participant earning above 8000 RMB. These socioeconomic factors likely shaped participants'perceptions and acceptance of smart products. For instance, lower education levels and income may have limited exposure to or confidence in technology, while living with family could provide support in navigating digital tools. Such contextual factors are essential to understanding the challenges and motivations behind technology adoption in this demographic.

Interview process

To explore the needs, technology acceptance, and perceptions of diet-related smart products among older adults with type 2 diabetes, interviews were conducted with 12 participants meeting specific inclusion criteria. These insights directly informed the development of the design framework, with a focus on functionality, appearance, and interface—key elements influencing user acceptance.

Each structured interview was organized into four sections: demographics, dietary needs, attitudes toward smart products, and perceptions of smart dietary tools. A set of seven semi-structured, open-ended questions (see Table 1) guided the conversations. The interviews took

place in hospital settings in Guangdong between June and October 2024, each lasting approximately 20–30 min.

All interviews were conducted by the primary researcher (Author himself) to ensure consistency in delivery, tone, and data collection. A standardized interview protocol was followed to minimize variability, and the same set of guiding questions was used across all sessions. This approach ensured uniformity in eliciting comparable data while allowing flexibility for participants to express individual experiences and perspectives. The qualitative findings are summarized in the following sections.

Data analysis

The qualitative data from interviews were analysed using ATLAS.ti software to ensure a systematic and rigorous approach to data coding and theme development. The analysis involved identifying meaningful text segments, assigning codes to these segments, and organizing them into broader thematic categories that reflected participants'needs, perceptions, attitudes, and experiences with ageing-oriented smart products. This process generated rich insights into the practical and emotional needs of older adults with type 2 diabetes, which are essential for informing a targeted interface design framework.

Table 2 Summary of the interview coding, category and themes

Interpretive Coding	Category/Code group	Pattern Coding (Themes)
cannot access smart products; cannot choose what they want; control blood sugar; Ease of use design; Emotion needs function; Feedback function; Have no idea on eating; Importance of diet knowledge; Importance of medicine intake; Interested to use app Lack of condition; Lack of diet knowledge; Lack of management; lack of motivation; Medicine intake reminder function; Recommend food choice; Record food intake function; Share diabetes information; Simple interface design; Tracking glucose function; Unsatisfied with diet; Want to have guidance; Want to have suggestion; Want to keep health; Want to learn diet knowledge; Want to reduce complications; Willing to recommend app	Healthy diet knowledge need; Healthy diet management need; Healthy diet suggestion need; User Engagement and Well-being; Dietary and Health Management Functions; Reminders and Feedback Functions; Ease of use design; Unable to access smart products	Knowledge and Guidance for Healthy Diet; Practical Dietary and Health Management; User Support and Motivation; Ease of use Design

(Source: Author's own drawings)

Following transcription and anonymization, the data underwent structured content analysis. All researchers participated in an initial familiarization phase, reading the transcripts to gain a general understanding of the content. A preliminary codebook was developed through team discussions, combining both deductive codes (based on predefined variables such as function, interface, and appearance design) and inductive codes (emerging from participants' narratives).

To enhance coding consistency and trustworthiness, each transcript was independently coded by at least two researchers. The coded data were then cross-compared, and discrepancies were resolved through consensus meetings. This process ensured inter-coder reliability and minimized subjective bias.

To provide a more detailed account of the process from code generation to theme development, we have expanded on the analysis procedures. The coding process was iterative, with researchers regularly reviewing and refining codes and themes. This involved several steps:

a) Initial Coding: Researchers independently coded the first set of transcripts, focusing on identifying initial codes based on the participants'responses. b) Code Review: Researchers met to review the initial codes, discussing discrepancies and reaching a consensus on code definitions. c) Refinement: Based on the consensus, codes were refined and applied to the remaining transcripts. d) Theme Development: Codes were then grouped into broader themes, reflecting common patterns and insights across the data. e) Reliability Check: To ensure reliability across coders, a subset of transcripts was re-coded by a different set of researchers. The results were compared, and any differences were discussed and resolved.

To illustrate the code-to-theme development process and ensure transparency in the analysis, we have included sample coding trees in the supplementary material (see supporting documents 7, 8, 9, 10). These trees show how individual codes were grouped into themes, providing a visual representation of the analysis process. By detailing these procedures and providing sample coding trees, we aim to demonstrate a clear and igorous approach to data analysis, ensuring that the themes identified are robust and reliable.

Results

This section summarizes the coding process used to analyse transcripts from interviews with 12 older adults participants with type 2 diabetes. With consent, interviews were recorded, transcribed, and translated, with transcripts included in the appendices. The coding process, summarized in Table 2, helped identify key themes and recurring issues related to dietary needs and perceptions of smart products, each coding collected from the transcript will be kept together to create themes in

the next section. These themes reflect a strong need for user-friendly, accessible technology that offers practical dietary support and integrates well with the daily routines and health management needs of older adults with type 2 diabetes. Next step will proceed to category the codes into theme for further research. Two main research questions guided the analysis: situation and needs of older adults with type 2 diabetes on their daily diet, and their perception toward smart applications for a healthy diet. A total 4 common themes were extracted and coded from transcribed interview through qualitative software Atlas.ti. These themes support the first research question and serve as criteria for the proposed framework, guiding future smart product design.

Summarised theme 1: knowledge and guidance for healthy diet

This theme reflects the participants'strong need for clear and practical dietary guidance to manage blood sugar effectively as Fig. 2 presented. Many expressed confusion about which foods are suitable for diabetes, revealing a gap in basic nutrition knowledge. Through inductive coding, four key categories emerged: "Lack of Diet Knowledge, Want to Learn Diet Knowledge, Importance of Diet Knowledge, and Have No Idea on Eating". Participants expressed a significant lack of confidence and knowledge regarding proper dietary habits. The interview participants used their own words to express their issues and worries, they reported confusion about what foods are suitable and how to manage portion sizes (see supporting documents 10).

> *"I don't know which foods are suitable for diabetics to eat. I do need more guidance to control my diet." — Participant A01*
>
> *"I'd appreciate guidance that's practical and easy to follow. Something that gives me meal ideas or tips on what to avoid would be really helpful." — Participant A05*

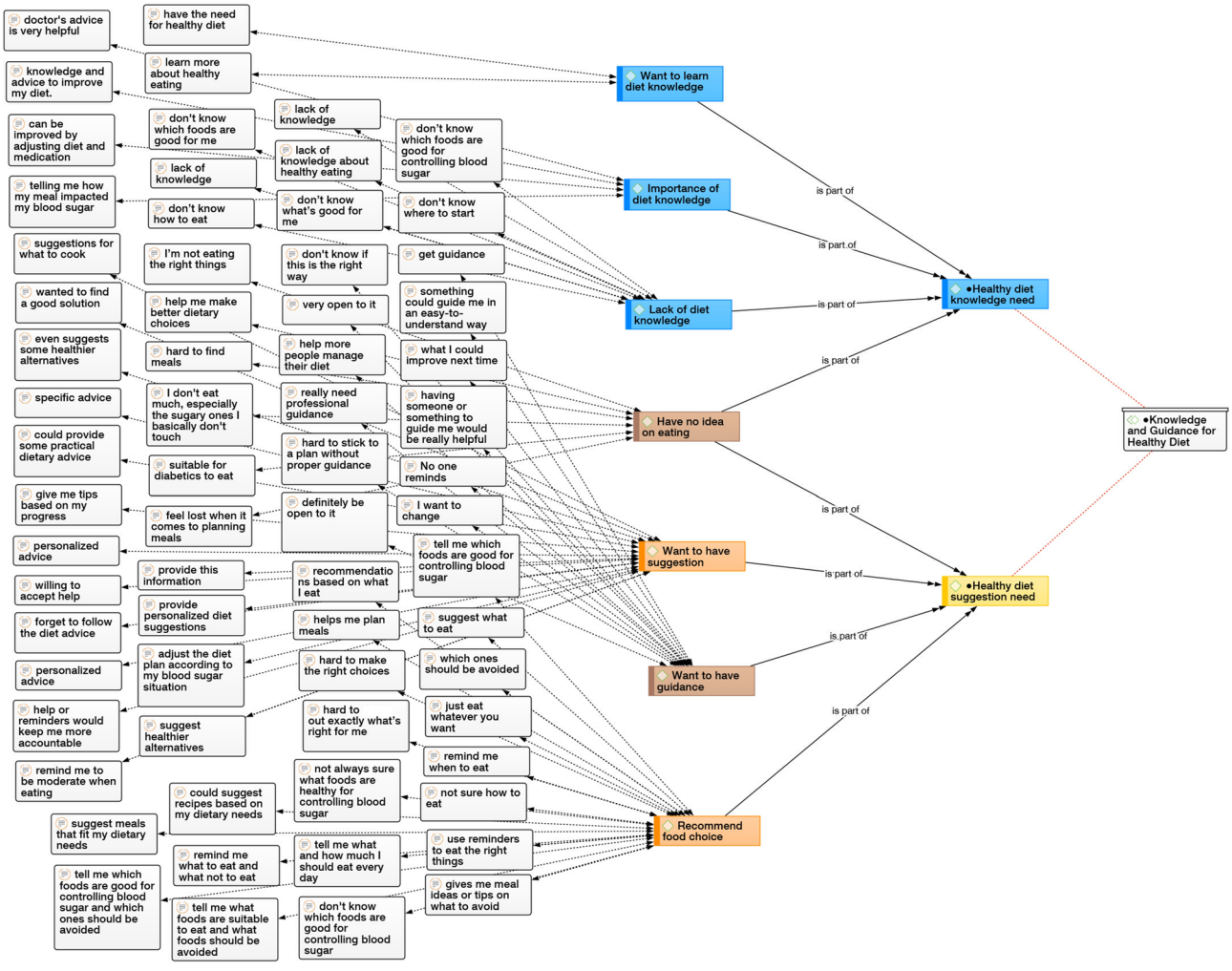


Fig. 2 Theme 1 generation and network among codes, categories and themes. (Source: Exported from Atlas.ti)

"I know that I need to be moderate and I can't eat sugary things, but I don't know how to eat them specifically."— Participant B01

Participants not only acknowledged diet as crucial to their health but also felt unsure about how to apply this knowledge. While some showed a desire to learn, others felt completely lost, indicating the need for structured, easy-to-understand resources. Smart products can address this gap by offering personalized advice, interactive tools, and meal planning features. By doing so, they can support older adults with type 2 diabetes in making informed food choices and improving their overall dietary habits.

Summarised theme 2: practical dietary and health management

This theme captures participants' need for smart product features that support daily diabetes management as Fig. 3 presented. Key functions desired include meal planning, real-time blood sugar monitoring, and dietary feedback. These tools help users make informed choices and adjust their habits based on glucose readings. Many interview participants emphasized the importance of practical features for managing their diabetes, including food tracking, blood glucose monitoring, and dietary feedback (see supporting documents 10).

"I know that diabetes requires diet control, but sometimes I am still not sure how to eat specifically. I also hope there will be a better way to manage it." — Participant B04
"It can help more people manage their diet, which is definitely meaningful." — Participant A02
"It definitely makes sense. It can help more people manage their diet. I also have the need for healthy diet. Designing it will help everyone."— Participant A03
"I'd appreciate guidance that's practical and easy to follow. Something that gives me meal ideas or tips on what to avoid would be really helpful."— Participant A05

Participants also emphasized the importance of easy integration into daily routines, preferring features that are simple, practical, and non-intrusive. Overall, this theme highlights the value of user-friendly smart products that provide ongoing support for healthy eating and effective diabetes control.

Summarised theme 3: user support and motivation

The emotional aspect of health management emerged as a critical factor, with users expressing a need for ongoing motivation and support. Participants noted that the presence of reminders, encouragement, and user communities could foster a sense of accountability and help them stay consistent with their dietary goals. This theme emphasizes the need for features that provide motivational support, such as goal-setting tools, reminders, and a feedback loop to reinforce healthy behaviors. Figure 4 presented the theme 3 generation and network among codes, categories and themes. The interview participants shared different opinions according to their own situation and experiences, several words were most frequently mentioned and recorded. Motivational features—such as goal tracking, reminders, and emotional encouragement—were identified as essential for sustaining long-term engagement (see supporting documents 10).

"I've tried to follow advice from my doctor, but I feel like having more structured help or reminders would keep me more accountable. I need that extra push to stay consistent." — Participant A04
"It would be useful to have regular reminders and alerts that ensure I'm staying on track with my dietary plan, as well as motivational support to encourage healthier eating habits." — Participant A01
"The main barrier for me is motivation. It's hard to stay disciplined when I'm not feeling well or when I'm busy."— Participant A05

Summarised theme 4: ease of use design

Ease of use was a recurring concern, with many participants expressing difficulties with complex technology. They preferred simple, intuitive interfaces with clear text and large buttons, making it easy for older adults users to navigate the product. This theme underscores the importance of designing user-friendly interfaces, particularly for older adults who may have limited experience with smart devices. Simple tutorials and customization options are also essential to ensure that users feel comfortable and empowered when using these products. Figure 5 presented the theme 4 generation and network among codes, categories and themes. Ease of use emerged as a critical factor. Participants emphasized the need for clear, simplified navigation with larger fonts and fewer steps (see supporting documents 10).

"I don't use smart devices very often, and my phone doesn't use too complicated functions."— Participant A03
"I have an old-age phone, I don't know how to use it. I don't understand." — Participant B05
"I am not very good at using complex smart devices, so the interface must be simple and intuitive. The buttons should be big, the text should be clear, and the operation steps should be few. It would be even

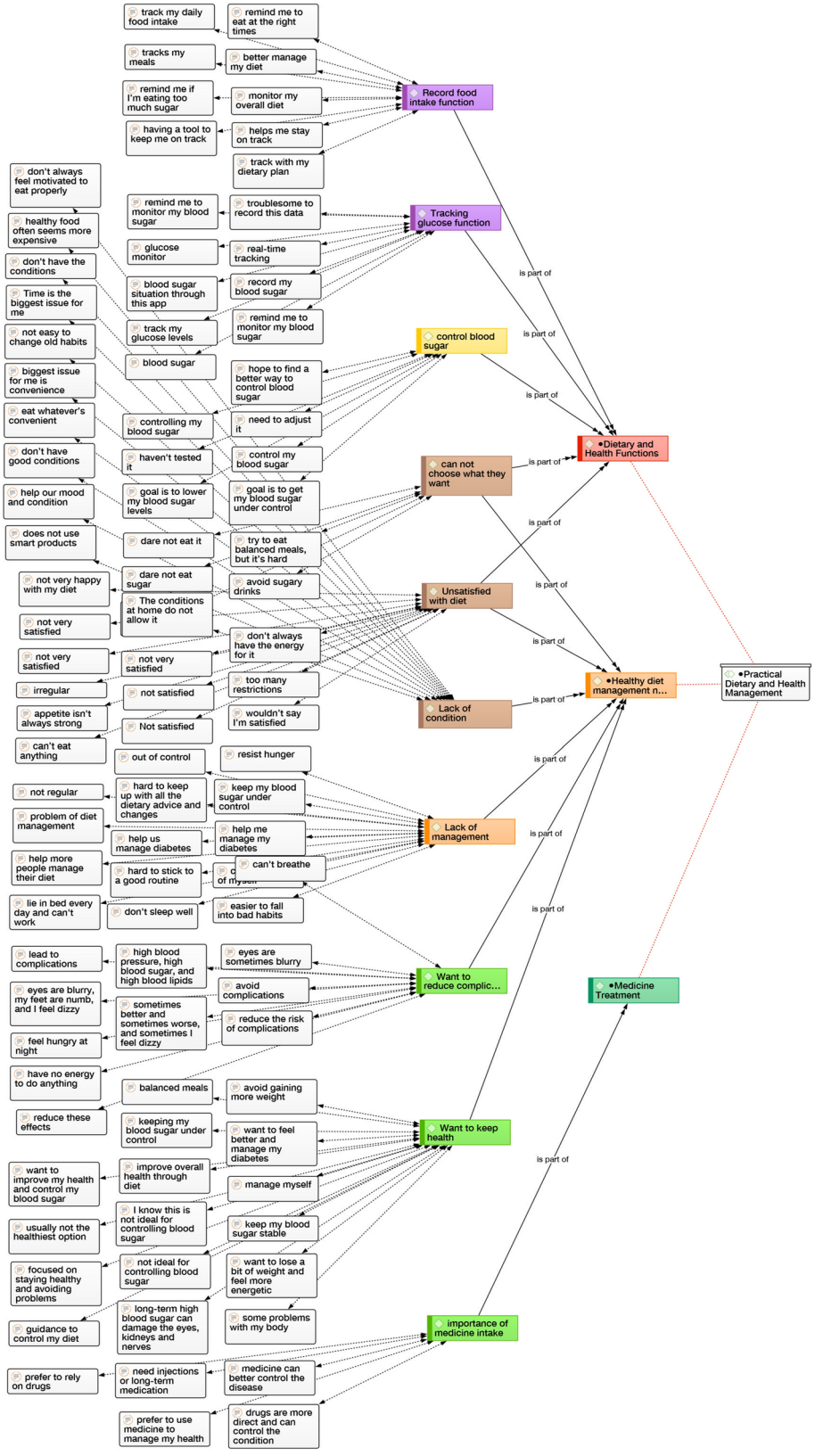


Fig. 3 Theme 2 generation and network among codes, categories and themes. (Source: Exported from Atlas.ti)

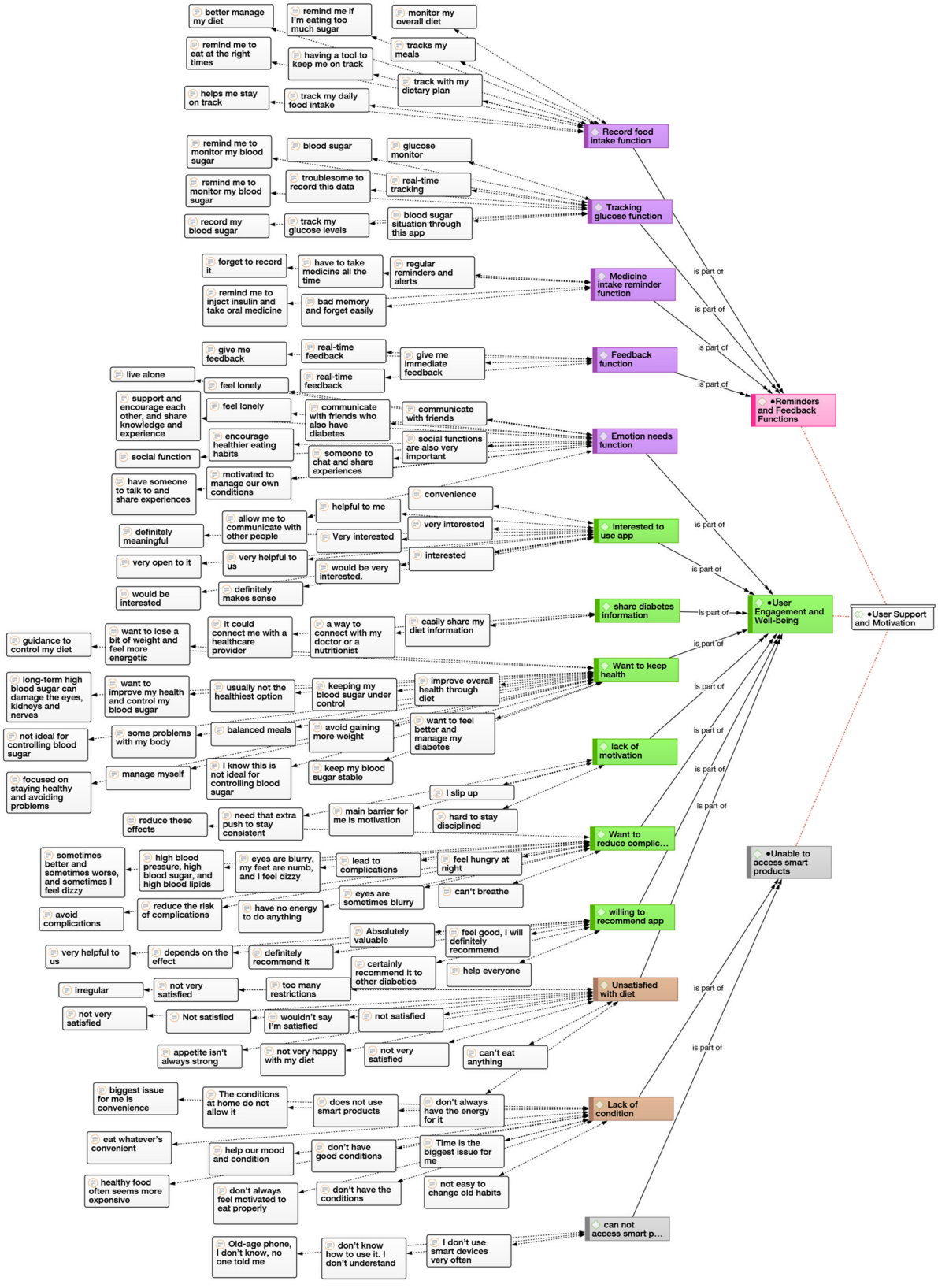


Fig. 4 Theme 3 generation and network among codes, categories and themes. (Source: Exported from Atlas.ti)

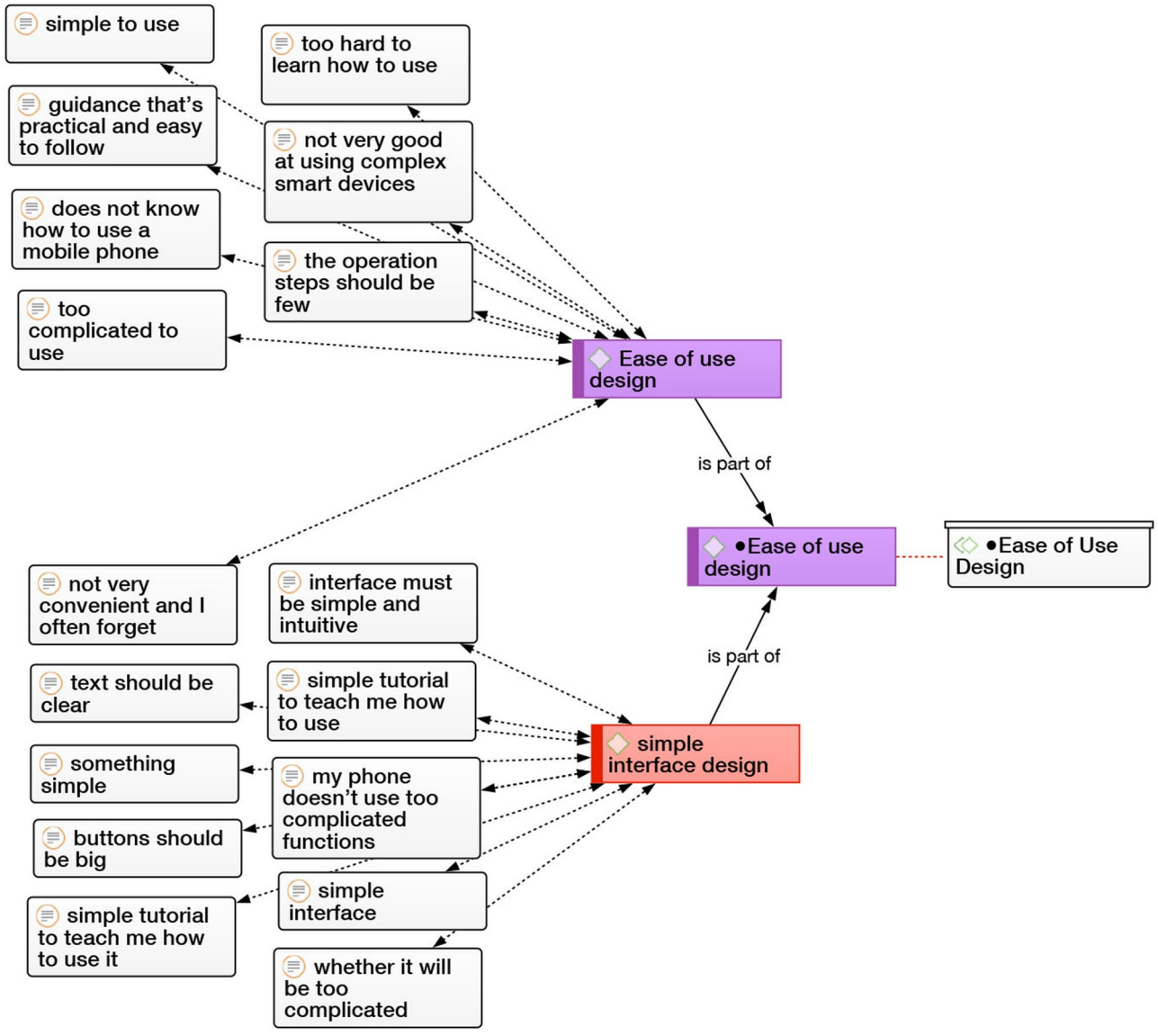


Fig. 5 Theme 4 generation and network among codes, categories and themes. (Source: Exported from Atlas.ti)

better if there was a simple tutorial to teach me how to use it."" — Participant B01

These four themes provide a grounded understanding of the practical, emotional, and cognitive needs of older adults with type 2 diabetes. They serve as core design criteria for the proposed ageing-oriented smart product interface design framework and support future development of inclusive digital health tools.

Validity and reliability of the interview

To ensure the validity and reliability of the interview data, several strategies were implemented. First, triangulation was applied by cross-verifying the interview results with findings from the literature review, as illustrated in Fig. 1. This approach helped confirm that the interview questions effectively captured the intended constructs related to the needs and experiences of older adults with type 2 diabetes. Additionally, thematic analysis was conducted using ATLAS.ti software to identify consistent patterns and themes across participants'responses. This analytical process contributed to the internal consistency and coherence of the findings. To further enhance the trustworthiness of the data, member checking was employed. Selected participants were contacted after the interviews to review and validate key points and interpretations derived from their responses. This step ensured that the findings accurately reflected the participants' perspectives. Finally, the study involved peer debriefing, where research team members independently reviewed coding procedures and thematic interpretations. This served as an internal audit to reduce potential researcher

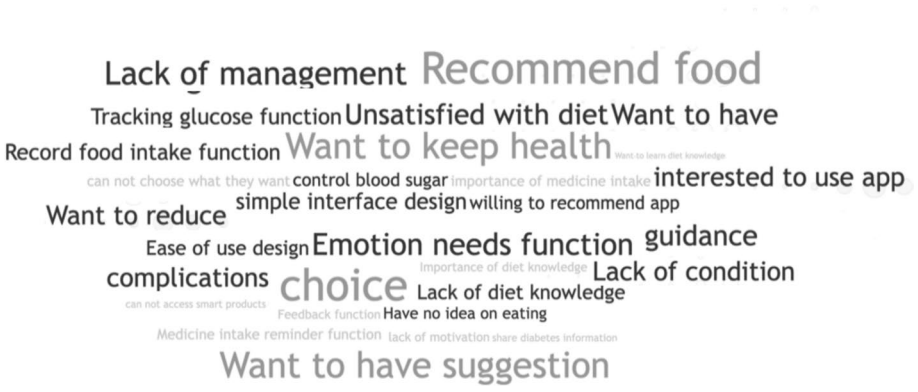


Fig. 6 The world's cloud of need for older adults with type 2 diabetes. (Source: Exported from Atlas.ti)

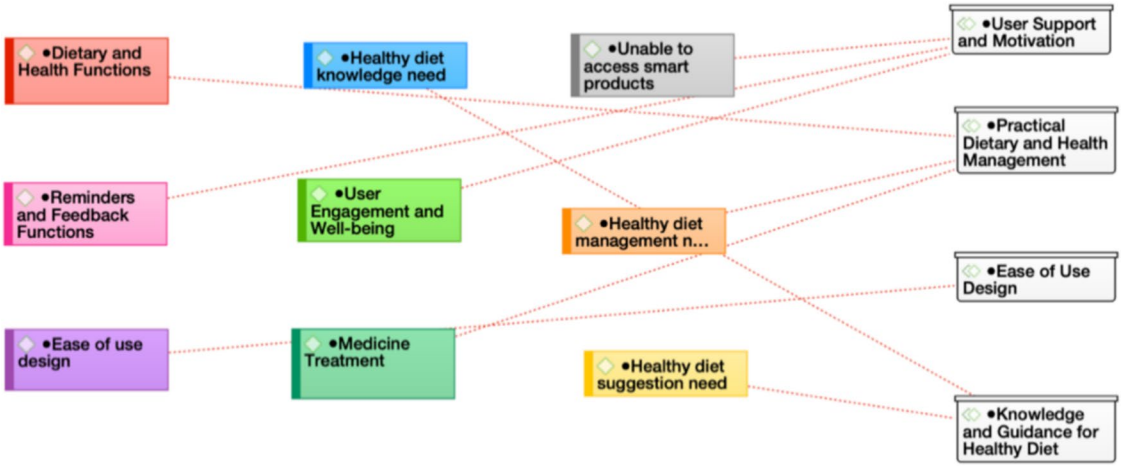


Fig. 7 Summary of The categories map. (Source: Exported from Atlas.ti)

bias and strengthen the credibility of the analysis. Collectively, these methodological steps ensured that the interview data were both valid and reliable, supporting the robustness of the qualitative findings presented in this study.

Summary of the findings of interview

This section synthesizes the insights gained from interviews with older adults with type 2 diabetes, addressing their preferences and needs regarding smart health products. The analysis, visualized through a word cloud and code mapping in Fig. 6, underscores the significance of a user-centered design approach. Key findings indicate that older adults with type 2 diabetes prioritize personalized food recommendations, user-friendly interfaces, and real-time glucose tracking capabilities in smart products.

Participants expressed a significant need for personalized dietary guidance, emphasizing the importance of tailored meal plans that consider their health conditions and lifestyle. They also highlighted the necessity for motivational support features within smart products, such as reminders and motivational messages, to help them adhere to their dietary and medical regimens.

Moreover, the interviews revealed a gap in dietary knowledge among the older adults, indicating a strong demand for educational content within smart health applications. This educational component should provide clear, practical dietary advice that is easy to understand and apply in daily life. The findings also pointed towards the importance of ease of use in design. Users desire interfaces that are simple, intuitive, and do not require extensive technical knowledge to operate, thereby reducing barriers to adoption and use.

According to these findings, the key themes identified from the interviews include "Knowledge and Guidance for Healthy Diet", "Practical Dietary and Health Management", "User Support and Motivation", and "Ease of Use Design". (As presented in Fig. 7). These themes are crucial for the development of a conceptual framework aimed at guiding the design of smart products for older adults with type 2 diabetes.

These insights are instrumental in shaping a proposed model that prioritizes comprehensive health

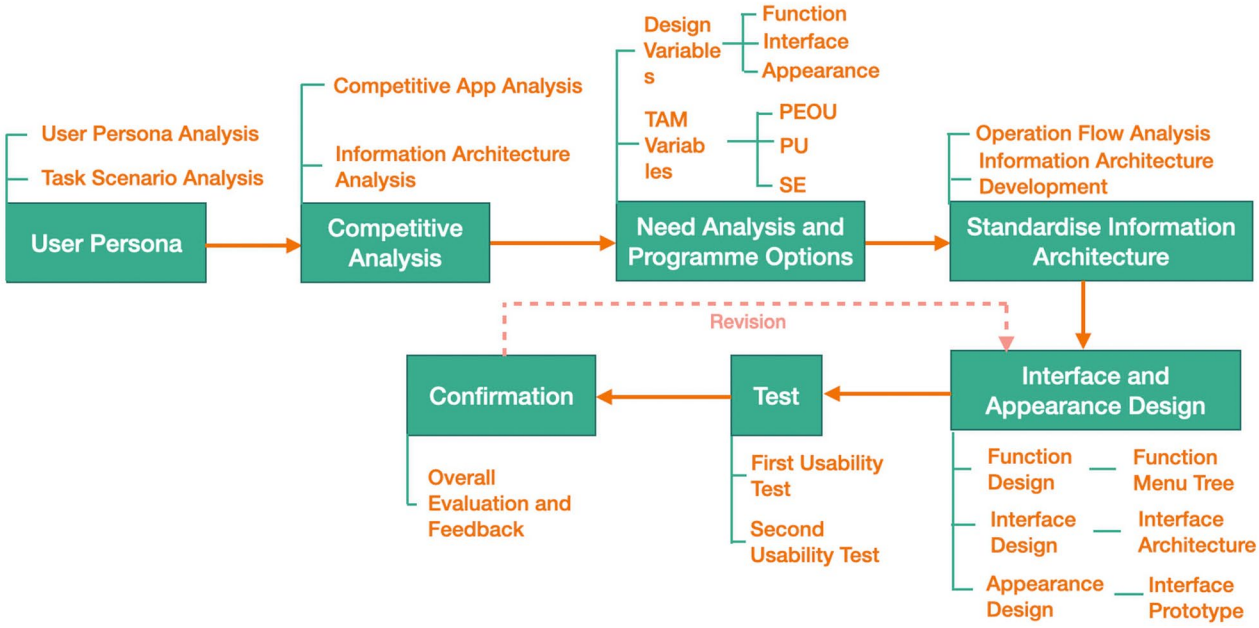
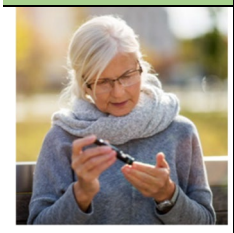


Fig. 8 Procedure of app design for older adults with type 2 diabetes. (Source: Author's own drawing)

Table 3 User persona and task scenario

User Persona	Basic information
	**Name:** Li Huifang **Age:** 66 Years **Gender:** Female **Career:** Cleaner **Diabetic Type:** II **Healthy Status:** Chronic diseases (high blood pressure), poor memory, reduced reflexes. **Incoming:** 3000 RMB/ Month **Living Status:** Lives with her partner and is visited regularly by her daughters. **Needs of Diet:** Healthy diet guidance and knowledge; Motivation and user support, health management, practical dietary.
Task	In the morning, she wants to have breakfast.
Scenario 1	Diabetic older adults' reminders and guidance on healthy eating before the breakfast preparation.
Scenario 2	Diabetic older adults want to shop for diabetic-friendly foods before doing a breakfast.
Scenario 3	Diabetic older adults want to know about the impact of different foods on their health, she needs to choose the health food for breakfast.
Scenario 4	Diabetic older adults seeking assistance or troubleshooting when doing the breakfast.
Scenario 5	After finished breakfast, diabetic older adults need know and record blood sugar levels.
Scenario 6	Diabetic older adults needing encouragement to maintain healthy eating habit when making breakfast.

(Source: Author's own drawing)

management, personalized guidance, and user-friendly, supportive design. The model serves as a valuable guide for future research endeavors and practical applications within the realms of healthcare and technology, ensuring that smart products are not only technologically advanced but also emotionally engaging and accessible to the older adults demographic.

Design and development of conceptual design

The conceptual design of the healthy diet app for older adults with type 2 diabetes is grounded in user-centered design (UCD) principles and supported by usability frameworks such as the Technology Acceptance Model (TAM). This phase integrates theoretical constructs with practical design inputs to ensure that the product addresses the cognitive, physical, and behavioural needs of older adults.

As illustrated in Fig. 8, the design process begins with the development of user personas and scenario-based analysis to contextualize user behaviour within real-world dietary routines. Drawing on Li et al.'s persona (Table 3), key attributes such as chronic illness, cognitive limitations, and dietary requirements inform the app's foundational structure. This aligns with UCD practices

emphasizing empathy and accessibility in early design stages.

A competitive analysis was conducted to assess existing market solutions and uncover usability gaps, particularly in interface simplicity and functionality alignment with older adults' abilities. Building on this, the need analysis incorporated TAM variables—Perceived Usefulness (PU), Perceived Ease of Use (PEOU), and Self-Efficacy (SE)—to translate user expectations into actionable design requirements.

The subsequent phases applied information architecture principles to structure content hierarchies and optimize navigation. Consistent with usability heuristics (e.g., Nielsen's principles), interface and appearance design focused on minimizing cognitive load, maximizing clarity, and ensuring error-tolerant interactions. Task scenarios, such as meal preparation and glucose monitoring, were simulated to validate operation flows under realistic constraints.

The iterative testing phase introduced prototype evaluations through usability tests, with revisions based on feedback loops aimed at refining the user experience. This holistic process demonstrates the fusion of theoretical usability principles with practical design strategies to support older adults with type 2 diabetes in managing their health more independently and effectively.

Need analysis and programme options

Based on the literature review and interviews, the study summarizes the key needs of older adults with type 2 diabetes—such as diet guidance, knowledge, motivation, and health management—into product design variables and user perceptions. Table 4 below outlines user scenarios, behaviors, goals, and indicators for each need. Proposed solutions include features like personalized meal plans, interactive learning, real-time tracking, reminders, and virtual assistants. These aim to support glucose control, improve knowledge, and simplify daily tasks. The design emphasizes AI recommendations, community interaction, and customization to enhance health outcomes and user satisfaction.

Development of high-fidelity prototype

The high-fidelity prototype was developed to represent the core functionalities and user interface (UI) tailored for older adults with type 2 diabetes. It incorporated five primary modules—"Home" icon (diet tracking), "Health" icon (health monitoring), "Scan" icon (food scanning), "Knowledge" icon (educational content), and "Activity" icon (exercise recommendations), each aligned with the needs identified through user persona analysis and task scenarios (see Table 5).

Developed using Figma, the prototype simulates realistic user interaction, allowing stakeholders to engage with the application's structure and interface flow. To streamline presentation, page content has been consolidated to focus on the functional value of each module while minimizing descriptive redundancy.

Although a full usability evaluation has not yet been conducted, a structured usability testing phase is planned. This will involve task-based scenarios to evaluate ease of navigation, comprehension of features, and overall user satisfaction among older adults with type 2 diabetes. (To preview the interactive prototype, please check supporting document 6.)

Diet function page

The Diet Function page is designed to help users manage their daily meal plans, track caloric intake, and monitor diet-related goals. Based on the key function 1 diet requirement, a diet function structure diagram was developed to provide guidance for the following prototype interface, wireframe and UI design which were presented in Fig. 9. It provides an overview of the daily meal plan, displaying caloric intake and progress through visual elements like bars and graphs. Users can view and log meals for breakfast, lunch, and dinner while keeping track of their macronutrient breakdowns, including carbohydrates, proteins, and fats. The interface supports personalized meal plans and manual input for food logging, with visual food recommendations to make the experience engaging. Additionally, the page includes a water intake tracker, allowing users to monitor their hydration through simple, intuitive icons.

The page also features comprehensive diet goal tracking with visual analytics, offering insights into users'caloric consumption trends over time. The interface emphasizes ease of use, providing meal recommendations based on previous dietary data, while also supporting users'dietary goals with clear visual representations of their progress. Through a combination of personalized meal planning, food logging, water tracking, and graphical feedback, the Diet Function page serves as a practical tool for users to maintain a balanced and healthy diet.

Health function page

The Health Function Page serves as another key function of the application, offering users a detailed and accessible overview of their health metrics, including blood sugar levels, weight, and other vital signs. Based on the key function 2 requirement, a health function structure diagram was developed to provide guidance for the following prototype interface, wireframe and UI design which were presented in Fig. 10. This page is meticulously designed to be both informative and user-friendly, featuring a dashboard that presents health data through intuitive graphs and charts. The visual representation of trends over time allows users to monitor their health

Table 4 Needs and task scenario analysis

Target User	User Needs	User Scenario	User Behaviour	Goal of User Experience	Key Factors	Solution
Diabetic older adults; general older adults	Healthy diet guidance	Diabetic older adults need reminders and guidance on healthy eating habits during meal preparation	Regularly checking app notifications for meal suggestions and following personalized diet plans	To receive clear, actionable dietary guidance and meal suggestions that are easy to follow	1). daily calorie and nutrient targeting, 2). ai-based recommendation,	Personalized Meal Plans: Incorporate a feature that allows users to input personal data (age, weight, blood glucose levels) to generate daily or weekly meal plans based on their dietary needs. The AI would adjust these plans dynamically based on daily glucose readings or user activity Real-Time Diet Tracker: A feature that tracks the intake of calories and nutrients in real-time, with a user-friendly interface to log meals and get instant feedback on their dietary choices
	Healthy diet knowledge	Diabetic older adults learning about the impact of different foods on their health, particularly in managing diabetes	Engaging with educational content in the app, such as articles, videos, or infographics on diabetic-friendly diets	To increase awareness and knowledge of healthy dietary choices tailored to their diabetic condition	1). education content,	Interactive Learning Modules: Develop a section of the app dedicated to educating users on diabetes management and healthy eating through short videos, infographics, quizzes, and articles. Content can be customized based on the user's current knowledge level Push Notifications: Regularly send reminders and educational tips through notifications to reinforce good dietary habits
	Motivation	Diabetic older adults needing encouragement to maintain healthy eating habits and manage their condition consistently	Responding positively to motivational messages, challenges, or goal-setting features in the app	To feel encouraged and supported in maintaining a healthy lifestyle	1). gamification & achievement badges; 2). community support;	Achievement Tracking: Implement a points-based system where users earn badges or rewards for completing certain health goals (e.g., consistent meal logging, maintaining blood sugar within a healthy range, etc.). Users can track their progress visually, which increases motivation Social Features: Build a community feature where users can share progress, tips, and recipes, or join challenges with other diabetic older aduts users. A virtual community will foster social support and motivation
	Health management	Diabetic older adults managing not only their diet but also their overall health, including blood sugar levels and exercise routines	Using the app to track blood glucose, medication schedules, and monitor overall health data	To easily monitor and manage health data in one place, with seamless integration into their daily routine	1). Diet logging & tracking, 2). health monitoring; dietary restrictions,	Integrated Health Dashboard: Create a dashboard that displays essential health metrics such as blood glucose levels, daily food intake, physical activity, and medication schedules in one place. The dashboard should provide a comprehensive view of the user's overall health Automated Alerts: Set up an alert system that notifies users of missed meal logs, irregular blood glucose levels, or medication schedules to help them stay on track

Table 4 (continued)

Target User	User Needs	User Scenario	User Behaviour	Goal of User Experience	Key Factors	Solution
	User support	Diabetic older adults seeking assistance or troubleshooting for app-related issues or health inquiries	Accessing user support via the app's customer service or FAQ sections or connecting with healthcare providers	To have easy access to reliable support when needed, including both technical support and health-related guidance	1). expert; virtual assistant& help center, 2). reminders & alerts, feedback loop,	Virtual Assistant: Develop a chatbot that provides real-time answers to common questions related to diet, glucose management, and the use of the app itself. The assistant can also help troubleshoot issues or guide users on how to log meals or check health stats Feedback Loop: Provide personalized feedback after every logged activity (e.g., food logging, glucose entry), offering suggestions for improvement or reinforcement when goals are met. This keeps users engaged and informed about their progress
	Practical dietary	Diabetic older adults needing practical solutions for meal preparation and shopping for diabetic-friendly foods	Using the app to get practical tips for grocery shopping, meal planning, and cooking healthy meals	To simplify the process of planning and preparing healthy meals through practical, real-world solutions	1). meal plan flexibility, 2). physical activity tracker	Customizable Meal Plans: Enable users to swap out ingredients or entire meals based on their preferences, allergies, or restrictions while still maintaining the nutritional goals of their plan. This allows flexibility in meal preparation Exercise Integration: Integrate an activity tracker that monitors physical activity such as steps, walking duration, and exercises that can positively influence blood glucose levels. Encourage users to follow simple exercises to complement their diet management

(Source: Author's own drawing)

status effectively and identify patterns that may require attention. At the forefront of the Health Function Page is the user's profile, complete with a profile picture, nickname, and a brief introduction, fostering a personalized experience. The page is equipped with interactive elements such as sliders and dropdown menus, enabling users to customize the data they view and filter it according to specific dates or time ranges. In this page, the family members or caregivers can easily access the health data to assist with the older adult's daily activities. Additionally, the page includes tools for health management, like medication reminders and a calendar for health check-ups, which are essential for users who need to adhere to treatment plans and maintain regular health monitoring.

Scan function page

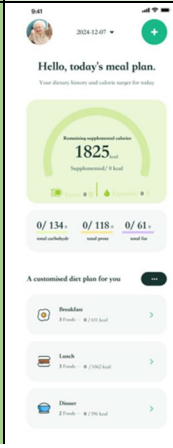
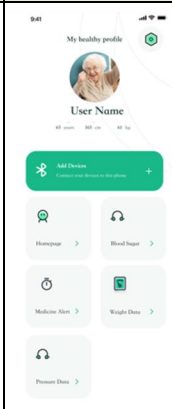
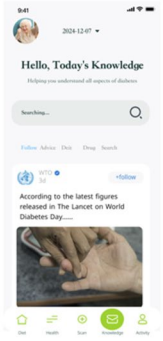
The Scan Function Page is a pivotal feature of the application, designed to streamline the food tracking and recording process for users. Based on the key function 3 requirement, a scan function structure diagram was developed to provide guidance for the following prototype interface, wireframe and UI design which were presented in Fig. 11. For future app development, the ML Kit platform—an open-source machine learning framework will support on-device AI analysis. ML Kit provides robust and accessible tools for integrating AI-powered features such as image recognition and text extraction, making it an ideal solution for elderly-friendly smart applications. Utilizing AI technology, this page allows users to capture images of their meals, which are then analyzed to log with the application. This, in turn, supports users in making well-informed decisions regarding their dietary habits and overall health. The Scan Function Page is a testament to the application's dedication to providing a comprehensive tool that meets the diverse needs of its user base, promoting a healthier lifestyle through informed food choices.

Knowledge function page

The Knowledge Function Page within the application is a specially crafted educational resource aimed at enhancing users'understanding of diabetes management. Based on the key function 4 requirement, a knowledge function structure diagram was developed to provide guidance for the following prototype interface, wireframe and UI design which were presented in Fig. 12. This page is a repository of curated articles and resources that provide comprehensive information on various aspects of living with diabetes. It is organized into accessible categories like'Recommendation','Diet', and'Medicine', each designed to offer focused insights into different facets of diabetes care. The page also features a robust search function with filters for'Hot news','Interested', and'History', allowing users to efficiently find relevant content and revisit past readings.

Furthermore, the Knowledge Function Page is a testament to the application's dedication to user empowerment through knowledge. It is designed to be a go-to resource for users seeking to deepen their knowledge

Table 5 Prototype UI function pages

Function Introduction	**Home page** (Diet track function) This page served as the primary hub for users to view their daily meal plan, track their caloric intake, and monitor their diet goals. The interface displayed remaining calories and categorized the user's meals (e.g., breakfast, lunch, dinner) to support personalized diet management.	**Health page** (Health management function) The health page offered users an overview of their health data, including blood sugar, weight, and other vital statistics. This page helped users track their health metrics and integrate their health devices for seamless monitoring. This feature is developed to ensure that older adults can choose to share specific data with selected caregivers, promoting both autonomy and collaborative care.	**Plus page** (Food scan and reorganization function) This page allowed users to scan and record their food data. Users could upload information about their meals, which would then be categorized for analysis and future reference, streamlining their dietary logging.	**Knowledge page** (Health diet related knowledge function) Here, users could access curated articles and resources related to diabetes management. The page was designed to help users stay informed on the latest research and advice, enhancing their understanding of healthy living with diabetes.	**Activity page** (Daily work out and acticities recommendation and record) This page encouraged users to maintain an active lifestyle by recommending personalized workout plans. The interface tracked calories burned through physical activities and suggested appropriate exercises to complement their dietary plans.
Prototype Function UI Pages					

(Source: Author's own drawing)

about diabetes, offering a mix of scientific articles and practical advice from healthcare professionals. The page's educational content is presented in an easily navigable format, with thumbnails and brief descriptions for each article, facilitating quick browsing and selection. By offering this wealth of information, the page supports users in making informed decisions about their health and encourages a proactive approach to managing their condition, ultimately contributing to their overall well-being.

Activity function page

The Activity Function Page encourages diabetic users to stay active by offering personalized workout plans, calorie tracking, and progress monitoring, as Fig. 13 presented. It includes daily exercise schedules, estimated calorie burn, and visual activity graphs. Users can log workouts, explore new activities, and track progress with intuitive features like"Start workout"and date selection. Designed to be engaging and motivational, this page supports users in building consistent, healthy exercise habits as part of overall diabetes management.

Discussion

This study examined the unique dietary and technological needs of older adults with type 2 diabetes and developed a conceptual mobile application to support their daily health management routines. Grounded in user-centered design principles, the study integrated interview findings and prototype testing to inform a high-fidelity app design that supports diet tracking, personalized meal planning, health monitoring, knowledge access, and motivational prompts.

As shown in Fig. 14, the prototype evolved through iterative stages—from early sketches to a refined, interactive interface—with core functions designed specifically for ease of use by older adults. The interface emphasized large, legible fonts, high-contrast visuals, minimal

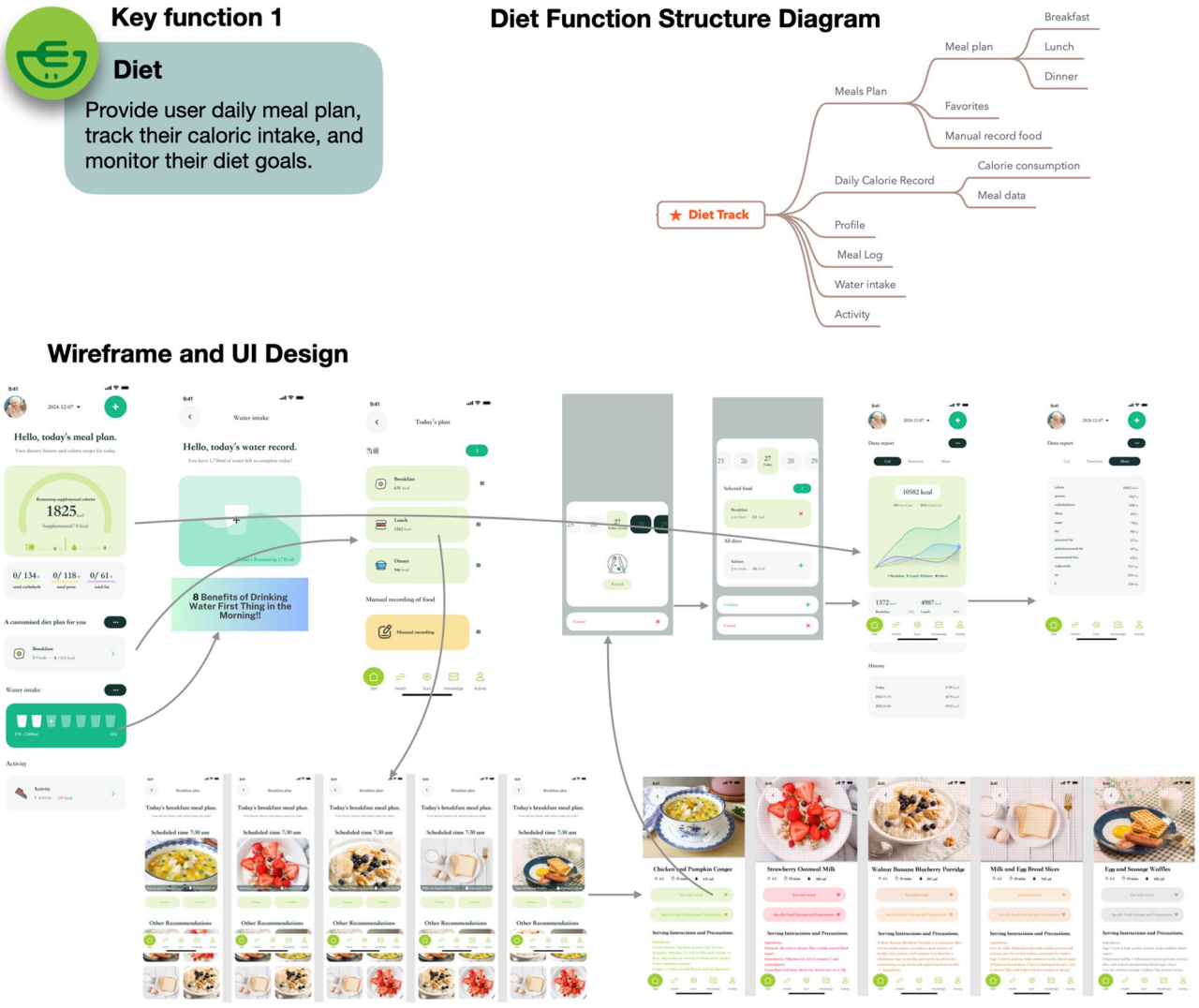


Fig. 9 Prototype design flow of diet function page. (Source: Author's own drawing)

cognitive load, and intuitive navigation, drawing on user centered design principles.

Beyond this individual app, the findings offer broader implications for both designers and healthcare providers. For designers, this study illustrates how a user-driven process—anchored in both qualitative insight and design theory—can produce products that genuinely meet older users' needs. Healthcare providers may draw from this model to implement or recommend digital tools that not only inform but also empower older adults patients in managing diet-related conditions. Embedding motivational and educational support features can bridge the gap between clinical recommendations and daily behaviour.

One of the key strengths of this study lies in its integration of qualitative insights with a user-centered design approach, specifically targeting the underrepresented group of older adults with type 2 diabetes. Unlike many previous studies that focus primarily on general adult users or adopt a purely technological perspective, this research grounds its conceptual design in the lived experiences, preferences, and challenges of the older adults population, gathered directly through interviews [42]. By incorporating specific age-related considerations—such as simplified navigation, large typography, and motivational support—the prototype addresses both functional and emotional needs, which are often overlooked in existing health applications. Furthermore, the study contributes a theoretically informed framework by applying the TAM, offering a structured lens through which to evaluate and improve older adults user acceptance. This combination of theory-driven design and practical interface development advances the current literature and provides a valuable foundation for future ageing-oriented health technology innovations [39].

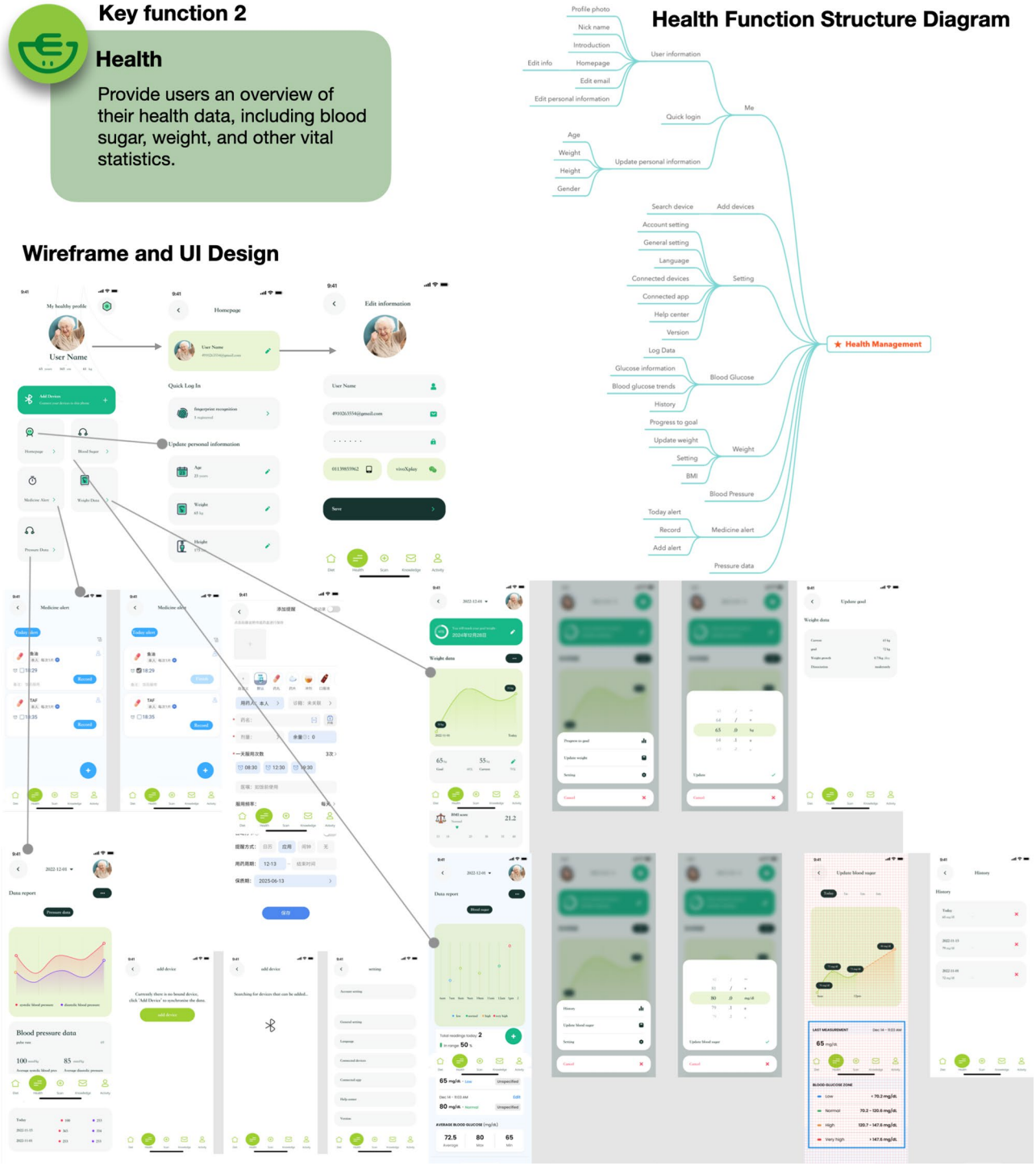


Fig. 10 Prototype design flow of health function page. (Source: Author's own drawing)

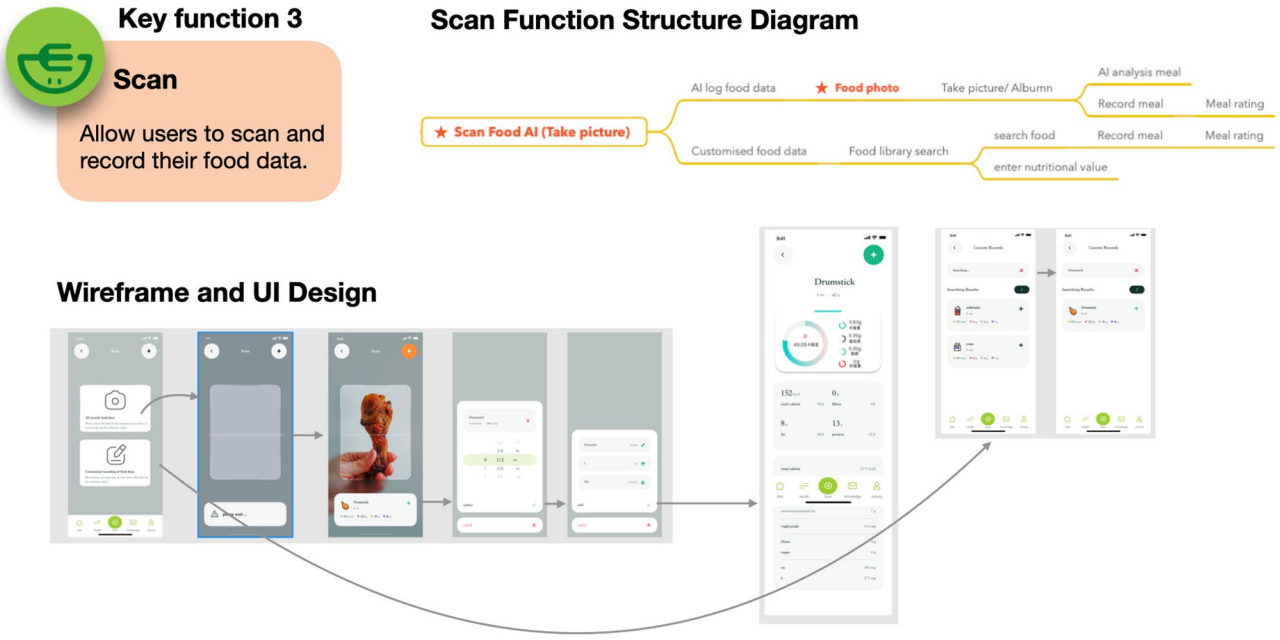


Fig. 11 Prototype design flow of scan function page. (Source: Author's own drawing)

Nonetheless, several limitations should be acknowledged. First, the interview sample was geographically limited and relatively small, which may affect the representativeness of findings [16], current qualitative research is a part of the first step research, so it is also note that future quantitative questionnaire research will continue in this research would enlarger from including a broader and more diverse sample across different regions, health conditions, and socioeconomic backgrounds to enhance the representativeness and applicability of the results. Second, while the prototype received preliminary evaluation in a controlled setting, it has yet to be tested in real-world environments with long-term usage. Factors such as digital literacy, ongoing usability, and compliance over time remain unexamined. Third, cultural and dietary variations across regions were not fully accounted for, potentially limiting the global applicability of the design [21].

Future research should include field-based usability testing across diverse populations, especially in rural or underrepresented settings. Longitudinal studies could provide insights into sustained engagement, behaviour change, and health outcomes. Expanding the framework to other chronic conditions or integrating with healthcare systems could further enhance the practical relevance of such tools. Additionally, comparative studies with other design frameworks (e.g., UTAUT or Health Belief Model) could help refine the theoretical underpinnings of ageing-oriented health tech design [22].

Conclusion

This study proposed a conceptual design framework for a healthy diet management application tailored to the specific needs of older adults with type 2 diabetes. Grounded in user-centered and ageing-oriented design principles, the application incorporates essential features such as personalized dietary guidance, real-time health tracking, and accessible user interfaces to improve usability and technological acceptance. The findings highlight the significance of designing inclusive smart health solutions that respond directly to the daily challenges faced by older adults with type 2 diabetes. This contributes to the growing field of digital health by offering a replicable framework for similar user populations managing chronic conditions.

Looking ahead, future development should prioritize real-world usability testing with more diverse and representative samples to assess long-term adoption and behaviour change. Integration with wearable IoT devices, collaboration with healthcare providers for clinical validation, and adaptability for other chronic illnesses are also recommended avenues for expansion. For practitioners, the study provides a practical reference for incorporating elderly-centric design features early in the development process. For policymakers, it emphasizes the value of supporting initiatives that bridge technology and elder care through accessible, evidence-based design.

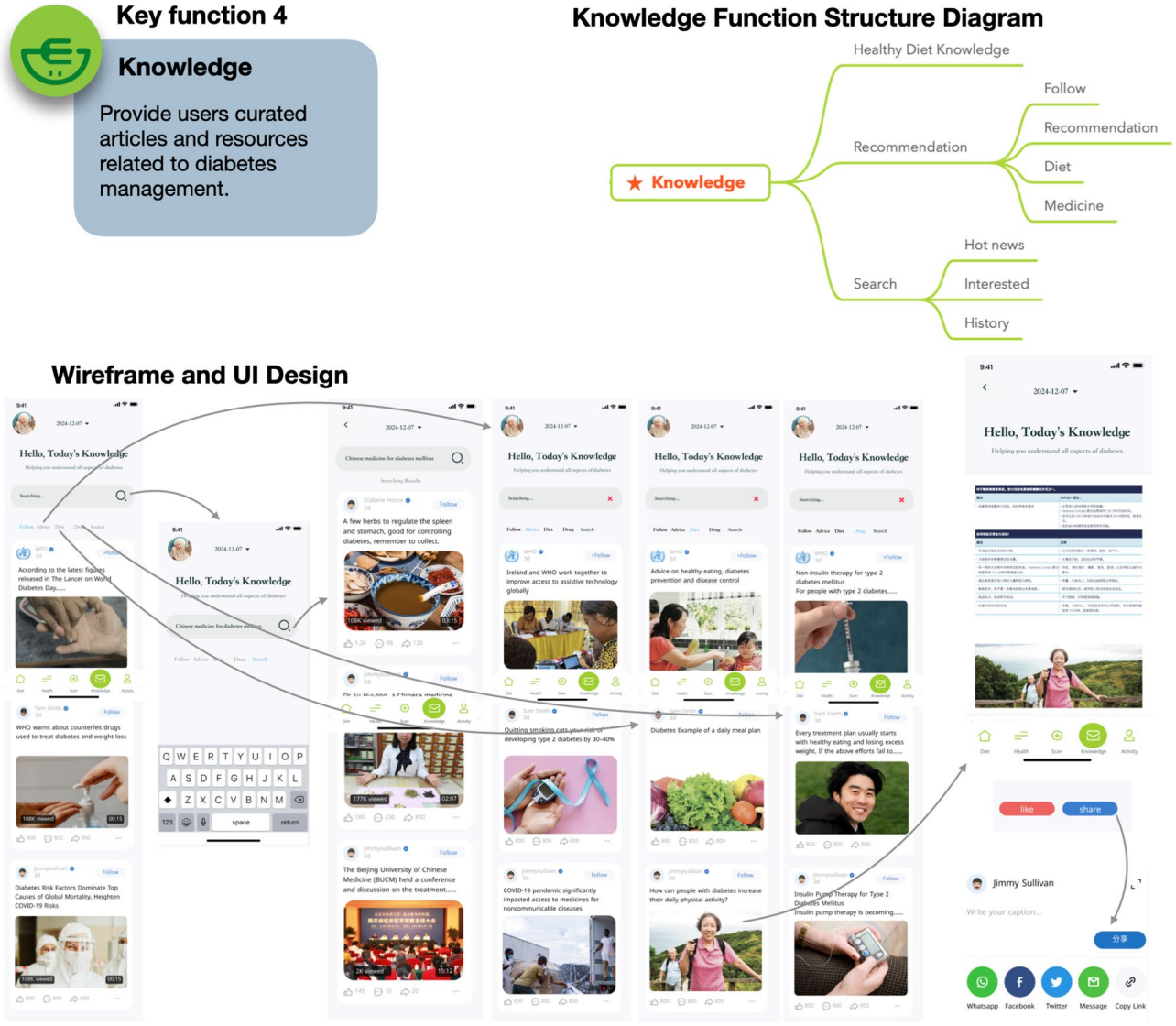


Fig. 12 Prototype design flow of knowledge function page. (Source: Author's own drawing)

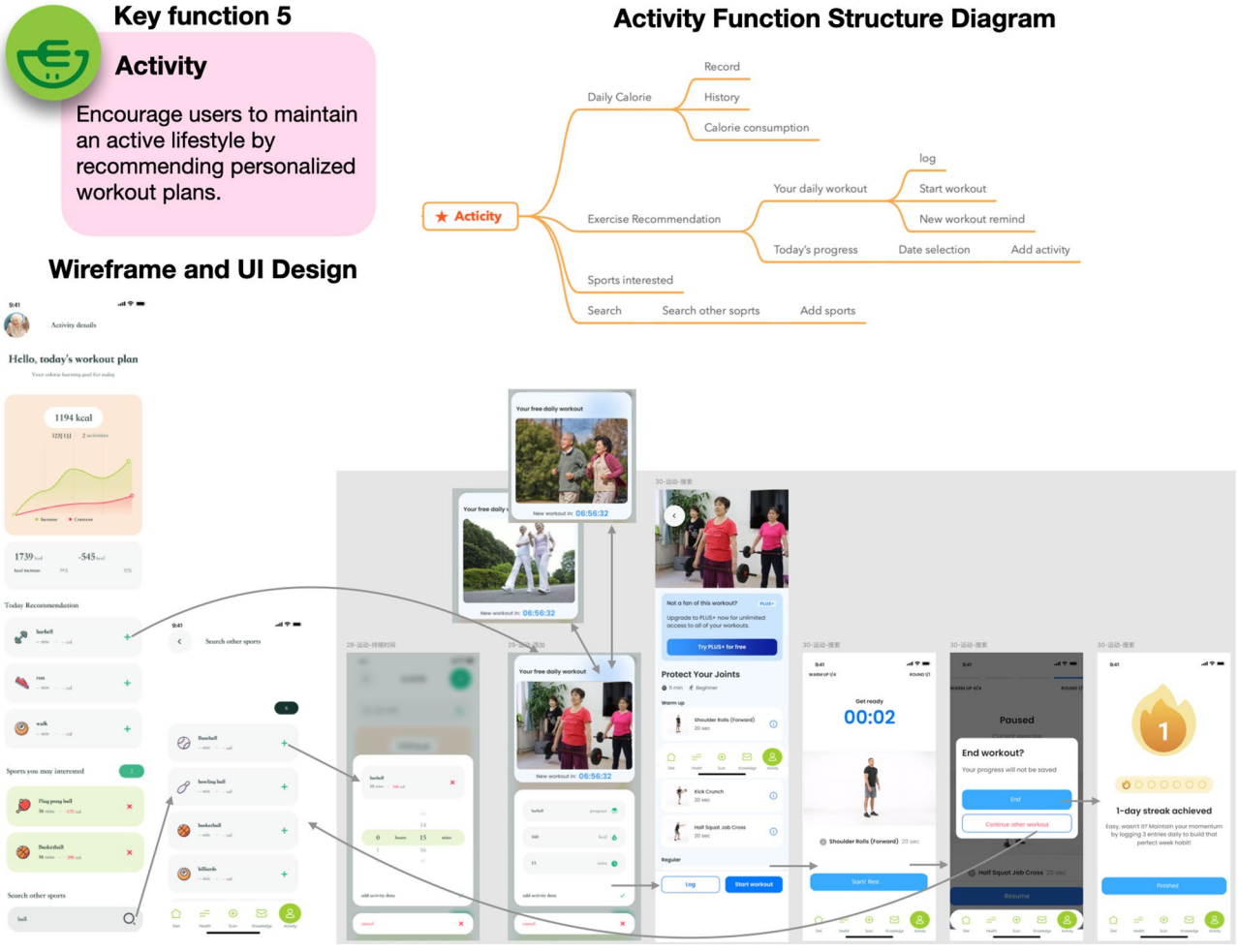


Fig. 13 Prototype design flow of activity function page. (Source: Author's own drawing)

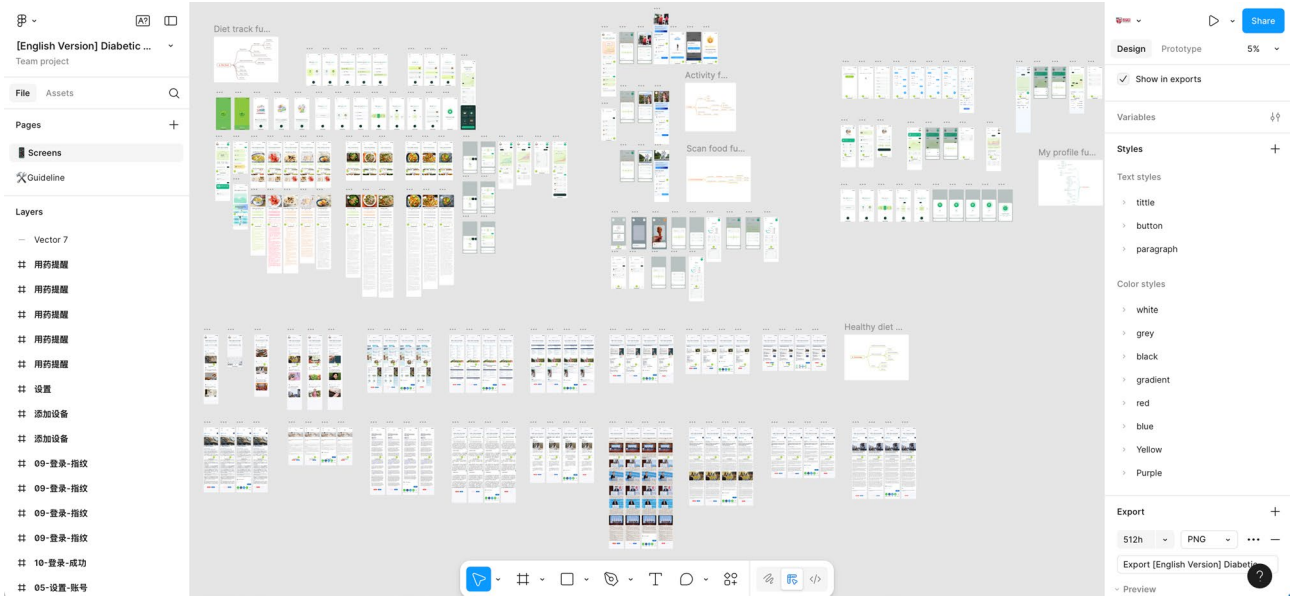


Fig. 14 Mockup and prototype of the first version. (Source: Author's own drawing)

Abbreviations

IoT	Internet of Things
AI	Artificial Intelligence
App	Applications
UI	User Interface
TAM	Technology Acceptance Model
WHO	World Health Organization
CGM	Continuous Glucose Monitor
T2DM	Type 2 Diabetes
ADA	American Diabetes Association
JKEUPM	Ethics Committee Universiti Putra Malaysia
RMB	Malaysian Ringgit

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12877-025-06265-1.

Supplementary Material 1: S1 File. Includes: Section 1: Ethical clearance, Section 2: Fund support, Section 3: Interview protocol, Section 4: Respondent's consent. (DOCX) https://figshare.com/s/788a6cc56e5a802fd230. S2 File. Includes: Records 1-9: the interview record data for participants, Section 5: Interview transcripts to code, Section 6: Code-category-themes-process, Section 7: Participants' demographic information, Section 8: Prototype Document, Section 9: Themes Coding Tree, Section 10: Interview Text Transcript. https://figshare.com/s/788a6cc56e5a802fd230.

Acknowledgements
Not applicable.

Clinical trial number
Not applicable.

Authors' contributions
All authors were involved in the research process: Jinglong Li, Nik Nur Izzati Nik Mohd Fakhruddinc and Rosalam Che Me proposed the interview questions and protocol and conducted the interview process. Faisul Arif Ahmad and Qisen Zhu contributed to this research software supporting and proofreading. All authors have made substantive intellectual contributions to the development of this research and approved the final manuscript for submission to the journal.

Funding
This research was supported by Universiti Putra Malaysia Geran Putra grant (GP-IPS). NO: [GP-IPS/2023/9772400]. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Data availability
All relevant data are within the manuscript and its Supporting Information files. Data documents are available in Figshare at: https://figshare.com/s/788a6cc56e5a802fd230.

Declarations

Ethics approval and consent to participate
The study was approved by the Ethics Committee for Research Involving Human Subjects at Universiti Putra Malaysia (JKEUPM) under reference number JKEUPM-2023–1320 (see supporting documents 1). All procedures involving human participants were conducted in accordance with the ethical principles of the Declaration of Helsinki. Written informed consent was obtained from all participants prior to their inclusion in the study, ensuring ethical compliance and participant confidentiality.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Industrial Design, Faculty of Design and Architecture, Universiti Putra Malaysia, Serdang, Malaysia
[2]Jeffrey Cheah School of Medicine & Health Sciences, Monash University Malaysia, Bandar Sunway, Malaysia
[3]Department of Computer and Communication Systems Engineering, Faculty of Engineering, Universiti Putra Malaysia, Selangor, Malaysia
[4]Faculty of Education, Universiti Kebangsaan Malaysia, Selangor, Malaysia
[5]Malaysian Research Institute on Ageing (MyAgeing), Universiti Putra Malaysia, Selangor, Malaysia

Received: 23 April 2025 / Accepted: 9 July 2025
Published online: 24 September 2025

References

1. Albanese AM, Huffman JC, Celano CM, Malloy LM, Wexler DJ, Freedman ME, Millstein RA. The role of spousal support for dietary adherence among type 2 diabetes patients: a narrative review. Soc Work Health Care. 2019;58(3):304–23. https://doi.org/10.1080/00981389.2018.1563846.
2. Al-Qerem W, Jarab A, Eberhardt J, Alasmari F, Alkaee SM, Alsabaa ZH. Development and validation of the Jordanian diabetic health literacy questionnaire: enhancing diabetes management in Arabic-speaking populations. Healthcare. 2024;12(7):801. https://doi.org/10.3390/healthcare12070801.
3. Alrasheeday A, Alshammari H, Alshammari B, Alkubati S, Llego J, Alshammari A, Alshammari M, Almohammed R, Alsheeb S, Alshammari F. Perceived barriers to healthy lifestyle adherence and associated factors among patients with type 2 diabetes mellitus: implications for improved self-care. Patient Prefer Adher. 2024;18:2425–39. https://doi.org/10.2147/PPA.S432806.
4. Alvarez SD, Fellas A, Wynne K, Santos D, Sculley D, Acharya S, Navathe P, Gironès X, Coda A. The role of smartwatch technology in the provision of care for type 1 or 2 diabetes mellitus or gestational diabetes: systematic review. JMIR mHealth uHealth. 2024;2024(12):e54826.
5. Audulv Å, Sampaio F, Sousa C. Nursing approaches to self-care, self-management, and adaptation to illness. BMC Nursing. 2025;24(1), 81, s12912-025-02737–2. https://doi.org/10.1186/s12912-025-02737-2
6. Bekele TA, Gezie LD, Willems H, Metzger J, Abere B, Seyoum B, Abraham L, Wendrad N, Meressa S, Desta B, Bogale TN. Barriers and facilitators of the electronic medical record adoption among healthcare providers in Addis Ababa. Ethiopia Dig Health. 2024;10:20552076241301944. https://doi.org/10.1177/20552076241301946.
7. Bellary S, Kyrou I, Brown JE, Bailey CJ. Type 2 diabetes mellitus in older adults: Clinical considerations and management. Nat Rev Endocrinol. 2021;17(9):534–48. https://doi.org/10.1038/s41574-021-00512-2.
8. Dimou K, Dragioti E, Tsitsas G, Mantzoukas S, Gouva M. Association of personality traits and self-care behaviors in people with type 2 diabetes mellitus: a systematic review and meta-analysis. Cureus. 2023. https://doi.org/10.7759/cureus.50714.
9. Essaouiba A, Jellali R, Gilard F, Gakière B, Okitsu T, Legallais C, Sakai Y, Leclerc E. Investigation of the exometabolomic profiles of rat islets of langerhans cultured in microfluidic biochip. Metabolites. 2022;12(12):1270. https://doi.org/10.3390/metabo12121270.
10. Fu L, Shi Y, Li S, Jiang K, Zhang L, Wen Y, Shi Z, Zhao Y. Healthy diet-related knowledge, attitude, and practice (KAP) and related socio-demographic characteristics among middle-aged and older adults: a cross-sectional survey in Southwest China. Nutrients. 2024;16(6):869. https://doi.org/10.3390/nu16060869.
11. González-Montero G, Guijarro Mata-García M, Moreno Martínez C, RecasPiorno J. Rehab-AMD: co-design of an application for visual rehabilitation and monitoring of age-related macular degeneration. BMC Med Inform Decis Mak. 2024;24(1): 233. https://doi.org/10.1186/s12911-024-02625-w.
12. Gupta SK, Lakshmi PVM, Chakrapani V, Rastogi A, Kaur M. Understanding the diabetes self-care behaviour in rural areas: perspective of patients with type 2 diabetes mellitus and healthcare professionals. PLoS One. 2024;19(2):e0297132. https://doi.org/10.1371/journal.pone.0297132.
13. He X, Zhang Y, Zhou Y, Dong C, Wu J. Direct medical costs of incident complications in patients newly diagnosed with type 2 diabetes in China. Diabetes Ther. 2021;12(1):275–88. https://doi.org/10.1007/s13300-020-00967-y.
14. Jinglong L, Me RC, Ahmad FA. Investigating Smart Product Design Elements Through a Conceptual Framework in Healthy Diet Monitoring System for Diabetic Elderly. In Y. G. Ng, D. D. I. Daruis, & N. W. Abdul Wahat (Eds.),

Human Factors and Ergonomics Toward an Inclusive and Sustainable Future. 2024;46:51–61. Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-60863-6_5
15. Jinglong L, Me RC, Ahmad FA. Investigating the health diet needs of diabetic elderly in daily life: a systematic review. Edelweiss Applied Science and Technology. 2024;8(4): 1.
16. Jinglong L, Me RC, Ahmad FA, Qisen Z. Enhancing diabetic elderly health diet education through mobile application: an interdisciplinary conceptual framework. Int J Religion. 2024;5(10):5309–19. https://doi.org/10.61707/ah32h289.
17. Jung H, Demiris G, Tarczy-Hornoch P, Zachry M. A novel food record app for dietary assessments among older adults with type 2 diabetes: development and usability study. JMIR Formative Research. 2021;5(2): e14760. https://doi.org/10.2196/14760.
18. Kosmalski M, Ziółkowska S, Czarny P, Szemraj J, Pietras T. The coexistence of nonalcoholic fatty liver disease and type 2 diabetes mellitus. J Clin Med. 2022;11(5): 1375. https://doi.org/10.3390/jcm11051375.
19. Lee J-E. Current status of foodservice nutrition management and effects of welfare facility support for the elderly in Cheongju City. Nurs Res Pract. 2022;16(4):527. https://doi.org/10.4162/nrp.2022.16.4.527.
20. Li C, Wang S, Du M, Wei Y, Jiang S. Clinical characteristics and controllable risk factors of osteoporosis in elderly men with diabetes mellitus. Orthop Surg. 2021;13(3):1001–5. https://doi.org/10.1111/os.12957.
21. Li J, Rosalam CM, Faisul AA, Zhu Q. Investigating the application of IoT mobile app and healthcare services for diabetic elderly: a systematic review. PLOS ONE.. (n.d.);20(4). https://doi.org/10.1371/journal.pone.0321090
22. Liu C, Chong MC, Lee WL, Zhang HY, Zhang JH. Perceptions and self-management of a healthy diet among middle-aged adults with risk of stroke in North China: a qualitative exploration. Open Access. 2025;14(5):e081840.
23. Liu S, Liu J, Yu Y, Si L, Tang C, Liu Z, Chen Y. What is valued most by patients with type 2 diabetes mellitus when selecting second-line antihyperglycemic medications in China. Front Pharmacol. 2021;12:802897. https://doi.org/10.3389/fphar.2021.802897.
24. Malterud K, Siersma VD, Guassora AD. Sample size in qualitative interview studies: guided by information power. Qual Health Res. 2016;26(13):1753–60. https://doi.org/10.1177/1049732315617444.
25. Matthews K, Dawes P, Elliot R, Maharani A, Pendleton N, Tampubolon G. What explains the link between hearing and vision impairment and cognitive function? analysis of mediating effects in the USA, England and Ireland. Int J Geriatr Psychiatry. 2024;39(9):e6149. https://doi.org/10.1002/gps.6149.
26. Miao Y, Luo Y, Zhao Y, Liu M, Wang H, Wu Y. Effectiveness of ehealth interventions in improving medication adherence among patients with cardiovascular disease: systematic review and meta-analysis. J Med Internet Res. 2024;26:e58013. https://doi.org/10.2196/58013.
27. Mohd Tohit NF, Haque M. Gerontology in Public Health: A Scoping Review of Current Perspectives and Interventions. Cureus. 2024. https://doi.org/10.7759/cureus.65896
28. Pai A, Santiago R, Glantz N, Bevier W, Barua S, Sabharwal A, Kerr D. Multimodal digital phenotyping of diet, physical activity, and glycemia in Hispanic/Latino adults with or at risk of type 2 diabetes. NPJ Digit Med. 2024;7(1):7. https://doi.org/10.1038/s41746-023-00985-7.
29. Palumbo F, Crivello A, Furfari F, Girolami M, Mastropietro A, Manferdelli G, Röcke C, Guye S, Salvá Casanovas A, Caon M, Carrino F, Abou Khaled O, Mugellini E, Denna E, Mauri M, Ward D, Subías-Beltrán P, Orte S, Candea C, et al. "Hi this is NESTORE, your personal assistant": design of an integrated iot system for a personalized coach for healthy aging. Front Digital Health. 2020;2:545949. https://doi.org/10.3389/fdgth.2020.545949.
30. Pan C, Yang W, Jia W, Weng J, Liu G, Luo B, Li X, Fu Z, Tian H. Psychological status of Chinese patients with type 2 diabetes: data review of diabcare-China studies: psychological status of Chinese patients with type 2 diabetes. Diabet Med. 2012;29(4):515–21. https://doi.org/10.1111/j.1464-5491.2011.03436.x.
31. Pan M, Li R, Wei J, Peng H, Hu Z, Xiong Y, Li N, Guo Y, Gu W, Liu H. Application of artificial intelligence in the health management of chronic disease: bibliometric analysis. Front Med. 2025;11: 1506641. https://doi.org/10.3389/fmed.2024.1506641.
32. Peleš M, Jevremović S, Simović A, Hadžić A. Possibilities for developing and implementing a mobile application for recognizing the shape of the environment, text, and reading QR codes using the Android CameraX framework and the Machine Learning Kit. (n.d.).
33. Peng S, Zhang X, Liu Y, Fu X, Zhou M, Xu G, Xie C. The efficacy of 5-element therapy for senile diabetes with depression: a protocol for a systematic review and meta-analysis. Medicine. 2020;99(50):e23622. https://doi.org/10.1097/MD.0000000000023622.
34. Qiu S, Sun XH, Liu WY, Kanu JS, Li R, Yu QY, Huang FX, Li B, Zhang YX. Prevalence and correlates of psychological distress among diabetes mellitus adults in the Jilin province in China: a cross-sectional study. PeerJ. 2017;5:e2869. https://doi.org/10.7717/peerj.2869.
35. Rampogu S, Rampogu Lemuel M. Network Based approach in the establishment of the relationship between type 2 diabetes mellitus and its complications at the molecular level coupled with molecular docking mechanism. Biomed Res Int. 2016;2016:1–6. https://doi.org/10.1155/2016/6068437.
36. Rizzi L, Rosset I, Roriz-Cruz M. Global epidemiology of dementia: Alzheimer's and vascular types. Biomed Res Int. 2014;2014:1–8. https://doi.org/10.1155/2014/908915.
37. Rojahn J, Palu A, Skiena S, Jones JJ. American public opinion on artificial intelligence in healthcare. PLoS ONE. 2023;18(11):e0294028. https://doi.org/10.1371/journal.pone.0294028.
38. Shefa FR, Sifat FH, Uddin J, Ahmad Z, Kim J-M, Kibria MG. Deep learning and IoT-based ankle-foot orthosis for enhanced gait optimization. Healthcare. 2024;12(22):2273. https://doi.org/10.3390/healthcare12222273.
39. Shin HR, Um SR, Yoon HJ, Choi EY, Shin WC, Lee HY, Kim YS. Comprehensive senior technology acceptance model of daily living assistive technology for older adults with frailty: cross-sectional study. J Med Internet Res. 2023;25:e41935. https://doi.org/10.2196/41935.
40. Tang S, Zhang R, Si Y, Cheng Y, Gong Y. Measurement of the equality of the drug welfare induction level of Chinese patients with chronic diseases in Gansu, Sichuan, Hebei, and Zhejiang based on the bivariate Theil-T index method. Front Public Health. 2020;8:581533. https://doi.org/10.3389/fpubh.2020.581533.
41. Wang X, Jie W, Huang X, Yang F, Qian Y, Yang T, Dai M. Association of psychological resilience with all-cause and cause-specific mortality in older adults: a cohort study. BMC Public Health. 2024;24(1):1989. https://doi.org/10.1186/s12889-024-19558-8.
42. Wu FL, Tai HC, Sun JC. Self-management experience of middle-aged and older adults with type 2 diabetes: a qualitative study. Asian Nurs Res. 2019;13(3):209–15. https://doi.org/10.1016/j.anr.2019.06.002.
43. Yang L, Shao J, Bian Y, Wu H, Shi L, Zeng L, Li W, Dong J. Prevalence of type 2 diabetes mellitus among inland residents in China (2000–2014): a meta-analysis. J Diabetes Investig. 2016;7(6):845–52. https://doi.org/10.1111/jdi.12514.
44. Yu Z, Luo W, Tse R, Pau G. DMnet: a personalized risk assessment framework for elderly people with type 2 diabetes. IEEE J Biomed Health Inform. 2023;27(3):1558–68. https://doi.org/10.1109/JBHI.2022.3233622.

Publisher's Note