


Acceptability of an AI-enabled family module in a mobile app for enhanced diabetes management: Patient and family perspectives

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Abstract

Objective: To explore the acceptability of family support through an AI-enabled mobile app and identify preferences for its novel family module features among patients with type 2 diabetes (T2DM) and family members.

Methods: Semi-structured interviews were conducted with patients with T2DM and family members. A mock wireframe of the FAMILY module was created to help participants visualize the module features. All interviews were audio-recorded and transcribed verbatim. Inductive thematic analysis using the constant-comparative method was performed to identify and interpret patterns within the data.

Results: A total of 25 patients with T2DM and 25 family members participated in the study. Participants viewed the FAMILY module as a valuable tool for reinforcing patients' self-discipline. However, some patients expressed concerns about family involvement, particularly among those who preferred greater control and autonomy over their self-management plan. Family members also raised concerns about caregiving burden and feelings of self-blame if they were unable to provide adequate support. Regarding module features, participants appreciated algorithm-driven nudges and in-app interactions but emphasized the importance of controlling the frequency of nudges. Features such as collaborative goal setting, report cards, and AI-powered smart logging were found useful. However, family members expressed a need for more personalized in-app advice on patient data and medical terminology to better support patient's self-care. In-app family resources should be tailored to meet the needs of first-time caregivers to enhance the module's usability.

Conclusion: The insights from this study will guide the development of the novel FAMILY module and inform targeted interventions aimed at mitigating risks, managing T2DM-related comorbidities, and enhancing self-care.

Keywords

Artificial intelligence, mHealth, diabetes, family intervention, self-care, digital health

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Introduction

Type 2 diabetes mellitus (T2DM) is a growing global burden due to its high rates of morbidity and mortality. The prevalence of diabetes was 10.5% in 2021, and this percentage is expected to rise to 12.2% in 2040.^{1,2} Poorly managed diabetes can lead to serious complications,^{3,4} including cardiovascular disease, neuropathy, nephropathy, retinopathy, and an increased risk of infections, many of which are worsened by insufficient self-care. These complications place a significant strain on healthcare systems.^{5,6} The mounting social and economic burden associated with poorly controlled T2DM underscores the urgent need for early intervention.

Self-management strategies, such as behavioral modifications and pharmacological interventions, have demonstrated effectiveness in improving the health outcomes of individuals with T2DM.^{6,7} However, many patients continue to experience inadequate glycemic control due to non-adherence to these recommendations. Moreover, some patients struggle with emotional issues, which can impede their ability to effectively manage their condition.⁸ Despite these challenges, conventional care models may be constrained by limited time and resources to adequately support patients.

Evidence suggests that positive family support improves patient health behaviors and outcomes.⁹ The family unit is a complex social system in which interactions among its members influence each other's behaviors.¹⁰ For example, family member can influence health behaviors such as dietary choices, physical activity and oral hygiene practices, and more.¹¹ In T2DM management, family members can offer both practical support, such as accompanying patients to appointments and preparing medications, as well as emotional support by making lifestyle changes alongside the patient. Increased family involvement has been linked to better glycemic control and improved self-care behaviors.^{12,13,14}

Various family-based interventions have been introduced to support adult patients with T2DM and their families in managing the disease and promoting healthy behaviors. Modes of interventions include family coaching sessions, automated calls, educational videos, phone calls from community health workers, and exercise with family members.^{15–17} Several reviews and meta-syntheses have highlighted the role of family support in improving effective self-management and health outcomes such as improved glycosylated hemoglobin levels, body mass index, blood pressure, fasting glucose, diabetes self-care, diabetes self-efficacy, diabetes distress, and positive family support.^{9,18–20} However, most family-based interventions primarily focus on increasing family member knowledge of diabetes management through education. Furthermore, many rely on telephone or face-to-face sessions,^{21–24} which acted as a key barrier to sustainable family participation.²⁵ More recent studies have explored the use of mobile phones to engage family

members, but these interventions mainly involve text messaging for family education and reminders about medication and medical appointments.^{15,26,27}

To date, no intervention has used real-time interactions between patients and family members, such as dynamic monitoring and personalized nudges based on the progress of patients' health behaviors.^{28–30} An AI-driven mHealth application may enhance family involvement and foster interaction within the family unit. However, despite the promise of smartphone-based applications in diabetes management, low user retention remains a significant barrier to their effectiveness in real-world settings. A recent meta-analysis reported a dropout rate of 29.6% in clinical trials of smartphone apps for diabetes management, with notably high rates in studies involving cultural adaptations and those conducted in high-income countries.³¹ These findings underscore the critical need for designing family-based digital health interventions that not only provide value to users but also sustain long-term engagement. Recognizing this challenge, we plan to expand our existing EMPOWER mobile app³² by introducing a new FAMILY module. This module will include features such as personalized nudges, collaborative goal setting, and tailored resources to address factors contributing to user attrition.

The aim of this study is, therefore, to explore the acceptability of family support via AI-enabled mobile app and preferences for FAMILY module features among patients with T2DM and family members. The findings will contribute to the understanding of how AI-driven app features can be tailored to meet the needs of patients with T2DM and families, with a focus on improving self-management, communication, and, ultimately, health outcomes.

Methods

Study design

This study employed a descriptive qualitative research design involving semi-structured interviews. This study was approved by the SingHealth Centralized Institutional Review Board (CIRB2022/2580).

EMPOWER mobile app

The EMPOWER mobile app is an AI-driven adaptive platform designed to provide real-time, personalized educational and behavioral interventions through in-app notifications or nudges. By integrating data from wearable devices such as smartwatches and AI algorithms, the app delivers tailored nudges at optimal moments to support users in maintaining healthy habits. The EMPOWER app's clinical effectiveness is currently being evaluated in ongoing studies.^{32,33}

Participant recruitment

We invited two groups of participants for this study: patients with T2DM and family members of T2DM patients. The eligibility criteria for patients included a diagnosis of T2DM, being aged 21 years and above, and no cognitive impairment. Patients who presented diabetes-related complications or gestational diabetes were excluded. Eligible patients were recruited by two co-authors (RL, HL) from a waiting area of a community health center in Singapore that provides diabetes-related ancillary services.³⁴ In addition, participants who had previously taken part in our past trials of app-based interventions and had given their consent to be contacted for future research were invited to participate in the current study through a phone call.

The eligibility criteria for family members included a spouse or an adult child (over 18 years old) of a patient diagnosed with T2DM, having knowledge of the patient's condition, and participating in some aspects of the patient's diabetes care. Eligible family members were recruited through the invitations extended to patients in the community health center as well as to patient participants in our previous study, as described above. During the recruitment process, a brief questionnaire was used to assess the eligibility for interviews. Since the primary objective of this study was to gather feedback regarding the family-based app intervention and preferred app features, recruitment was not limited to patient-family member dyad. To ensure a diversity of opinions and perspectives, purposive sampling was adopted for both groups, considering factors such as age, gender, patient-family member relationship, and the extent of family member's involvement in patient's care.

Data collection

Semi-structured interviews were conducted by two research team members who had no prior personal relationships with the participants and underwent formal training in qualitative research methods. A semi-structured interview guide was developed, and key topics included (1) potential benefits and drawbacks of the family module in the EMPOWER app in diabetes management, (2) perception and feedback on the specific app features, and (3) willingness to use the app with family members. To aid participants in visualizing the app features, a mock wireframe was presented, showcasing core elements like the profile page, nudges (AI-driven notifications based on patient's clinical record and lifestyle behaviors), medication log, food log, collaborative goal setting, report card, and courses and resources (Figure 1). Prior to the interviews, a written consent was sent to and signed by all participants. The interviews were conducted via online video conferencing and lasted approximately 45 min on average (35 min–65 min). All sessions were audio-recorded with participant consent. Field notes were taken during the interviews to document observations, capture non-verbal

cues, and record any contextual details that could complement the interview data. Data collection continued until data saturation was achieved.

Data analysis

All interviews were transcribed verbatim. Inductive thematic analysis using the constant-comparative method was conducted using NVivo 12 software.³⁵ Transcripts were not returned to participants. Two independent coders (RL and HL) reviewed the transcripts and notes, read through each interview transcript line by line, and extracted relevant text segments, which were then organized into coding categories to derive themes and subthemes. A coding frame was developed after the initial coding of five transcripts with a third research member (SY) and was subsequently applied to all the transcripts. Any emerging code categories that did not fit the initial coding frame were further discussed until consensus was reached. The study team held regular meetings to discuss the interpretations of coding categories, subthemes, and themes to minimize discrepancies between the two coders and ensure that the codes accurately reflected the themes relevant to the research. The findings were not shared with participants for feedback due to time limitations and the logistical challenges involved in re-engaging participants after the data collection phase. However, member checking was performed during interviews. This approach allowed participants to confirm the accuracy of their responses and elaborate further, helping to ensure the validity of the data collected. The reporting in this study follows the Consolidated Criteria for Reporting Qualitative Research (Supplemental material).³⁶

Results

Participant characteristics

We approached 63 individuals, of whom 13 declined participation. In total, 50 participants took part in this study, including 25 patients with T2DM and 25 family members of patients with T2DM (Table 1). Among the patient participants, 60% were male, with a mean age of 53, and 60% had an HbA1c level of 7% and higher. Among the family members of patients with T2DM, 64% were the patients' spouses, while the remaining were patient's children, with a mean age of 45.

Themes and subthemes regarding perceptions and acceptability of the FAMILY module within the EMPOWER app and specific module feedback are presented in Tables 2 and 3, respectively.

Perceptions and acceptability of app-based family involvement in T2DM self-management

Facilitating increased family awareness and involvement in patient's diabetes management. Participants saw the

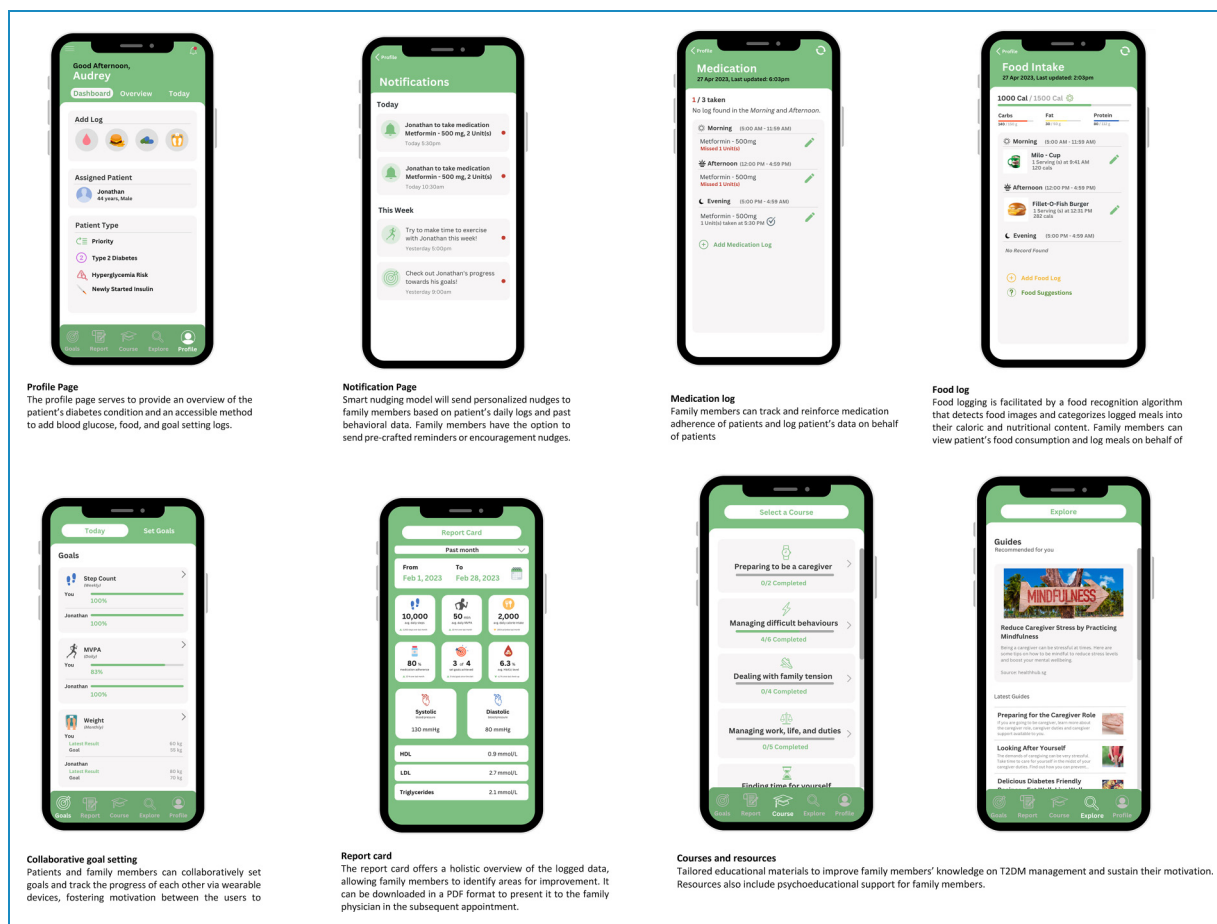


Figure 1. EMPOWER-FAMILY module features.

FAMILY module as a platform for family members to play a more active role in patients' self-management. Some participants mentioned that their busy schedules often hindered them from engaging in discussions about lifestyle habits of the patient. They believed that this module could serve as a catalyst for meaningful conversations about health and nutrition within the family unit, fostering awareness of the patient's condition and enhancing mutual accountability. In addition, participants noted that family members often relied on sporadic updates from the patient and have limited awareness about various aspects of the patient's health routine. They felt that the FAMILY module would enable a more proactive approach in monitoring patient's activities, which can strengthen familial support and bond with the patient.

Positive reinforcement for patients requiring self-discipline.

For better glycemic control, patients must adapt to healthier lifestyle changes, and some acknowledged that the involvement of family members could serve as a positive reinforcement for patients who require more discipline in adhering to these lifestyle regimes. Other participants noted that the

sharing of health data and progress could create a collaborative environment by promoting mutual motivation between patients and family members to adopt these changes together.

Module's utility subject to sustained patient determination and compliance. While the FAMILY module and familial support can significantly improve self-care practices of T2DM patients, it was recognized that the impact of family involvement may be limited under specific conditions. These included a lack of patient's intrinsic motivation to adopt active lifestyle behaviors and limited compliance in consistently logging their data into the module. Some participants were concerned about the potential resistance to family involvement amongst patients who desire greater control and autonomy over their self-management plans. These challenges were seen as factors that could potentially diminish the effectiveness of the module.

Benefits of module for specific family types and patient profiles. Another theme that cut across the interviews was

Table 1. Participant characteristics (N = 50).

Participant characteristics	Patients with T2DM (N = 25)	Family members of patients with T2DM (N = 25)
	N (%)	N (%)
Age (year)		
Mean (range)	53 (31–68)	45 (22–69)
Gender		
Male	15 (60%)	10 (40%)
Female	10 (40%)	15 (60%)
Ethnicity		
Chinese	14 (56%)	16 (64%)
Non-Chinese (Indian, Malay, others)	11 (44%)	9 (36%)
Employment status		
Employed	21 (84%)	16 (64%)
Retired/unemployed	4 (16%)	9 (36%)
Relationship to patient		
Spouse	-	16 (64%)
Child	-	9 (36%)
Patient's HbA1c		
Less than 7%	10 (40%)	6 (24%)
7% and above	15 (60%)	19 (76%)
Duration since patient's diabetes diagnosis (years)		
1 to 10	15 (60%)	19 (76%)
11 to 20	9 (36%)	4 (16%)
More than 20	1 (4%)	2 (8%)

the perception that the FAMILY module would be particularly beneficial for certain family types and patient profiles. Several participants noted that it would be particularly useful for older, more dependent patients who may be less tech-savvy and require assistance from family members in navigating the technical complexity of mobile apps.

Family burden and competing priorities. Although the FAMILY module was recognized as being useful, participants raised concerns regarding the need to reconcile other competing life priorities, including employment and caring for other family members. In addition, there was a concern that family members may experience feelings of self-blame and demotivation if the patient's improvement falls short of expectations, which may potentially lead to a sense of pressure.

Privacy concerns related to sharing patient data. Most participants were open to using the FAMILY module. Nonetheless, a subset of patients indicated a preference for sharing a summary of their activity log with their family members as opposed to disclosing all logged information. This approach allows patients to retain a certain degree of autonomy and independent decision-making. Conversely, some participants emphasized the importance of transparency to allow family members to effectively identify and address patient's needs. Therefore, to accommodate the varying levels of comfort amongst patients, the module should consider offering customizable sharing options with family members to individual patient's preferences.

Usability and preferences for specific EMPOWER-FAMILY module features

Nudges for family members and in-app interaction with patients. Leveraging AI technology, the FAMILY module delivers tailored, algorithm-driven nudges to family members based on lifestyle behaviors of the patient. These nudges cover medication adherence, food intake, sleep, and overall activity progress. In addition, family members can choose from pre-crafted nudges and send them to the patient either as a reminder or as encouragement. Both patient and family member participants acknowledged the value of the nudges that improve family awareness of the patient's health behaviors, enabling family members to offer support accordingly. However, some participants expressed a desire for greater flexibility in customizing both the frequency (e.g. receiving notifications at the end of the day) and content of the nudges (e.g. limiting notifications to medication reminders). Additionally, several patient participants expressed confidence in their ability to adhere to lifestyle changes and thus preferred fewer reminders from family members, indicating a preference for independent management of app nudges.

Collaborative goal setting. The collaborative goal-setting feature and achievement tracking via wearable devices were viewed as beneficial, fostering motivation of patients and encouraging dedicated family time to engage in healthy behaviors together. However, one potential barrier

Table 2. Acceptability of family involvement in AI-enabled mobile app for improved T2DM management.

Themes	Sub-themes	Illustrative quotes
Facilitating increased family awareness and involvement in patient's DM management	<ul style="list-style-type: none"> Improving family awareness Increased family involvement 	<p>"I love the feature where you set the goals...at least at the end of the day, we can discuss what we ate for the day. Actually, sitting down and talking to family members takes time and sometimes they are quite busy, but by having this app, we can look through and make time to discuss." (P25, F, 54)</p> <p>"With this app, I can monitor a bit more because without it, I don't really know about the diet and physical activity record. The medication, most of the time, I don't actively monitor. It's just that I know that she's regular about it. If she misses, sometimes she'll tell me but if she never says, then I don't know. With the app, it can tell me more, I can play a more active role." (F22, M, 52)</p>
Positive reinforcement for patients requiring self-discipline	<ul style="list-style-type: none"> Serving as a form of encouragement for patient's self-discipline Promoting mutual motivations 	<p>"Frankly, speaking, I am really looking forward to all these [features] because sometimes, discipline is very important. I got no discipline. So, it's good to have this [family module]." (P25, F, 54)</p> <p>"I think it's a very good idea to connect the two of us, so it's not just in silo, I will know what she is doing, and I guess we can motivate each other to have a healthier lifestyle in terms of workout and stuff, to be more active." (F15, F, 31)</p>
Module's utility subject to sustained patient determination and compliance	<ul style="list-style-type: none"> Importance of patient determination Challenges of maintaining patient compliance 	<p>"In terms of time spent, this [module] is secondary especially [since] this is my own problem, so I need to focus on resolving it myself. If I can't motivate myself, then having someone to motivate me is not going to benefit much." (P15, M, 42)</p> <p>"This app depends on the person.... for my husband [with diabetes], I don't think he will track. He won't have the diligence to log meals.... I think after a while people may not have that kind of determination to really do it every day consistently. So how do we [family] make them do it? I think that's another thing." (F17, F, 52)</p>
Benefits of module for specific family types and patient profiles	<ul style="list-style-type: none"> Perceived greater benefits for older, vulnerable and more dependent patients 	<p>"If the patient really cannot decide for herself and a caregiver comes, this is a very good thing. The caregiver can look out for the food consumed and give the medicine when there is a missing dose. For a caregiver with a patient who is unable to reach out for her own medicine or anything like that, this is a good app I must say." (P20, F, 60)</p> <p>"...I think some patients don't use the phone regularly, especially for elderly patients, which will be a bit more difficult to manage condition through the app. It's good that there's an extension to the family members who can help with all these things. I think it's a good idea." (F10, M, 27)</p>

(continued)

Table 2. Continued.

Themes	Sub-themes	Illustrative quotes
Family burden and competing priorities	<ul style="list-style-type: none"> • Sense of reluctance due to additional family burden • Family's competing demands 	<p>"I think in general, yes it should help [with my diabetes] but whether we can find time, that's a different thing. Because right now, between my wife and I, we have our own things we need to settle such as our parents." (P15, M, 42)</p> <p>"If family is going to be involved, it's a burden and if things don't move the way they are supposed to move, then I'll feel like I'm not doing my job as a caregiver. My father had cancer, and I was also a caregiver; I know the burden that a caregiver carries and the stress." (P21, M, 52)</p>
Privacy concerns related to sharing patient data	<ul style="list-style-type: none"> • Weighing between willingness to share data with family and concerns about potential privacy implications • Desire to personalize sharing options according to individual comfort levels 	<p>"I think at the end of the day, the whole objective is to get family to help us to look after each other and for us to give them the right information. I think we must be very transparent in what we ate... At least you have somebody helping you and not depending on yourself alone." (P16, M, 57)</p> <p>"If you made it such a way that it gives a summary at certain hour checkpoint for instance, by noon, how much have I eaten in terms of calories, what's my goal, how much have I exercised...I'll be more comfortable rather than a detailed breakdown of everything I do." (P21, M, 52)</p> <p>"I mean everyone would look at their personal information differently. I think when you are developing an app, it should cater for all audiences with consensus, and they should be able to revoke it if they feel otherwise." (F16, M, 49)</p>

Note: P: patient, F: family member.

could be conflicting schedules between patients and family members, as this function requires commitment from both parties. The FAMILY module would enable users to set goals for step counts, moderate to vigorous physical activity, and body weight. Some participants proposed incorporating a wider variety of exercise forms and receiving AI-driven personalized recommendations while also advocating user flexibility to modify the suggested goals. This seemed important due to their perceived lack of knowledge regarding the benefits of various activities. Participants also expressed a desire for both short-term goals as an encouragement to initiate healthy behaviors and strive forward, and long-term goals, which provide a holistic overview of the user's journey towards sustainable adoption of healthy behaviors.

Viewing and smart logging on behalf of patients. The wireframe included a blood glucose log, medication log, and meal log. For the medication log, users could receive alerts for missed doses, while the food log categorizes

logged meals by their calories, carbohydrate, protein, and fat content, leveraging a food recognition algorithm. These logs enable family members to have a better understanding of the patient's glycemic control, medication adherence, and food consumption. An additional feature was logging meals and data by family members on behalf of patients. Participants appreciated a user-friendly meal-logging feature using smart AI technology for enhanced dietary habit tracking. However, they had reservations about the accuracy of a smart AI model. Additionally, participants desired more personalized feedback from the app, such as the impacts of dietary intakes and suggestions for healthier alternatives to their usual food choices. Such feedback would be particularly beneficial to family members who take on a more active role in the patient's diet management.

Report card for tracking. Participants valued the holistic overview provided by the report card that could consolidate logged information on physical activity, food intake, blood

Table 3. Usability and preferences for FAMILY module features.

Module feature	Feedback	Illustrative quotes
Patient profile and nudges	<ul style="list-style-type: none"> • Offering a timely platform for nudging patient by family members • Patient's desire to manage reminders independently • Preference for options to customize the frequency of notifications 	<p>"...because I'm not with my wife during lunch time so with this, at least I know whether she has taken her medicine for lunch or not. So, I can see and then if she hasn't, I can remind her." (F23, M, 43)</p> <p>"I think for me, it [module] is more for myself to remind myself and I already manage quite well. I don't have any issues for people to remind me." (P17, M, 54)</p> <p>"I think if the app keeps prompting me, I'm going to be very tempted to turn off the notifications. Is it possible to tailor it if I only want to receive notifications on the medications because the rest are not as vital to me." (F15, F, 31)</p>
Collaborative goal setting	<ul style="list-style-type: none"> • Collaborative goal setting as a source of motivation and enhancing dedicated family time • Requiring commitments from both patients and family • Desire to receive AI-enabled personalized suggestions with flexibility to set different goals 	<p>"We can do it together now, and we can talk to each other and share anything under the roof. So, the time we exercise together, we also can build our rapport and our relationship better, I think that really helps us. We can share our agreements and disagreements." (F12, M, 69)</p> <p>"If you're alone, sometimes a bit lazy and tend to slack off. [Goal setting] will be quite encouraging but it also depends on family. Sometimes kids are busy studying and my wife is busy. Then I cannot force them." (P15, M, 42)</p> <p>"If we set ourselves, it might not be enough. If we set too difficult, then that's fine but if we set too low, then not enough. The AI can give a reference, then based on the reference, we adjust, that might be good." (F22, M, 52)</p> <p>"If it's just long term, the focus might be lost. I prefer short-term goals because as of right now, like checking the glucose, the patient can see little successes. But long-term goal is good to get the overall picture, the holistic picture. But the short-term goals can help to motivate them to have a better, healthy lifestyle." (F24, F, 44)</p>
Viewing and smart logging on behalf of patients (blood glucose, blood pressure, meal, weight and medication)	<ul style="list-style-type: none"> • Perceived benefits of monitoring patient's medication intake and food consumption & facilitating communication • Reservations about the precision of AI meal logging • Desire for personalized feedback on logging (e.g. calorie target, impact of food consumption, suggestion for dietary change) 	<p>"I can see what she's having for lunch then I can remind her maybe at dinner time not to eat too heavy...So this app will be good for the family members to personally look out for the patients... For many diabetic patients, food intake is very important so if it can give a very accurate analysis...then it will be very useful." (F23, M, 43)</p> <p>"[Medication logging] is good because sometimes when I go to hospital, the doctor asks me the medication my wife takes.</p>

(continued)

Table 3. Continued.

		<p>Instead of verbally telling the medication, I can show the app...easy for the doctor to understand.” (F20, M, 48)</p> <p>“...He [Father] might find it troublesome. I am not sure if he is willing to [log] every time he takes his medications” (F14, F, 22)</p> <p>“Will the AI be able to do some size calculation? The Vietnamese pho will be in a huge bowl where the Chinese always serve in smaller bowls. But it can be silly because small bowl can also be bigger and more filled.” (F09, M, 60)</p> <p>“AI can be more predictive. If I had nasi lemak for breakfast and salad for lunch, maybe the AI can suggest, based on 2000 calories intake, you would like to eat noodles or rice?” (P21, M, 52)</p>
Report card for tracking	<ul style="list-style-type: none"> • Viewed as a holistic overview to help understand patient’s behavior and trends • More clarifications of clinical outcomes needed to improve the family’s understanding 	<p>“Report card is good because we’re busy, we like to see things at a glance, like a summary. Like for October, this is your average readings, and you can kind of improve, then if you’ve not been doing too good in October, then you tell yourself, okay, November, I’m going to walk more, I’m going to have to bring my blood pressure down a bit more, things like that.” (P24, F, 48)</p> <p>“The report card, I really like that too...it’s easy for me to know how well she is doing. Because right now, if you ask me to recall how she’s doing, it is difficult to tell you that quantitatively. But here when I look at the card, I can see for myself that over the month, what the changes are that she has made or even if she is keeping it constant, that’s also fine. It’s better than going downwards.” (F15, F, 31)</p> <p>“...the systolic and diastolic...give us a brief on what the number means and an acceptable range to be in... because we wouldn’t be able to tell whether 130 is a good range or out of the range.” (F19, F, 24)</p>
Module feature	Feedback	Illustrative quotes
Resources for family members	<ul style="list-style-type: none"> • Valued as a reliable source of accurate information and family education • Preference for bite-sized content • Suggestions for content tailored to various needs (e.g. first-time family, diet education, DM complication and suitable exercises) 	<p>“I think I might want to take part in those caregiver courses because either for myself or if I support my family member, it’s going to be useful in the long run so I definitely would want to know if somebody is taking care of me or so I can also help to ease that person’s burden.” (P24, F, 48)</p>

(continued)

Table 3. Continued.

Module feature	Feedback	Illustrative quotes
		<p>"I believe for families with the elderly with diabetes problems, getting them to take medication regularly and things like that is not easy, it's tough for them. So, they need someone to give them support. so having these courses and resources [will help them]." (F04, F, 44)</p> <p>"A minute or two, not more than that. To get the information across, if there are additional details, then they can look more into it. But the attention spans to capture the person with an attractive heading and for them to click on the video, it should be a minute or two." (F16, M, 49)</p> <p>"It's good to have a guideline for the family member on the things to prepare. For example, if someone doesn't know how to do foot care, it's good to learn how to manage, otherwise she becomes very stressful." (P22, M, 55)</p>

Note: P: patient; F: family member.

glucose, blood pressure, and medication intake, which could encourage a comprehensive understanding of the interplay between various lifestyle factors and the patient's glycemic control. Family members felt that the report card would allow them to easily pinpoint areas requiring more attention for effective diabetes management. However, participants expressed a need for clearer explanations of medical terminologies in the report, such as systolic blood pressure and ideal target range of HbA1c.

Resources for family members. App-based educational materials under the resources feature were highly appreciated as a reliable source of information for users. Participants expressed a preference for concise, easily digestible materials to allow them to incorporate the acquired knowledge into the patient's self-care management. Given that family members have diverse needs based on the nature of care they provide, participants highlighted the importance of tailoring the content, such as guidance for first-time caregivers, dietary education based on patient's logged data, and information on T2DM complications, to cater to these diverse needs. Such customization was deemed essential to enhance the effectiveness and applicability of these resources.

Discussion

Active family involvement can serve as a valuable asset in improving self-care practices of patients with T2DM.³⁷ This study sought to explore the acceptability of mobile app-

based family support and preferences for specific features of a FAMILY module within an AI-enabled EMPOWER mobile app among patients with T2DM and family members. While perspectives varied to some extent across patients and family members, common themes emerged regarding the benefits and concerns of a family-based intervention for diabetes self-management as well as preferred app features deemed beneficial within the family module.

Our findings suggest that participants saw the FAMILY module as a tool to facilitate more meaningful conversations between patients and family members about patient's self-management practices, thereby strengthening familial bonds and support. Literature indicates that a lack of understanding of patient's needs and concerns, ineffective communication, and limited family togetherness create barriers to managing T2DM.^{38,39} Furthermore, family member's social skills, such as problem-solving and affective responsiveness, have been identified as critical factors in successful family-based intervention for T2DM management.^{20,38} Our findings, together with existing studies, demonstrate the potential benefits of the FAMILY module in which real-time data and personalized nudges naturally facilitate patient-family communication and assist patient-family discussion over self-management. At the same time, a family-based intervention incorporating the FAMILY module could enhance family members' confidence and social skills through more guidance on positive techniques and communication skills. A potential way for the FAMILY module to enhance support for family

members is by offering app-based resources and guides using AI learning. These resources would provide effective communication strategies, support tips, and personalized actionable information to help family members engage more effectively in patient care. Family-based interventions delivered via digital platforms (e.g. automated calls, tele-monitoring) have shown potential in improving clinical outcomes such as better HbA1c control.^{40–42} However, evidence directly linking increased family knowledge and skills and patient's clinical outcomes remains scarce. Further research is required to elucidate the mechanism of action in family-supported mHealth interventions.

While participants acknowledged the benefits of the FAMILY module in the context of T2DM management, concerns were raised regarding potential compromises to patient autonomy, particularly amongst patients who valued a high degree of independence in managing their condition. A few patients also expressed reservations about sharing their behavioral data with family members, citing concerns about maintaining their ability to make autonomous decisions. Indeed, literature suggests that over-involvement of family members could undermine patient's self-efficacy and motivation,⁴³ while greater autonomy support from an informal supporter was associated with greater patient activation among patients with T2DM.⁴⁴ However, contrasting evidence also exists; non-directive support upholding patient autonomy does not necessarily lead to improved patient outcomes such as glycemic control.⁴⁵ In light of this, it is important to explore methods to tailor the features for family support to accommodate variations in patient needs, readiness to change, and individual preferences. In terms of module development, considerations could be given to implementing customizable sharing options that respect patient autonomy and varying comfort levels regarding the disclosure of certain logged information to family members. For example, patients can choose specific data to share, such as blood glucose levels, while keeping other information, like meal details, private. Additionally, the module could allow patients to set boundaries on how frequently family members receive updates. Such features would empower patients to maintain control over their personal health data while fostering collaborative family involvement tailored to individual preferences, ultimately supporting sustained engagement with the FAMILY module.

Our analysis revealed that certain family members expressed concerns about the potential caregiving burden arising from the inability to provide adequate family support to facilitate patients' T2DM management. Family members commonly mentioned that if the app frequently notifies them about tasks that they find difficult to assist with or are beyond their capacity, it may lead to feelings of self-blame. This finding highlights the need for a clearer definition of the family members' roles, their level of involvement in the intervention and a specific target for the patient's self-management to sustain long-term

user engagement. Incorporating a collaborative goal-setting feature, which involves both the patient and the family, along with tailored action plans based on the patient's specific needs, may potentially alleviate these concerns. For instance, customized action plans that align with the patient's specific needs (e.g. medication adherence or dietary regimen) can guide family members toward more focused and manageable support efforts. This adaptable feature can reduce the cognitive and emotional strain of caregiving by minimizing unnecessary involvement in areas that are not prioritized by the patient. Family's concerns regarding patient compliance and maintenance of their motivation for continued logging could be addressed by incorporating features such as reward systems and gamification, which have been demonstrated to be successful in providing positive reinforcement for patient's lifestyle changes.⁴⁶ AI-powered smart logging of meals and medications may also help mitigate the burden on family members.

In line with current literature,^{47–49} participants highlighted the need for personalized recommendations, particularly for features of goal setting and diet. Our FAMILY module will leverage AI-driven technology to provide personalized suggestions and strategies, enabling family members to gain a better understanding of diabetes management based on the patients' data and to access additional coaching advice about how to best assist the patient in achieving diabetes management goals. The need for personalization is also mirrored for the courses and resources features, where participants preferred concise content tailored to their needs that can be easily accessed within the app. Research demonstrates that a substantial proportion of health app usage is transient with low user retention.⁵⁰ In the development of FAMILY module, it is crucial to prioritize the improvement of personalized experiences, with the aim of making users perceive the module as a relevant tool that aligns with their motivations and needs, thereby increasing the potential for sustained user engagement. Lastly, despite the integration of cutting-edge AI technology and automated nudges in our FAMILY module, family health coaching by a trained healthcare professional still remains necessary.²² Although our family-based intervention and FAMILY module does not incorporate human coaching, future research should explore the potential of a hybrid model that combines full automation with human coaching, particularly for older patients, a segment that is more susceptible to uncontrolled T2DM and their older family members to expand the reach of the intervention to a broader population.⁵¹

While the current FAMILY module primarily targets improved blood sugar control (HbA1c level) through family engagement, it also holds significant potential for cardiovascular risk monitoring and holistic diabetes management. A recent meta-analysis reported the efficacy of diabetes digital apps on reduction in systolic blood pressure and triglycerides. However, no significant effects were

observed on weight, BMI, or lipid profiles.⁵² These findings underscore the need for digital health apps to address complications beyond glycemic control, particularly cardiovascular risk factors, which are often underexplored in such interventions. Future iterations should incorporate features aimed at monitoring and mitigating cardiovascular risks in patients with T2DM, fostering a more comprehensive approach to diabetes care.

Strengths and limitations

The strength of this study lies in the deliberate selection of both family members and patients with T2DM, enabling a comprehensive exploration of their perspectives. This approach allowed us to identify both commonalities and differences in their viewpoints to tailor the FAMILY module to effectively address the unique needs of both parties. This study has several limitations. First, the inclusion of solely English-speaking participants limited our exploration of insights from individuals who could communicate only in Chinese, Malay, or Tamil. However, our initial focus is on developing the module in English, with plans to adapt it to other languages in the future. Future iterations of the module will involve linguistic and cultural adaptations, including translation into Chinese, Malay, and Tamil, user testing with non-English-speaking populations, and tailoring content to reflect diverse cultural and religious contexts. These efforts will enhance the module's inclusivity and applicability across a broader range of populations. Second, the voluntary nature of family member participation may have introduced a selection bias, as those already extensively engaged in the patient's T2DM management may have been more inclined to participate in the interview. This could have led to an underrepresentation of perspectives from less-engaged family members. Relatedly, the inclusion of participants from prior trials may have introduced a bias, as these individuals could possess preexisting positive perceptions of app-based interventions. This may affect the generalizability of our findings to populations without such prior exposure. Third, the exclusion of patient-family member dyads limits the ability to explore interaction dynamics directly. Such dynamics could influence module feature preferences, as dyads may negotiate, prioritize, or perceive features differently based on their roles in managing patient's health. Understanding these dynamics is critical for designing features that support collaborative use, such as shared progress tracking, communication tools, or customized reminders. Future studies should include dyads to gain deeper insights into these relationships and assess how the module can be optimally tailored to real-life settings. Lastly, given the small sample size and specific setting of this study, the findings may not be fully generalizable to other populations or contexts. Future research should explore the applicability of

the FAMILY module in diverse settings and populations to assess its broader relevance and effectiveness.

Conclusion

This study yielded valuable insights into the acceptability and feature preferences of the FAMILY module within the AI-enabled EMPOWER app. Both patients and family members generally accepted the module, but concerns were raised about potential impacts on patient autonomy and heightened caregiver responsibilities. These findings offer valuable information for refining our upcoming FAMILY module intervention, which will be tested using a pragmatic trial. Additionally, the implications extend beyond T2DM, potentially informing interventions for other chronic conditions such as hypertension and hyperlipidemia, where family support plays a critical role in self-management. Lastly, our findings underscore the importance of exploring the role of significant others, such as relatives and close friends, as a key source of virtual support in T2DM self-care.

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