Original Paper

Exploration of user’s perspectives and needs and design of a type 1 diabetes management mobile app: mixed-methods study

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Background: With the popularity of smart phones, mobile apps have great potential for the management of diabetes, but the effectiveness of current diabetes apps for T1DM is poor. No study has explored the reasons from the user’s perspective.

Objective: To explore the perspectives and needs of T1DM patients and diabetes experts concerning diabetes app and to design a new T1DM management mobile app.

Methods: A mixed methods design combining quantitative surveys and qualitative interviews was used to explore user needs and perspectives. Experts were surveyed at two diabetes conferences using paper questionnaires. T1DM patients were surveyed using Sojump on a network. We conducted semi-structured in-depth interviews with adult T1DM patients or parents of child patients who had ever used diabetes apps. The interviews were audio-recorded, transcribed and coded for theme identification.

Results: The expert response rate was 63.5% (127/200). They thought that the reasons for app invalidity were that patients did not stick to using the app (76.4%, 97/127), little guidance was received from health care professionals (HCPs) (73.2%, 93/127), diabetes education knowledge was unsystematic (52.8% 67/127) and the app functions were incomplete (44.1%, 56/127). A total of 245 T1DM patient questionnaires were collected, of which 21.2% (52/245) of the respondents had used diabetes apps. The reasons for their reluctance to use an app were limited time (39%, 20/52), complicated operations (25%, 13/52), uselessness (25%, 13/52) and cost...
Both the experts and patients thought that the most important functions of the app were patient-doctor communication and diabetes diary.

Two themes that were useful for app design were identified from the interviews: (1) problems with patients’ diabetes self-management and (2) problems with current apps. Additionally, needs and suggestions for a diabetes app were obtained.

**Conclusions:** Patient-doctor communication is the most important function of a diabetes app. Apps should be integrated with HCPs rather than stand alone. We advocate that doctors follow up with their patients using diabetes app. Our user-centered method explored comprehensively and deeply why the effectiveness of current diabetes apps for T1DM was poor and what T1DM patients needed for a diabetes app, and provided meaningful guidance for app design.

**Key words:** type 1 diabetes; mobile app; mixed-methods study; diabetes management

**Introduction**

The incidence of type 1 diabetes mellitus (T1DM) has been increasing worldwide [1, 2]. An estimated 13,000 new T1DM cases occur every year in China [3]. Failure of islet β cell function occurs in the early stage of T1DM [4], and thus controlling blood sugar is difficult. Despite the development of therapeutic drugs and treatment techniques, the blood sugar of T1DM patients is still poorly controlled [5]. The 3C study in China showed that the average HbA1c of T1DM patients in Beijing and Shantou was 8.5%, which was far higher than the guideline recommendations [6], and a clear gap existed between China and developed countries [7]. Poor glycemic control can cause various complications and place heavy financial burdens on the country and patients [8].

For T1DM patients, self-management ability is very important [9]. Increasing communication with doctors and strengthening blood sugar monitoring are beneficial for blood sugar control [10, 11]. The following challenges are present in outpatient clinics: inconvenience due to time and space limitations; limited ability to gain diabetes knowledge in a short period of time; and patients lack blood sugar records, which hinders doctors from providing effective treatment guidance [12]. Mobile apps can record, transmit and receive feedback anytime and anywhere. Smart phones have been integrated into personal life due to their popularity [13]. Thus, an app has great potential for the management of diabetes [14].

Numerous diabetes apps have been developed, but few are specific for T1DM [15], and even fewer have shared their methodology. The majority of diabetes apps contain only a few functions [16], and health care professionals (HCPs) do not play a role in these functions [14]. The number of functions offered by apps influences HbA1c levels [17]. Diabetes apps achieve different results in terms of glycemic control [14, 18]. The effects in T1DM patients were poor [19], and patients did not continue to use the app [20, 21]. App development must be closely integrated with clinical guidelines and must work closely with HCPs and patients [22]. Most apps are developed by software engineers without medical backgrounds. Thus, the developed apps are not well integrated with guidelines and clinical needs [19].

Gaining a deep understanding of the perspectives of patients is important when developing a mobile app for their use [21, 23]. Qualitative research methodology has become more recognized and valued in diabetes behavioral research. By exploring patients' motivations, perspectives, and expectations, this approach can answer questions that cannot be addressed using a quantitative study. Mixed methods study can combine qualitative and quantitative results to provide a more
comprehensive and deeper understanding of user perspectives [24]. No study has explored the reasons for inefficacy of current diabetes app in T1DM patients from the user’s perspective. To improve glycemic control of Chinese T1DM patients, we used a mixed methods study to explore user perspectives and needs and cooperated with a software development team to develop a mobile app for T1DM management.

Methods:
A mixed methods design combining quantitative surveys and qualitative interviews was used to explore user’s needs for and perspectives of a diabetes app. Figure 1 shows the flow chart of app development.

**Figure 1.** Flow chart of app development

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**Part 1: Questionnaire survey**

**Questionnaire design:** An expert panel was established consisting of three diabetologists [YZ, SL, and XL] and a diabetes education nurse [FL] from our hospital. The expert panel designed expert and T1DM patient questionnaires according to the functions of current diabetes management apps [16, 19, 25-28], the problems they encountered during clinical practice and diabetes guidelines [29]. The questions were presented in a choice format. If responders did not agree with the listed options, they could select the option "none of the above" and write their answers in the remarks column. The expert questions covered their use of and perspectives about diabetes management apps. The patient questions covered their use of, perspectives about and needs for diabetes apps, demographic information, including gender, age, and education level, and basic disease information, including diabetes type, disease duration and treatment. Before questionnaires were administered, we did pilot tests with ten diabetologists in our hospital and twenty diabetes patients from our outpatient department.

**Samples and survey methods:** The expert questionnaires [Multimedia Appendix 1] were administered using a paper format at two national diabetes conferences held in October 2017 and December 2017, with a total of two hundred diabetologists attending. From 23 January to 1 March 2018, the T1DM patient questionnaires [Multimedia Appendix 2] were administered using an on-line questionnaire tool Sojump on the WeChat network [30]. The questionnaire links were spread among the first author’s WeChat friends circle and WeChat groups of diabetes patients. The questions were answered for free by adult patients or the parents of child patients.

**Data analysis:** Descriptive statistics was used to characterize the samples. Frequencies and percentages were used to describe categorical variables. Incomplete responses were included in
the analysis.

Part 2: Qualitative study

Data collection: After administering the questionnaire surveys, semi-structured one-on-one in-depth interviews were conducted by a diabetologist [YZ] trained for qualitative studies. T1DM patients who once used diabetes apps were contacted. First, we introduced the objective of the study to establish trust. Adult patients or the parents of child patients were invited for a one-on-one interview. The interview environments were quiet, and interruptions were minimized. An interview guideline was created by the expert panel and covered questions about the patients’ daily diabetes management conducts, problems with apps they had used in the past, and their needs and suggestions for an app. The questions were open-ended. Each interview lasted approximately 30-60 minutes. Data collection ended when data saturation was achieved [31], which occurred when 16 participants were interviewed. An additional 2 participants were interviewed to ensure data saturation. All interviews were audio-recorded, and all participants gave written informed consent.

Data analysis: The data analysis was on-going during the data collection process to ensure data saturation. Records were transcribed by the interviewer [YZ] literally and were verified by the interviewees. Data analysis was managed using Nvivo11.0. Information that could lead to identity recognition was deleted, and the transcripts were all anonymized. Using inductive thematic analysis [32], the transcripts were independently read and coded by two investigators [YZ and XL]. Disagreements and emerging themes were discussed with the expert panel.

Part 3: App prototype design and development: Based on the results of the questionnaires and interviews, the expert panel combined their clinical experiences and clinical guidelines [9, 29, 33] to determine the app contents. A software development team developed the app iteratively and discussed the development with two members of the expert panel [YZ and SL] face-to-face at least once a week. During each discussion, one patient was invited to share user experiences. The software development team designed the app accordingly in the next iteration.

Ethical Approval: The study was approved by the ethics committee of the Second Xiangya Hospital, Central South University.

Results

Part 1 Questionnaire survey

Expert survey:

Influencing factors of experts’ use and recommendation of diabetes management app

The response rate for the expert survey was 63.5% (127/200). A total of 52.8% (67/127) of the experts had recommended diabetes apps to their patients. The factors influencing their recommendations were not knowing which app was suitable (52.8%, 67/127), busyness (38.6%, 49/127), the effectiveness of the apps was not evidence-based (14.2%, 18/127), and not having information about diabetes apps (11.0%, 14/127). A total of 34.6% (44/127) of the experts had used diabetes apps to manage diabetes patients. These experts thought that the biggest obstacles for their use of apps to manage diabetes patients were limited time (57.6%, 68/118), legality issues (16.9%, 20/118) and patients’ distrust (12.7%, 15/118). A total of 57.5% (73/127) of the experts did not know whether using an app to manage patients was legal. 26.7% (34/127) thought that using an app for this purpose was legal, and 15.0% (19/127) thought that it was illegal.

Experts’ perceptions about diabetes management app
Their proposed reasons for app invalidity were that patients did not stick to using them (76.4%, 97/127), patients received little guidance from HCPs (73.2%, 93/127), diabetes knowledge on app was unsystematic (52.8%, 67/127) and the app functions were incomplete (44.1%, 56/127). The experts thought that the most important functions of an app were patient-doctor communication (42.4%, 53/125), the diabetes diary (39.2%, 49/125), diabetes education (10.4%, 13/125) and abnormal blood sugar reminders (6.4%, 8/125). Most experts did not recommend or were opposed to insulin calculators (62.0%, 75/121), because 78.2% (97/124) of them thought that these tools were dangerous or very dangerous. A total of 82.5% (104/126) of the experts thought that the prospect for diabetes apps was good or very good.

**Patient survey:**

**Influencing factors of patients’ use of diabetes app**

A total of 245 T1DM patient questionnaires were collected. Table 1 shows the characteristics of the responders. A total of 61.2% (150/245) of the responders did not know about the existence of diabetes apps, and only 21.2% (52/245) had ever used diabetes apps. Only 7.7% (4/52) of their apps were recommended by HCPs. Most of the apps were recommended by patients (38.5%, 20/52) or selected randomly (36.5%, 19/52), because the respondents did not know which app was best. The reasons for their reluctance to use diabetes apps were limited time (39%, 20/52), complicated operation (25%, 13/52), uselessness (25.0%, 13/52) and cost (25%, 13/52). The most common functions of their apps were diabetes knowledge (92%, 48/52) and blood sugar records (90%, 47/52) (see Figure 1). A total of 70% (33/47) of the patients thought manual input of blood glucose was troublesome or a little troublesome. A total of 58% (30/52) of the apps could consult HCPs, but only 30% (9/30) of the patients had ever used this function.

**Patients’ needs for diabetes app**

The patients thought the most important functions of the apps were consulting HCPs (33.9%, 83/245), the diabetes diary (24.4%, 55/245), diabetes knowledge (12.7%, 31/245), the insulin calculator (11.8%, 29/245), abnormal blood sugar reminders (10.6%, 26/245), peer support (2.9%, 7/245) and blood sugar test reminders (1.2%, 3/245). Almost all of the patients thought the above functions were important or very important (see Figure 2). A total of 65.3% (160/245) of the patients thought that they were in need or in great need (32.7%, 80/245) of a good app to manage their diabetes.

**Table 1:** characteristics of patients responding to the surveys

<table>
<thead>
<tr>
<th>characteristics</th>
<th>Total (n=245)</th>
<th>Adolescent (n=115)</th>
<th>Adults (n=130)</th>
</tr>
</thead>
<tbody>
<tr>
<td>gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male, n (%)</td>
<td>98 (40.0%)</td>
<td>49 (42.6%)</td>
<td>49 (37.7%)</td>
</tr>
<tr>
<td>Female, n (%)</td>
<td>147 (60.0%)</td>
<td>66 (57.4%)</td>
<td>81 (62.3%)</td>
</tr>
<tr>
<td>Age in years</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Median (quartile, third quartile)</td>
<td>18 (11-30)</td>
<td>11 (8-14)</td>
<td>29 (23-35.3)</td>
</tr>
<tr>
<td>Disease duration in years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median (quartile, third quartile)</td>
<td>3 (1-9)</td>
<td>2 (1-4)</td>
<td>5 (1.75-15)</td>
</tr>
<tr>
<td>Treatment type</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insulin pump, n (%)</td>
<td>65 (26.5%)</td>
<td>27 (23.5%)</td>
<td>38 (29.2%)</td>
</tr>
</tbody>
</table>
Figure 2. Proportions of different functions of patients’ diabetes apps

<table>
<thead>
<tr>
<th>Function</th>
<th>Adult patients</th>
<th>Parents of young patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insulin calculator</td>
<td>280(73.5%)</td>
<td>88(76.5%)</td>
</tr>
<tr>
<td>Blood glucose test reminder</td>
<td></td>
<td></td>
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<tr>
<td>Consultation with doctor</td>
<td></td>
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<tr>
<td>Activity record</td>
<td></td>
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<tr>
<td>Abnormal glucose reminder</td>
<td></td>
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<tr>
<td>Diet record</td>
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<tr>
<td>Blood glucose record</td>
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<tr>
<td>Diabetes knowledge</td>
<td></td>
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</tr>
</tbody>
</table>

Figure 3. Usefulness of app functions reported as important by patients.

Part 2 Qualitative study

Participants
The final sample consisted of 18 participants (12 adult patients and 6 parents of young patients) (Table 2).

Table 2: characteristics of interviewees

<table>
<thead>
<tr>
<th>characteristics</th>
<th>Adult patients</th>
<th>Parents of young patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Female</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>Patients’ age in years, mean(range)</td>
<td>26.8(20-33)</td>
<td>10.5(6-16)</td>
</tr>
<tr>
<td>Patients’ disease duration in years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment type</td>
<td>mean (range)</td>
<td>Education</td>
</tr>
<tr>
<td>-------------------------</td>
<td>--------------</td>
<td>-----------</td>
</tr>
<tr>
<td>Insulin pump</td>
<td>4.0(1-12)</td>
<td>Postgraduate</td>
</tr>
<tr>
<td>insulin injection</td>
<td>3.3(0-9)</td>
<td>University</td>
</tr>
</tbody>
</table>

Diabetes self-management education (DSME), diet, exercise and self-monitoring of blood sugar are four important parts of diabetes self-management. Understanding the problems with their self-management helped target the design of our app.

**DSME:** Most patients did not receive DSME programs in the hospital. DSME in the hospital had many handicaps, including inconvenience, reluctance of young people to go to the hospital, lack of individualization, and low efficiency. Compared to receiving DSME in the hospital, study on mobile apps was preferable. The patients could select knowledge in which they were interested, learn repeatedly and learn when they had time. Additionally, the time and economic costs were lower.

*From Monday to Friday, there is no time. Secondly, I think sometimes we will select contents to learn after we have mastered some knowledge. Because we have mastered some basic knowledge, if lectures are about such contents, we will not go to learn. [p5, 30-year-old female]*

*Both are fine. But if I go to the hospital, I feel I have no time. Because if I learn on a mobile app, videos can be preserved; I can learn when I have time. I think the app is better. [p10, 24-year-old female]*

**Self-monitoring of blood sugar:** Space, time, economy and pain were all factors that influenced blood sugar tests. Some patients forgot to test, because they did not form a habit of testing their blood sugar or they were doing other things. Some patients did not know when they needed to test, and some were not aware of the importance of testing.

*It is not as important as insulin injection. If you don’t inject insulin, your blood sugar will surely be high. But if you pay attention to your food, you have a sense of your blood sugar level, so you don’t attach much importance to it... [p11, 31-year-old female]*

**Diet:** Some patients had incorrect diet conceptions. Calculating carbohydrates and calories is
important for blood sugar control, but most patients do not perform these calculations for their daily diets. They thought that the calculation process was complicated and troublesome.

*I don’t know. At the beginning, they told me to calculate. It is complicated.*

In a WeChat group, some people told me how to calculate, and when I come to the nutrition department, they told me how to calculate. But after that I will say, I try to eat vegetables as much as possible [p15, 27-year-old female]

Exercise: Most patients knew the importance of exercise for blood sugar control, but many of them lacked the time and will. Some patients selected the wrong time to exercise. Some were afraid to exercise, because they were worried about hypoglycemia.

*Blood sugars fluctuate very big. I dare not exercise. I’d rather have a higher blood sugar. I’d rather give a bolus. I’m not willing to exercise* [p12, 26-year-old male]

Theme 2: Problems with functions of the current apps and patients' needs and suggestions for a new app (see table 3)

Diabetes diary: Although they thought mobile diabetes diary was more convenient than paper diary, most of them thought manual input of blood sugar was burdensome. The patients wanted glucose data to be transmitted to the apps automatically. Diet and exercise records were even more troublesome. Some of the patients thought that these types of records were useless, and display was not as intuitive as paper diary. Most of the patients only recorded blood sugar.

*If input manually, when you are outside, testing blood sugar is inconvenient, but you have to record... you will think it doesn’t matter. They are just in the glucose meter. It’s very burdensome. But if it can be transmitted to app automatically, it is convenient* [p7, 33-year-old female]

Most patients reported that the biggest problem with the diabetes diaries was the lack of feedback from HCPs. Because the diary was useless for blood sugar control, they did not continue to use the apps. They hoped to obtain feedback after recording and to have a doctor analyze their data.

*It is meaningless you record there. But if these data, I think, let me think, if after these data are submitted, there is an online doctor analyze them for you, I think people will like it* [p6, mother of a 10-year-old patient]
Patient-doctor communication: Some diabetes apps had a function for consulting HCPs. However, most users did not consult with HCPs using the app, because they did not trust unfamiliar doctors. App communication in the form of typing words was inconvenient, and the communication efficiency was low. Consultations needed to be charged, feedback was not timely, and the consultation effect was low. These factors hampered consultation with doctors by the patients using the apps.

I tried once to make an appointment with a doctor in the weltang app. But for his few minutes he needed to charge, so I exited. An unfamiliar doctor, you consult him, but you need to pay. Maybe you have a sense of... [p11, 31-year-old female]

I consulted once. Because the doctor was busy, the response was not timely. Describing our condition by typing words, maybe it is not so good to meet the needs of patients. After all, they are not our familiar doctors, they don’t know our condition. I hope to communicate directly with the doctor. [p4, 30-year-old female]

Most patients want to consult doctors on the app. However, internet doctors are not familiar with the patients' conditions. The patients wanted their outpatient doctors to continue to follow them up. Doctors from primary hospitals lack experience with managing T1DM. Moreover, the patients do not trust them, and indeed only trust doctors from large tertiary hospitals.

Yes, unless he is your outpatient doctor. I think it can be set on that app, for example, you consult your outpatient doctor and have good effects. [p7, 33-year-old female]

There are only two type 1 diabetes patients in our county. When I went to the county hospital to ask the doctors, they never heard of this disease... [p8, father of a 12-year-old patient]

Diabetes education: Most patients hoped to learn diabetes knowledge on app. They were most concerned about the latest progress of diabetes, knowledge about complications, nutrition, exercise and insulin dose calculation. Some patients thought diabetes knowledge on apps was unsystematic and unprofessional. Patients didn’t know whether diabetes knowledge was accurate. Patients hoped authoritative and practical knowledge to be included.

It’s too miscellaneous. You can’t tell which is right. Because now most of us get information through the Internet, I think accuracy is important for information about disease. [p7, 33-year-old female]
The patients liked different modes of educational materials. Some liked to watch videos, while some liked to read articles. They hoped diabetes knowledge could be classified according to categories, and that knowledge about T1DM could be separated from that of type 2 diabetes, which would enable the patients to learn pertinently and avoid excessive information interference.

*Because I’m type 1, so it is more targeted...we are all type 1. It is not mixed with type two. Because other apps were mixed with type two diabetes, gestational diabetes, and so on, it’s really very chaotic. There is lots of information. You need to screen which is useful, which is useless [p7, 33-year-old female]*

**Peer support:** Almost all of the patients wanted to communicate with similar diabetes patients. Some patients said they had no way to find such patients after diabetes onset. They thought peer support could help them exchange glycemic control strategies and emotional experiences. Some of them even thought that patients’ experiences were more important than consulting doctors, because patients’ experiences were person-specific and practical.

*There are a lot of these patients in our group. Their disease durations are many years. Their own experiences may be better than that of doctors, because they are more practical. What doctor said is theoretical. Some diabetes friends, they themselves, based on their own experiences, may be more practical. [p6, mother of a 10-year-old patient]*

Many patients believed that having a peer leader was very important. Patients with a long disease duration and rich experience in blood sugar control can act as peer leaders. Peer leaders can play a leading, interactive and cohesive role and activate an atmosphere of a peer support module.

*For example, the key is, like a family, there is no backbone. There is not a person with comprehensive knowledge. His knowledge is comprehensive, what questions you put forward, he can help you to solve it. Like that teacher, his prestige is high. He is willing to listen to others, and then he is willing to help others [p8, father of a 12-year-old patient]*

The patients hoped to have different kinds of peer support modes. However, peer
communications in the diabetes apps all took place in the form of forums. Most patients thought that communicating in that way was inconvenient and that responses were not timely. Very few patients chatted in the diabetes apps.

(WeChat)Group chat is timely. Questions you ask can be answered immediately. But on the forum, you will wait a few days. I think feedback in group chat is more timely. It is better. I don’t use forums now... [p5, 30-year-old female]

Psychological module: Mental health specialist is recommended as a part of diabetes management by diabetes guidelines. Almost all patients said diabetes brought negative emotions to them more or less. Some patients suggested that the apps had no psychological module, and they hoped we could pay attention to their mental health.

Another is psychological, a psychological module for patients. I have lots of apps in my mobile phone. Almost they are all about knowledge, how to control blood sugar. Attention to children's mental health, a psychological module doesn’t exist. [p8, father of a 12-year-old patient]

Electronic medical records: The patients hoped to access their hospital electronic medical records through the app (e.g., to view their test results and their diagnostic and treatment records and to register for out-patient visits). This possibility would represent a convenience, allow them to build health records in the app and motivate them to continue using the app.

Connect to hospital health records systems directly. You can register for outpatient, and whenever you have problems you can consult your outpatient doctor. Maybe these can be included. [p5, 30-year-old female]

<table>
<thead>
<tr>
<th>Table 3. Problems of current diabetes apps and needs for a new app</th>
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<tbody>
<tr>
<td><strong>Modules of current app</strong></td>
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<tr>
<td>patient-doctor communication</td>
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<tr>
<td>Diabetes diary</td>
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<tr>
<td></td>
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<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td>Diabetes education knowledge</td>
</tr>
</tbody>
</table>
Unprofessional
Avoid irrelevant knowledge interference
Find interested materials easily
Update in time
Interaction is needed
Tend to learn pop-up knowledge
Different learning habits

Peer-support
Inconvenient
Avoid excessive information interference
Peer leader is needed
Privacy protection

Psychological module
Most apps lack this module

Electronic health records
Access to hospital electronic medical records

**Part 3 App prototype**

The final app prototype modules are shown in Figure 3. The following functions are all included: patient-doctor communication, diabetes diary (blood sugar, diet, exercise, medication and weight record), diabetes education, peer support, blood sugar test reminder, and abnormal blood sugar reminder. Its design principle is shown in Multimedia Appendix 2.

*Figure 4.* Homepage screenshot of the app

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**Discussion:**

**Principle findings:** Our study found why the effects of current diabetes app on T1DM were poor and what patients need from user’s perspectives.

The questionnaire surveys suggested patient-doctor communication and diabetes diary were the most important functions of diabetes app. Detailed records of blood sugar, diet, exercise and medication can help doctors to analyze influencing factors of blood sugar. The blood sugar record was the most used function of the apps, but the users did not continue to use this feature [34]. The in-depth interviews revealed that the biggest problem with the diabetes diaries was the absence of feedback from HCPs. Automatic feedback could not meet patients’ needs. Patients thought that the diary was useless and thus gradually stopped using it. Most experts thought one
important reason for app invalidity was that patients received little guidance from HCPs. Our study suggested that the role of the doctor was central for a diabetes app. A recent meta-analysis revealed that the effects of diabetes apps were explained by the frequency of HCP feedback. HCP functionality was important to achieve clinical effectiveness [35], but a role for the HCP was missing from most diabetes apps [14]. The questionnaire surveys showed that some diabetes apps had a HCP consultation function, but only a small number of patients had used this function. Through in-depth interviews, we found the reasons for this lack. One important reason was that patients didn’t trust unfamiliar doctors on app and doctors from primary hospitals in China lacked experience in managing T1DM patients. We advocate that doctors follow up with their outpatients or inpatients using this app. Doctors from primary hospitals in China need train to enhance their expertise [36]. Many doctors didn’t know whether using app to guide patients’ medication was legal, and doctors in China are overloaded [37]. These issues discouraged doctors from using an app to manage patients. The Chinese government is energetically advocating internet medical treatment, but there is no relevant legislation in China at present, and a subsidy policy is needed to incentivize doctors who manage their patients using apps.

Our study suggested lack of time and complicated operations were factors influencing patients’ use of app. Most patients thought manual input of diabetes diary data was burdensome. Paul Krebs’ survey showed people stopped using health app because of high data entry burden [38]. So in our app, blood sugar and daily steps were recorded automatically, and our app design principle was that the operation should be simple and clear.

DSME is an important part of diabetes management. Several studies had shown the benefits of DSME [39]. But few patients in China received DSME programs in hospitals [7]. Our in-depth interview found some problems in patients’ self-management conducts, and suggested that a mobile app was preferable to study in a hospital for DSME. Digital health interventions can help overcome some of the barriers to self-management posed by limitations of existing health care systems [40]. The questionnaire surveys suggested both experts and patients thought DSME was very important for a diabetes app. The experts believed one important reason for app invalidity was that diabetes education knowledge on app was unsystematic. Many diabetes apps do not have sound educational quality [15]. Different modes of systematic diabetes education knowledge made by a multi-discipline expert panel are needed for the app.

Effectiveness of peer support on diabetes outcomes was ambiguous because of different support modes [41]. Our study showed most patients thought peer support was an important function of diabetes app, and most patients hoped to communicate with similar patients. Peer support can help them to exchange glycemic control strategies and emotional experiences. They considered role of peer leader was very important. Peer leaders can play a leading, interactive and cohesive role and activate the atmosphere of peer support module. Internet-based mentoring program could increase frequency of blood sugar monitoring [42], and studies proved peer leader could provide effective diabetes self-management support [43, 44]. But exchange in current diabetes apps all took the form of forum, which was inconvenient. Few patients exchanged with others in diabetes app.

The patient survey suggested the patients greatly needed an insulin calculator, but they did not know whether it was accurate. The expert surveys suggested most experts did not recommend or were opposed to an insulin calculator, and most of them thought insulin calculators were dangerous or very dangerous. Similar results were found in a New Zealand survey [34]. Because
these algorithms were found to have limited efficacy and were incorrect [45], we do not set an insulin calculator in our app. Artificial intelligence may have potential use in this area [46].

Our study revealed awareness rate and utilization rate of app in China were low. Only a small portion of patients’ apps were recommended by HCPs. One important reason was that effects of apps were not evidence-based, and thus the patients did not know which app was better. Only one Chinese diabetes app was tested in a short-term randomized control trial [47]. Thus, high-quality randomized controlled trials are needed [48]. We will initiate a multi-center randomized controlled trial to test app efficacy.

**Limitations:** We did not interview child or adolescent patients. Their needs and diabetes management models are a little different from those of adults. However, child patients’ diseases are always managed by their parents, so our app is also suited for this population. But sometimes they managed their diseases independently. Therefore, our next step is to improve the app for this population. We did not interview diabetes experts either. Because our expert panel was consisted of diabetes experts with rich experience of T1DM management, we did not think that interviewing diabetes experts was necessary.

**Comparison with prior work:** The effects of current diabetes apps on T1DM were poor [19]. No study had explored the reasons for this ineffectiveness from a user’s perspective, and very few diabetes apps have shared their methodology; thus, app developers do not know how to choose a valid method. App development should be based on thorough knowledge about user needs [49]. Two studies designed diabetes apps by exploring users’ needs though in-depth interviews with young patients and their parents [50, 51]. However, because the interviewees had never used diabetes apps, their understanding of diabetes apps was abstract, and they had difficulty describing their needs accurately. Additionally, a purely qualitative study may not provide comprehensive understanding of user needs. Castensoe-Seidenfaden et al first introduced a mixed-method study to design an app for improving self-management of young patients [52]. But their quantitative and qualitative pre-studies did not investigate patients and doctors’ perspectives of diabetes management apps. Our app design was led by diabetes experts. First, we conducted a quantitative survey to grasp the perspectives of patients and diabetes experts about diabetes apps from a macro level; then, in-depth interviews with experienced patients supplemented and deepened the results of the questionnaire survey and gave us a better understanding of the problems that existed in the current apps and the needs for a new diabetes app.

**Conclusions:** Patient-doctor communication is the most important function of a diabetes app. A mobile app is the preferable method for patients to receive DSME compared to studying in a hospital, but apps should be integrated with HCPs rather than stand alone. We advocate that doctors follow up with their patients using diabetes apps. Our mixed-method study combined qualitative and quantitative data, comprehensively and deeply explored why the effects of current diabetes apps in T1DM were poor and what T1DM patients needed for a diabetes app from user perspectives, and provided meaningful guidance for our app design. This study has reference significance for development of similar apps in the future.

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Conflicts of Interest: none

Multimedia Appendix 1
Survey for diabetologists.

Multimedia Appendix 2
Survey for T1DM patients.

Multimedia Appendix 3
Interview guideline.

Multimedia Appendix 4
App design principle.

References:


[13]. Baron, J.S., S. Hirani and S.P. Newman, A randomised, controlled trial of the effects of a mobile


[29]. American Diabetes Association, Standards of medical care in diabetes--2014. Diabetes Care,


[34]. Boyle, L., et al., Use of and Beliefs About Mobile Phone Apps for Diabetes Self-Management: Surveys of People in a Hospital Diabetes Clinic and Diabetes Health Professionals in New Zealand. JMIR mHealth and uHealth, 2017. 5(6): p. e85. [DOI: 10.2196/mhealth.7263] [PMID: 28666975]


Abbreviations
- **DSME**: diabetes self-management education
- **HCP**: health care professional
- **T1DM**: type 1 diabetes